# Population characteristics and taxonomy of lantern fishes of genus *Diaphus* (Family Myctophidae) off south west coast of India

*Thesis submitted to*

Cochin University of Science and Technology

*in partial fulfilment of the requirement for the degree of*

DOCTOR OF PHILOSOPHY

*under the*

FACULTY OF MARINE SCIENCES


MANJU SEBASTINE

Reg. No. 3481


October 2014


केंद्रीय समुद्री मात्स्यिकी अनुसंधान संस्थान

(भारतीय कृषि अनुसंधान परिषद)

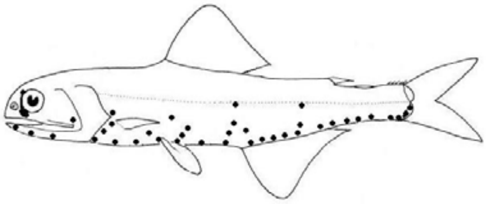
**Central Marine Fisheries Research Institute**

*(Indian Council of Agricultural Research)*

पोस्ट बोक्स सं.1603, उच्च न्यायालय के पीछे, एरणाकुलम नोर्त पी.ओ.,कोच्ची - 682 018, भारत

Ernakulam North P.O., Kochi-682 018, India

# Population characteristics and taxonomy of lantern fishes of genus *Diaphus* (Family Myctophidae) off south west coast of India



*Thesis submitted to*

*Cochin University of Science and Technology*

*in partial fulfilment of the requirement for the degree of*

**DOCTOR OF PHILOSOPHY**

*under the*

**FACULTY OF MARINE SCIENCES**


## MANJU SEBASTINE

**Reg. No. 3481**

केंद्रीय समुद्री मात्स्यिकी अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
Central Marine Fisheries Research Institute
(Indian Council of Agricultural Research)
पोस्ट बोक्स सं.1603, उच्च न्यायालय के पीछे, एरणाकुलम नोर्त पी.ओ.,कोच्ची - 682 018, भारत
Post Box No. 1603, Behind High Court, Ernakulam North P.O., Kochi-682 018, India


October 2014

# D E C L A R A T I O N

I, Manju Sebastine, hereby declare that the thesis entitled ‘‘**Population characteristics and taxonomy of lantern fishes of genus *Diaphus* (Family Myctophidae) off south west coast of India**” is an authentic record of the research work carried out by me, under the supervision and guidance of **Dr. N. G. K. Pillai**, ICAR Emeritus Scientist, Central Marine Fisheries Research Institute, Kochi 682 018, in partial fulfilment of the requirement for the award of Ph. D. degree of Cochin University of Science and Technology under the Faculty of Marine Sciences and no part of this work has previously formed the basis for the award of any degree, associateship, fellowship or any other title or recognition of any University or Institution.

.

**Manju Sebastine**

Kochi - 18

Date: 23.10.2014

केंद्रीय समुद्री मात्स्यिकी अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
Central Marine Fisheries Research Institute
(Indian Council of Agricultural Research)
पोस्ट बोक्स सं.1603, उच्च न्यायालय के पीछे, एरणाकुलम नोर्त पी.ओ.,कोच्ची - 682 018, भारत
Post Box No. 1603, Behind High Court, Ernakulam North P.O., Kochi-682 018, India
Phone: +91-484-2394798 (Per), 2394867 (PBX), 2394909 (Fax)
E-mail: mdcmfri@md2.vsnl.net.in Website: www.cmfri.org.in

# CERTIFICATE

This is to certify that the thesis entitled **''Population characteristics and taxonomy of lantern fishes of genus *Diaphus* (Family Myctophidae) off south west coast of India"** is an authentic record of research work carried out by Mrs. Manju Sebastine, full-time Research Scholar of this Institute and registered student for Ph. D. degree under the Faculty of Marine Sciences, Cochin University of Science and Technology (Reg. No. 3481) under my guidance and supervision and no part thereof previously presented for the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

**Dr. N. G. K. Pillai**
(Supervising Guide)
ICAR, Emeritus Scientist, CMFRI
Kochi – 682 018

Kochi - 682018

Date: 23.10.2014

DEDICATED TO MY PARENTS…

# ACKNOWLEDGEMENTS

I am greatly indebted to Dr. N.G.K. Pillai (Supervising guide), ICAR Emeritus Scientist, Central Marine Fisheries Research Institute, Kochi for the guidance, valuable suggestions, constant encouragement, constructive criticism and support during the course of my investigation and documentation. I also owe my deep sense of gratitude to Dr. E. M. Abdussamad (Co-guide), Principal Scientist, Pelagic Fisheries Division, CMFRI, Cochin for the constant help, guidance, subjective criticism and encouragement during the course of my study.

I owe my thanks to Dr. A. Gopalakrishnan, Director CMFRI, and Dr. G. Syda Rao, Former Director, CMFRI, Kochi for extending all facilities for successful completion of my research work.

I would like to express my gratitude to Dr. E. Vivekanandan (Former Head, DFD and ICAR Emeritus Scientist, CMFRI), Dr. K. S. Mohamed (Head MFD), Dr. V. Kripa (Head FEMD), Dr. U. Ganga (Sr. Scientist, PFD), Dr. Somy Kuriakose and Dr. Mini K. G. (Sr. Scientists, FRAD), Kochi, CMFRI for their timely guidance and support during the work.

I am deeply indebted to Dr. K. K. Vijayan (Former Head, MBTD) Dr. Kajal Chakraborty, (Sr. Scientist, MBTD), CMFRI, Kochi for their invaluable guidance and help given to me while carrying out works related to biochemical analyses. The support from technical staff and scholars especially Mr. Deepu Joseph of Marine Biotechnology Division, CMFRI, Kochi in sample analysis is gratefully acknowledged.

I owe my sincere thanks to Dr. S. Bijoy Nandan, Associate Professor, CUAST, who served as the Subject Expert in my Doctoral Committee, for supporting me with kind advice and valuable suggestions during my research work.

I thank the Director, School of Marine Sciences, Cochin University of Science and Technology, the Dean, Faculty of Marine Sciences and the Head, Department of Marine Biology, Microbiology and Biochemistry for all facilities and support provided during the tenure of the research programme.

I wish to express my sincere thanks to Dr. V. N. Sanjeevan (Former Director) Central Marine Living Resources and Ecology, Ministry of Earth Sciences, Kochi, for giving me an opportunity to work as a Senior Research Fellow in the project entitled "Assessment of myctophids resources in the Arabian Sea and development of harvest and post harvest technologies" and funding support.

I am highly indebted to Dr. P. C. Thomas SIC, HRD Cell, CMFRI, Kochi) for the timely help in all matters concerned with my Ph. D. programme. The help and support extended by the HRD cell Staffs especially Mr. C. N. Chandrasekharan is greatly acknowledged.

I specially thank Mr. V. Edwin Joseph, (Former Librarian), CMFRI for enabling me to collect several valuable references. My sincere thanks to other staff members of CMFRI library for the help and cooperation extended.

My Special thanks to Dr. Sreedhar Utravalli (Sr. Scientist, CIFT) who included me in *FORV Sagar Sampada* Cruise and helped to collect myctophid samples. Also my sincere thanks to Mr. K. P. Said Koya, (Sr. Scientist, CMFRI) for providing me myctophid samples from Lakshadweep. The support from Mr. Sahaya Kaintin and his crew members for providing fish samples is greatly acknowledged.

I acknowledge with thanks for the invaluable help given by Dr P. A. Hulley, Research Associate in Ichthyology, Iziko Museums of Cape Town and John Paxton, Senior Fellow, Australian Museum, Sydney for the support and advice in identification of the species.

I thank Mr. D. Prakasan, Mr. M. N. Kesavan Elayathu, Mrs. K. V. Rema and Mrs. Bindu Sanjeeve (Staff of CMFRI, Kochi) for their help and constant encouragement to carry out my work. Special thanks to P. K. Karuppasamy and Simmy Joshy for providing references and suggestions.

I thank my project colleague Mr. K. K. Bineesh for all the help rendered in collection and analysis of samples during the tenure of this study. I also thank my co-labmates K. V. Akhilesh, C. P. Rajool Shanis, Hashim M. and N. Beni for the stimulating discussions and support for the work. Sincere thanks to all my friends, especially, Manjusha U., Remya R., Preetha G. Nair, Manju Rani, Menaka Sooraj, Melna Rodriguex, T. B. Ratheesh T. V. Ambrose and Ragesh N. for their affection, help and encouragement on several occassions. Special thanks to my classmate Chaithanya E. R. for the help rendered for sample collection during the cruise.

My sincere gratitude goes to family members, especially my parents Mr. Sebastine Augustine P. A. and Mrs. Molly T. S. and my parents-in-law, Prof. T. P. Antony and Mrs. Lilly Leon for all their helpful mind, understanding and encouragement throughout the work. Last but not least, I owe special thanks to my husband Mr. Leon T. Antony for patiently bearing all the inconvenience during the tenure of this work.

Above all, I am very much obliged to almighty for the blessings rendered to me, without which the completion of this work would have been a dream only.

**MANJU SEBASTINE**

# CONTENTS

# LIST OF TABLES

# LIST OF PLATES & FIGURES

# CHAPTER 1

# GENERAL INTRODUCTION

# CHAPTER 1

# GENERAL INTRODUCTION

Myctophids are the most ubiquitous fishes in the world Oceans. They are comonly called as lantern fishes owing to the presence of photophores on the ventral, lateral and head regions of the body. The name myctophids was originated from Greek, where mykter means nose and ophis means serpent. Lantern fishes belonging to class - Osteichthyes, Order – Myctophiformes. Myctophiformes includes two families namely Myctophidae and Neoscopiliade. Fishes coming under family myctophidae are commonly called as myctophids and those under neoscopilidae are neoscopilids. Myctophids are small to medium sized (3 - 35 cm), most being under 15 cm mesopelagic fishes with compressed body, large eyes, large jaws and terminal mouth. Genus *Diaphus* are commonly called as head light fish due to the presence of secondary photophores on the head. They are distributed throughout the world Oceans from subartic and antartic to tropical waters and from waters over shelves and slopes to the open seas. Species diversity is high in tropical and subtropical latitudes, but abundance of individual species is high in temperate and higher latitudes.

Myctophids normally inhabit deeper waters beyond continental shelf edge, between 200 and 1000 m depths. Myctophids are predominant among the fish fauna of Deep Scattering Layer (DSL) of open seas. Some myctophid species are benthopelagic, but not in contact with, the bottom. They exhibit diel vertical migration; ascending to surface (5-100 m) at night and sink to deeper water (250-1000 m) during day. Adolescents and adults of all myctophid species move from mesopelagic depths into very shallow epipelagic waters at night. Numerical difference in the abundance of myctophids in the day and night catch showed that 93% was caught during night using Issacs-Kidd midwater Trawl (Mini  and James, 1990). The genera *Diaphus* includes a considerable number of species that are common along the continental slope.

The myctophids resemble anchovies, with very large terminal to subterminal mouths and large eyes. In some Russian papers, myctophids are referred to as "luminescent anchovies" (Bekker, 1967a and Gorelova, 1978). Their jaws possess numerous tiny teeths and gills with enlarged gill rakers along the first gill arch, number of which vary for different species. The photophores are concentrated along the head and ventral region, which are more concentrated along the belly region. They are arranged in patterns that are distinct for each species. In addition, many species bear luminescent scales and glands at particular regions. The production of light in the glands and photophores is the result of a chemical oxidation reaction that can be triggered and regulated by the animal's nervous system. The light produced is in the blue-green range.

Lantern fishes (family Myctophidae) are the largest component of the world's mesopelagic fish biomass. Arabian Sea has an estimated potential of 100 million tonnes of myctophids and later revalidated to 48 million tonnes in 2001 by US GLOBEC. One species (*Benthosema pterotum*), known in the Indian Ocean from the Gulf of Oman represents the largest single-species biomass in the world (GLOBEC, 1993). Iran is also developing required infrastructure for exploitation of *B. pterotum* (QFPCO, 2011). Shilat and Valinassab (1998) accounted that about 75% of the total global catch of small mesopelagic Ocean fishes were myctophids. Valinassab (2005) reported that 100 million tonnes of *B. pterotum* perishing downward yearly. Pon Siraimeetan (1990) recorded frequent occurrence of *Myctophum elucens* in the deeper waters of the south west coast of India. Mini and James (1990) reported that 31% of the DSL catch from the Indian waters contributed by myctophids; the southeast coast comprised of 64% and north east coast with 35% and the group was abundant along the northern Arabian Sea and south west coast with density maximum at off Cochin and Manglore; along the south east coast maximum abundance was found in areas off Chennai and in the Oceanic areas of south Nicobar Islands. According to that study the common genera occurred in the DSL were *Diaphus*, *Lampanyctus*, *Diogenichthys*, *Hygophum*, *Symbolophorus*, *Bolinichthys*, *Benthosema* and *Myctophum*. A study on deep scattering layer of Arabian Sea indicated the presence of 27 species belonging to 11 genera dominated by *Benthosema fibulatum*, *Diaphus aliciae* and *Lampanyctus turneri* (Karuppasamy *et al*., 2008).

Blindheim *et al*. (1975) reported a large concentration of myctophids along certain parts of the southwest coast of India and stated that they had been commercially exploited at certain localities. Only limited information is available on the commercial exploitation of lantern fishes. Local people of Suruga Bay, Central Japan exploited *Diaphus* spp. (Kubota, 1982). Commercial fishery for *D. coeruleus* and *Gymnoscopelus nicholski* (edible species) in the southwest Indian Ocean and southern Atlantic began in 1977 and catch by former USSR countries reached 51,680 t in 1992, after which the fishery ceased due to decline in catch. The Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) estimated 2,00,000 t TAC (Total Allowable Catch) for this resource in its jurisdiction area. Industrial purse seine fishery for *Lampanyctodes hectoris* was developed in South African waters and closed in the mid-1980s due to processing difficulties caused by the high oil content in the fish (FAO, 1997). Lantern fishes are harvested commercially only along off South Africa and in the sub-antartic waters (Nafpaktitis *et al*., 1977; Hulley, 1994).

Currently 230 - 250 species of myctophids in 30 - 35 genera are generally recognized (Paxtron, 1972 and 1979). Majority of the species belongs to the genera *Diaphus*. Globally about 100 species of *Diaphus* were reported and in Indian Ocean, 42 species were available (Bolin, 1946; Bekker, 1976; Nafpaktitis, 1978; Nafpaktitis, 1984; Hulley, 1986 and Menon, 2002).

Along the southwest coast of India, lantern fish forms a major portion of the bycatch in the deepsea shrimp trawls. These fishes, when landed are mostly used for fishmeal or manure production. Though *Diaphus* spp. formed the dominant component of the lantern fish catch, their biological and population characteristics are least studied. In view of the importance of this group in the DSL biocomposition and their role as predator/prey of several planktonic and pelagic exploitable fish resources, the group deserves special attention. The present study aimed at documentation of the species diversity of myctophids, their distribution patterns and population characteristics with special reference to *Diaphus* spp. This study is expected to provide base line data on the taxonomic and biological aspects, which is essential to evaluate their viability for exploitation, potential for human consumption and sustainable management of the resources. Researchers all over the world anticipate the emergence of mesopelagics as future source of protein for humans as well as domestic animals. So basic scientific knowledge about these resources will be relevant for future plans.

**Objectives of the study**

- To develop data base on catch, catch composition and stock of myctophids exploited from deep-sea shrimp trawlers operated off south west coast of India. To study the species composition of genus *Diaphus* along the south west coast of India
- To study taxonomy (morphological and meristic characters) of the genera *Diaphus*
- To estimate population parameters of genera *Diaphus*
- To estimate length - weight relationship of genera *Diaphus*
- To study biology - sex ratio, maturity, and food and feeding of genera *Diaphus*
- To estimate proximate composition and fatty acid profile of dominant myctophid species.

# CHAPTER 2

# TAXONOMY

# CHAPTER 2

# TAXONOMY

## 2.1. INTRODUCTION AND REVIEW OF LITERATURE

Taxonomy lays a strong foundation on which fruitful biological works can be carried out. The primary challenge before the biologists is to get the species identified systematically. Proper classification can in fact throw light into the diversity of the biota and the environment. Today the need for a standardized systematic account for each group is recognized by all sections of the scientific community, especially in the time when biodiversity has acquired a prime position. The taxonomic and systematic position of fishes are the basic requirement to carry out further studies on the species.

Till date 250 myctophid species have been described, which have been assigned to 35 genera. Different classifications are available for the family myctophidae, Paxtron (1979) classified family Myctophidae into 250 species belonging to 35 genera. Nelson (2006) classified family Myctophidae into 32 genera with 235 species. Majority of the species in family Myctophidae belongs to genera *Diaphus*, to which they were described. Recent taxonomic studies have been reduced the number of species because most of the past studies were restricted to particular regions. Lack of comparative material from wide geographical areas made conspecific geographical variants into separate species. Also sexual dimorphic males and females have been assigned to different species. Taxonomic confusion has often arised as a result of inadequate original descriptions and inadequate preserved specimens (Kawaguchi and Shimizu, 1978; Nafpaktitis, 1978; Fischer and Bianchi, 1984). Though the taxonomic classification of myctophids to species level was difficult in earlier period, these confusions were gradually mitigated as some comprehensive identification keys to species were formulated for different regions. The identification of myctophids depends strongly on the number and position of luminous organs which are called as photophores on the head and ventral parts of the body.

Major taxonomic studies on myctophids are that by Goode and Bean (1896), Gilbert (1908), Gilbert (1913), Taning (1928), Norman (1929), Parr (1929), Taning (1932), Frasaer (1949), Bolin (1959), Kulikova (1961), Jordan (1963), Bekker (1967), Nafpaktitis (1968, 1973, 1978), Craddock and Mead (1970), Wisner (1971), Hulley (1972), Paxtron (1972), Clarke (1973), Nafpaktitis (1973), Nafpaktitis (1974), Wisner (1974, 1976), Hartmann and Clarke (1975), Nafpaktitis *et al*. (1977, 1995), Kawaguchi and Shimizu (1978), Fischer and Bianchi (1984), Hulley (1984), Smith and Heemstra (1986), Dalpadado and Gjosaeter (1993), Nelson (2006) and Froese and Pauly (2009).

Major works on myctophid taxonomy in Indian waters were of Gilbert (1913), Wisner (1974), Kawaguchi and Shimizu (1978), Nafpaktitis (1978), Fischer and Bianchi (1984), Smith and Heemstra (1986), Dalpadado and Gjosaeter (1993), Alcock (1994), Froese and Pauly (2009). The first record of occurance of *Diaphus lutkeni* and *Neoscopelus macrolepidotus* were reported from the Kerala coast by Samuel (1932). Mini and James (1990) reported eight genus of myctophids from the Deep Scattering Layer of Indian EEZ. Dalpadado and Gjosaeter (1993) reported 16 species of lantern fishes from off Srilankan waters. *Diaphus* spp. and neoscopilids were reported from south west coast of India by Sajeevan and Nair (2006). Twenty seven species of myctophids were reported from the Indian EEZ of Arabian Sea (Karuppasamy *et al*., 2006).

In case of *Diaphus*, the luminous organs on the head are diagnostically important. Genera *Diaphus* is represented in the Indian Ocean by 42 species (Bolin, 1946, Nafpaktitis, 1984; Hulley, 1986 and Menon, 2002). *Diaphus* is the largest genera of the family myctophidae with 100 described species of which 50 of them in Pacific and Indian Oceans (Bekker, 1976; Nafpaktitis, 1978).

The most distinctive external characters of the myctophids are their large eyes (situated close to the tip of the blunt snout), wide mouths gaping back beyond the eye, one soft-rayed dorsal fin, a deeply forked tail, and the presence of a series of luminous organs as conspicuous pale spots along the sides. Some of the species have an adipose fin on the back behind the dorsal fin, but others lack this. When present, this fin is so small and fragile that it is apt to be destroyed by the rough handling of the fish receive in the tow net in which they are taken. They resemble the anchovy; but they are readily distinguished from them by the presence of luminous organs and snout that does not project beyond the mouth; wider mouth; and large eyes.

Species of *Diaphus* possess a short dorsal fin, backwardly positioned adipose fin; deeply forked tail; large eyes; wide, oblique mouth; and numerous luminous organs along the ventral sides. The members of the genus are distinguished by differences in the arrangements of the luminous organs; dorsal, ventral and pectoral fin rays count and number of gill rackers on the first gill arch.

*Diaphus watasei* and *D. garmani* are observed all along the south west and south east coast. The presence of these two species in Indian waters has been reported by Gjosater (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Karuppasamy *et al*. (2006), Froese and Pauly (2009), Bineesh *et al*. (2010).

## 2.2. MATERIAL AND METHODS

Myctophid samples for the study were collected on a weekly basis from the deep-sea shrimp trawl landings at Cochin and Kollam harbours during 2009 – 2011. The trawlers operated between 250 to 500 m depth in the outer shelf of southwest coast of India between $8^0$ N - $12^0$ N and $74^0$ E - $75^0$ E. Some samples were collected from Bay of Bengal, Lakshadweep Seas and Andaman waters during onboard cruises. Details such as colour, pigmentation, body shape etc. of the fresh specimens were noted. They were identified following the key and description of species by Nafpaktitis (1968, 1978), Kawaguchi and Shimizu (1978), Hulley (1984), Smith and Heemstra (1986) and FAO species identification sheets. Species were segregated by noting the distinguishing characters and then preserved in formalin and later subjected to analysis. Morphometric and meristic data were recorded following Hubbs and Lagler (1958) method. The different body proportions were expressed in percent of standard length.

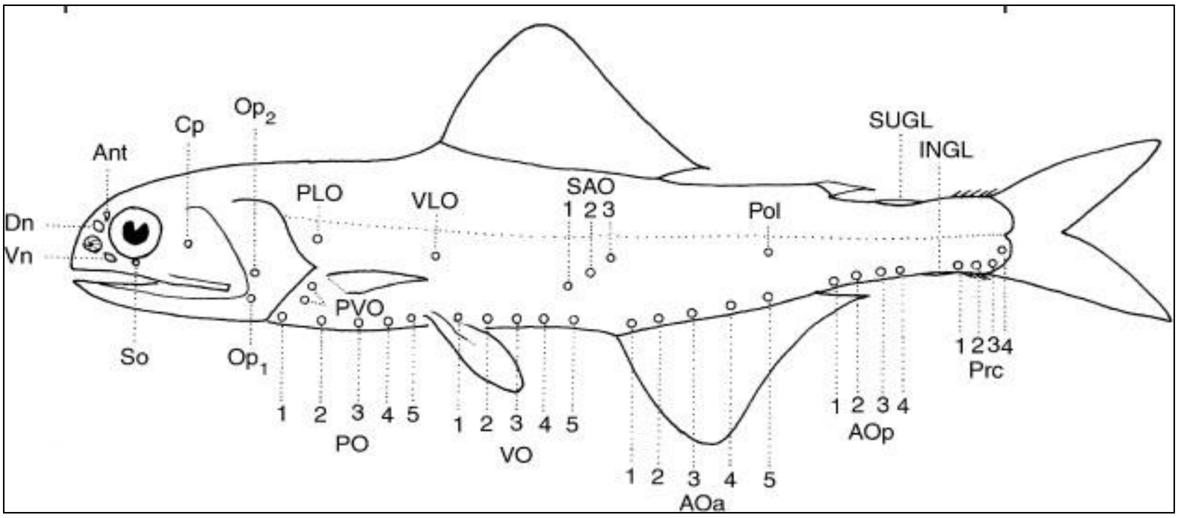
## 2.3. SYSTEMATIC DESCRIPTION

### CHARACTERISTICS OF FAMILY MYCTOPHIDAE

Body and head compressed. Eyes large and lateral. Mouth terminal, extending beyond vertical through middle of eye; upper edge of jaw formed by premaxillary only. Teeth small and numerous. Rudimentary spine at base of dorsal, anal, uppermost pectoral and outermost ventral fin ray. Adipose fin present. Anal fin origin under or close behind base of dorsal fin. Scales are cycloid or ctenoid. Photophores are present and are arranged in distinct groups on head and trunk.

The taxonomic key given by Smith and Heemstra (1986) has been followed

| | |
|---|---|
| Phylum | Chordata |
| Sub phylum | Vertebrata |
| Super - class | Gnathostomata |
| Grade | Pisces |
| Class | Osteichthyes |
| Sub - class | Actinopterygii |
| Infra – class | Neopterygii |
| Division | Halecostomi |
| Sub – division | Teleostei |
| Infra – division | Euteleostei |
| Super – order | Scopelomorpha |
| Order | Myctophiformes |
| Family | Myctophidae |
| Genus | *Diaphus* |




Abbreviations: Ant – anterior orbital (antorbital), AOa –Anal organs anterior, AOp – Anal organs posterior, Cp – Cheek photophore, Dn – Dorsal nasal (dorsonasal), INGL – Infracaudal gland, LO – Luminous organs, Op – Opercular organ, PO – Pectoral organ (thoraci organ), Pol – Posterior organ lateral, PLO - Pectro lateral organ, Prc – precaudal organs (precaudals), PVO – Pectro ventral organs, SAO – Supra anal organs, So – Suborbital, SUGL – Suprcaudal gland, VLO – Ventral lateral organ, Vn – Ventral nasal (ventronasal), VO – Ventral organs.

**Fig. 2.1.** Diagram of a myctophid fish showing the location and terminology of photophores

**KEY TO GENERA OCCURING IN INDIAN WATERS**

**1a** Minute secondary photophores on head and body, under each scale pocket and on fin membranes; primary photophores indistinct………………………………… *Scopelopsis*

**1b** Secondary photophores absent, or if present clearly distinct from primary photophores…………………………………………………………………………....2

**2a** Ventral lateral organ (VLO), Supra-anal organ$_3$ ($SAO_3$) and Posterior organ lateral (Pol) close to dorsal contour of body; 2 Precaudal organ (Prc), with $Prc_2$ well above horizontal septum…………………………………………………………. *Notolychnus*

**2b** VLO, $SAO_3$ and Pol below or slightly above lateral line (LL), well below dorsal contour of body; 2 or more Prc, with $Prc_2$ never above horizontal septum or LL……….3

**3a** Two Prc……………………………………..…………………………………4

**3b** More than two Prc…………………………………………………..………..15

**4a** Pectro lateral organ (PLO) from less than its diameter above to well below level of upper end of pectoral (P) base……………………………………………………………….5

**4b** PLO more than its diameter above level of upper end of P base……………………11

**5a** Mouth subterminal; snout conical and more or less protruding; PLO at or slightly above level of upper end of P base; Anal organ (AO) series divided into Anal organ anterior (AOa) and Anal organ posterior (AOp); Caudal (C) peduncle markedly slender, Its least depth 2.5 or more times in its length……………………………….………………6

**5b** Mouth terminal; snout not protruding; PLO well below level of upper end of P base; AO series continuous; C peduncle not markedly slender, its least depth less than 2.5 times in its length ……………………………………………………………….………..8

**6a** Gill racker (GR) absent – reduced to spiny knobs…………………… *Centrobranchus*

**6b** GR present…………………………………………...……………………..7

**7a** Anal (A) origin under middle of Dorsal (D) base; none or only one AOp above A; least depth of caudal peduncle above 2.5 times in length……………………….. *Loweina*

**7b** A origin on or slightly in advance of vertical through base of last D ray; 5-7 AOp over anal base; least depth of caudal peduncle 3.5 or more in its length…….. *Gonichthys*

**8a** Body slender, with dorsal and ventral profiles parallel; PLO, Pectoral ventral organ$_1$ (PVO$_1$) and PVO$_2$ on same straight horizontal line; 2 SAO; Prc$_2$ above anterior procurrent caudal ray, Prc1 infront…………………………………………..… *Krefftichthys*

**8b** Dorsal and ventral profiles not parallel; PLO slightly above to well above PVO$_1$; 3 SAO; Prc$_1$ above anterior procurrent C ray, Prc$_2$ behind………………..………………….9

**9a** PLO in front of and slightly higher than PVO$_1$; PLO, PVO$_1$ and PVO$_2$ on somewhat angulate line………………………………………………………….. *Protomyctophum*

**9b** PLO almost directly above PVO$_1$; PLO, PVO$_1$ and PVO$_2$ forming a triangle………..…………………………………………………………………………10

**10a** Ventral organ$_2$ (VO$_2$) elevated; posterodorsal margin of operculum sharply rounded and serrate………………………………………………………………... *Metelectrona*

**10b** VO$_2$ level with rest of series or only slightly raised; posterodorsal margin of operculum broadly rounded and without serrations……………………………. *Electrona*

**11a** PVO series horizontal, with PVO$_1$ not more than its own diameter below level of PVO$_2$; VO$_2$ elevated…………………………………………………………………..12

**11b** PVO series on an inclined line, with PVO$_1$ more than its own diameter below level of PVO$_2$; VO series level…………………………………….…………………….13

**12a** Prc horizontal, or with Prc$_2$ only very slightly raised, lying more than 2 times its diameter below LL; outer, posterior teeth in both jaws broad-based and hooked……………………………………………………………...… *Diogenichthys*

**12b** Prc2 much higher than Prc$_1$, lying at or less than its diameter below LL; outer posterior teeth in both jaws small and conical ………………………………. *Benthosema*

**13a** Two Pol………………………………………………………………… *Hygophum*

**13b** One Pol…………………………………………………………………..14

**14a** SAO series strongly angulate, with $SAO_1$ in advance (seldom directly over) $VO_3$……………………………………………………….……… *Symbolophorus*

**14b** SAO series in a straight or slightly angulate line, with $SAO_1$ behind the vertical through $VO_3$………………………………………………………….…. *Myctophum*

**15a** $PO_1$, $PVO_1$ and $PVO_2$ on a straight ascending line; $VO_1$, $VO_2$ and $VO_3$ on a straight ascending line…………………..………………………………………………16

**15b** $PO_1$, $PVO_1$ and $PVO_2$ not on a straight ascending line; $VO_1$ $VO_2$ and $VO_3$ not on a straight ascending line…………………………………………...……………………17

**16a** Dorsonasal (Dn) and Vntronasal (Vn) present on head; supracaudal and infracaudal luminous glands absent in both sexes……………………………………………. *Diaphus*

**CHARACTERS OF GENUS *DIAPHUS***

*Diaphus* Eigenmann and Eigenmann, 1890: 3 (type species *Diaphus theta* Eigenmann and Eigenmann, 1890, by original designation.

**Diagnostic Charaters:** Circumorbital luminous organs well developed, of various sizes and shapes and often sexually dimorphic; Dorsonasal (Dn) and Ventronasal (Vn) present; Suborbital (So) and Anterior orbital (Ant) present or absent; no supra and infracaudal luminous gland; luminous patch, so called luminous scales, usually present at Pectro lateral organ (PLO) photophore, occasionally numerous luminous patches associated with the upper series of body photophores or others; no photophores above lateral line; Orbital photophore ($OP_1$) small, placed just behind posterior tip of mouth, sometimes covered with whitish tissue and invisible; $OP_2$ large, its size approximately equal to that of the largest body photophore *ie*., Pectoral organ (PO) and located directly above $OP_1$; Pectoral $organ_1$ ($PO_1$), Pectro ventral $organs_1$ ($PVO_1$), $PVO_2$ forming a straight line or straight angle; five PO, first three PO above level; $PO_4$ elevated to the level of $PVO_2$; five Ventral organs (VO), first three VO forming an ascending straight line or slight angle; Supra anal organs (SAO) series curved to strongly angulate; Anal organs (AO) series divided into Anal organs anterior (AOa) and Anal organs posterior (AOp), $AOa_1$ usually elevated, sometimes level; AOp evenly spaced and on a nearly straight line along the ventral margin of caudal peduncle; one Posterior organ lateral (Pol), sometimes continuous with AOa; four precaudal organs (Prc); body colour black with bluish tint in fresh specimens and becoming light brown during long preservation; lateral line scales forming a silver band in fresh intact specimens, but are easily rubbed off.

### 2.3.1. SPECIES DESCRIPTION:

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


**Plate 2.1.** *Diaphus watasei*

*Diaphus watasei* Jordan and Starks 1904: 580, fig. (type locality off Atami, Sagami Bay, Japan; holotype USNM 51443); Parr 1929:39, Fig. 19 (description of holotype, distinction from *D. coeruleus*). *Diaphus* (*Lamprossa*) *watasei*. Fraser-Brunner 1949: 1072, figure; Nafpaktitis, 1978: 29, figs. 25, 26, Indian Ocean.

**Common name:**

Watase's lantern fish

**Synonyms:**

*Diaphus coeruleus* (Klunzinger, 1871) - misapplied name

*Diaphus elucens* (Brauer, 1904) - misapplied name

**Material:**

Studied on 1500 specimens of length range 5.3 to 18.6 cm in total length, obtained from south west coast of India ($8^0$ 81' – $12^0$ 79' N; $75^0$ 58' – $74^0$ 11' E) at a depth range of 250-500 m.

**Description:**

D. 15 (14); A. 15 (14); P. 11; GR 5 (4-6) + 1 + 12-13 (7 + 1 + 14 in holotype), total 18-19 (20); AO 6 (7) + 5 (6), total 11 (12); lateral-line organs 37-38.

Operculum rounded posterodorsally, pointed posteriorly. Origin of dorsal fin directly over or slightly in advance of base of ventral fin. Origin of anal fin behind base of dorsal fin. Pectoral fin extending to $PO_5$. Ventral fin reaching anus. Base of adipose fin from directly over to somewhat in advance of end of base of anal fin.

A round Dn, equal in size to or somewhat smaller than a body photophore. Vn large, roughly triangular, occupying most of space between anteroventral margin of eye and upper jaw, extending dorsally along anterior margin of eye to Dn with which it is in contact, terminating ventrally at or behind vertically through anterior margin of pupil. A roughly triangular or oval-shaped Ant. A luminous scale at PLO.

**Colour:**

Body colour black with bluish tint in fresh specimens and becoming light brown during long preservation; lateral line scales forming a silver band in fresh specimens.

**Distribution:**

Indian Ocean, Southeast Asian Seas, over the insular slopes and shelves off the central and southern Japan, east coast of Africa, west coast of Madagascar. Its occurrence in the open sea is very rare.

**Remarks:**

This is a common species seen off south west coast of India, captured with trawls that fished on or very near the bottom and at depths ranging from 100 to 500 m. Morphologically this species has close similarities with *Diaphus coeruleus*. This species commonly considered as trash fish and used for fishmeal preparation in India.

**2. *Diaphus garmani* Gilbert, 1906**

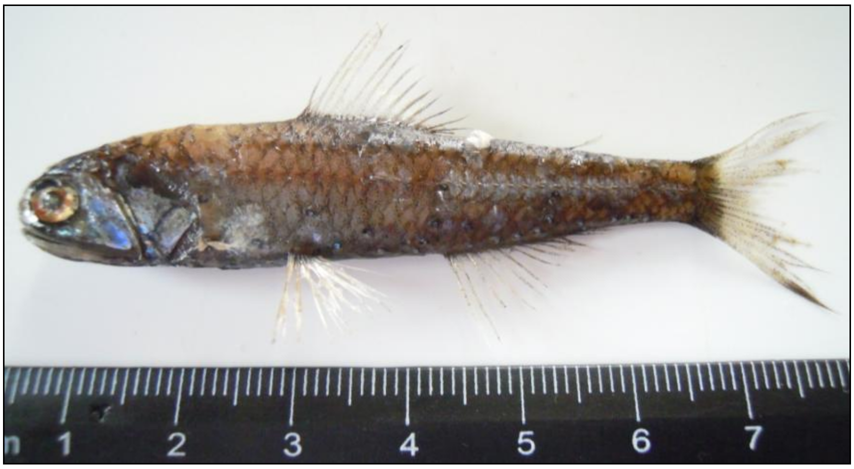


**Plate 2.2.** *Diaphus garmani*

*Diaphus garmani* Gilbert 1906 : 258, Pl. 2 (type locality "Cuba"; holotype MCZ 29070); Parr 1928: 145, Fig. 33 (records from western North Atlantic, characters); Nafpaktitis 1968: 35, Figs. 17 – 19 (key, description); Nakamura 1970: 374 (report on "swarming" in shallow waters, Christmas Island).

**Common name:**

Garman's lantern fish

**Synonyms:**

*Diaphus latus* Gilbert, 1913

*Diaphus ashmeadi* Fowler, 1934

**Material:**

Studied on 500 specimens of length range 1.2 to 7.4 cm in total length, obtained from south west coast of India ($8^0$ 81' – $12^0$ 79' N; $75^0$ 58' – $74^0$ 11' E) at a depth range of 250-500 m.

**Description:**

D. 15 (14 -16); A. 16 (15 – 17); P. 12 (11); GR 7 (rarely 6 or 8) + 1 + 13 -14 (rarely 12 or 15), total 21 – 22 (rarely 20 or 23); AO 7 (6 – 8) + 5 (4 – 6), total 12 (11 – 13); lateral–line organs 38 – 39.

Origin of dorsal fin over base of ventral fin. Origin of anal fin behind end base of dorsal fin. Base of adipose fin directly over or slightly in advance of end base of anal fin. Dn directly anterolaterally, tapering downward in between nostril and eye where it meets and often overlaps with dorsal, attenuated extension of Vn. Main bulk of Vn at anteroventral aspect of orbit. PLO distinctly near to lateral line than to base of pectoral fin. VLO midway between lateral line and base of ventral fin or a little higher. SAO on a straight line, sometimes $SAO_2$ slightly in front of or behind line through centers of $SAO_1$ and $SAO_3$; $SAO_3$ at lateral line. $AOa_1$ abrruptly elevated, sometime directly above $AOa_2$; last AO also elevated. Pol in contact with lateral line. $AOp_1$ sometimes over end of base of anal fin. First three Prc evenly spaced, forming a gentle arc; $Prc_3$-$Prc_4$ inter space enlarged, with $Prc_4$ about 1.5 times its diameter below midlateral line. A vertically elongated, roughly rectangular luminous scale at PLO.

**Colour:**

Body colour black with bluish tint in fresh specimens and becoming light brown during long preservation; lateral line scales forming a silver band in fresh specimens.

**Distribution:**

Indian Ocean, western tropical Atlantic, central and western tropical Pacific, Southeast Asian Seas, east coast of Africa, the Comoro Islands and west coast of Madagascar.

**Remarks:**

This is an occasional species seen in south west coast of India. The species has two synonyms and has been least studied in India. Bineesh *et al*. (2010) reported the first occurrence of *D. garmani* from Kerala waters. This species has close similarities with *D. signatus*.

**3. *Diaphus coeruleus* (Klunzinger, 1871)**

**Plate 2.3.** *Diaphus coeruleus*

*Diaphus coeruleus* : *Scopelus (Lampanyctus) coeruleus* Klunzinger 1871:592(Red Sea). *Diaphus (Lamprossa) coeruleus*. Fraser-Brunner 1949:1070, fig. (in key). *Diaphus coeruleus.* Aron and Goodyear 1969:241 (records from the Gulf of Elat and the Red sea).

**Common name:**

Blue lantern fish

**Synonyms:**

*Scopelus (Lampanyctus) coeruleus* Klunzinger 1871

*Diaphus (Lamprossa) coeruleus* Fraser-Brunner 1949

**Material:**

Single specimen of length 9.21 cm in total length, obtained from $09^0$ 05' – $09^0$ 09' N; $75^0$ 50' – $75^0$ 52' E at a depth range of 279 – 328 m.

**Description:**

D.15 (14); A.15 (14); P. 10-11; GR 6 (5-7) + 1 + 13 (12-14), total 20 (18-21); AO 6 (5) +5 (6); lateral-line organs 37.

Operculum somewhat angular posterodorsally, attenuated to a sharp point posteriorly. Origin of dorsal fin in advance of base of ventral fin. Origin of anal fin behind end base of dorsal fin. Pectoral fins extending about to $PO_5$. Ventral fins reaching anus. Base of adipose fin over end of base of anal fin.

Dn immediately posterodorsad to nasal apparatus, lentil-shaped and smaller than body photophore. Vn massive, roughly crescent-shaped, along anterior and anteroventral margin of eye, in contact with Dn dorsally, terminating in advance of vertical through anterior margin of pupil ventrally. A broad, massive band of dark tissue obscuring Dn and much of Vn from lateral view.

PLO 2 -2.5 times as close to base of pectoral fin as to lateral line. VLO nearly twice as close to base of ventral fin as to lateral line. SAO on a straight line or very nearly so; $SAO_3$ on or slightly in front of vertical through origin of anal fin and about 2.5 times its own diameter below lateral line. $AOa_1$ about 1.5 times its diameter anterodorsad to $AOa_2$; rest of organs of same series progressively raised forming a gentle curve with Pol. Pol under or slightly in advance of base of adipose fin, 2-2.5 times its own diameter below lateral line and often continuous with AOa. AOp behind base of anal fin. Prc forming an arc with $Prc_3$ - $Prc_4$ interspace often distinctly enlarged; $Prc_4$ about twice its diameter below lateral line. A luminous scale at PLO, its size 3-4 times that of a body photophore.

**Colour:**

Body colour black with bluish tint in fresh specimens and becoming light brown during long preservation; ventral with lateral part silvery, lateral line scales forming a silver band in fresh specimens.

**Distribution:**

Indian Ocean, Indo-West Pacific: Red Sea and the Andaman Sea, Papua New Guinea, Indonesia, Taiwan, Chesterfield Islands, and Australia. South China Sea, Gulf of Elat.

**Remarks:**

This is an occasional species seen in Indian waters. This species is very similar to *D. watasei*. This species can be distinguished from the larger, deeper bodied *D. watasei* with the luminous organs on the head, the shape of the operculum and some morphometric differences. These species are found close to the bottom of shelves and slopes.

**4. *Diaphus thiollierei* Fowler, 1934**


**Plate 2.4.** *Diaphus thiollierei*

*Diaphus thiollierei*: Fowler 1934:289, Fig. 48 (type locality 09° 31′ 50″ N, 124° 40′ E; holotype USNM 93158**).**

**Common name:**

Thiolliere's lantern fish

**Synonym:**

*Diaphus jouani* Fowler, 1934

**Material:**

4 specimens of length range 5.2 to 6.1 cm in total length, obtained from Lakshadweep Seas ($10^0$ 47' – $10^0$ 48' N; $72^0$ 11' – $76^0$ 12' E) at a depth range of 10 - 50 m with scoopnet during the surveys onboard *MV Titanic*.

**Description:**

D.16 (15-17); A.15 (14-16); P. 11 (10-12); GR 7 (6-8) + 1 + 14 (13-15), total 22 (20-24); AO 6 (5-7) + 4 (3-5), total 10 (9-11); lateral-line organs 36 - 37.

Mouth and eye moderately large. Inner series of teeth on upper and lower jaw enlarged, sharp bent forward. Operculum tapering posteriorly to a sharp point below and somewhat behind PLO. Origin of dorsal fin a little in advance of base of ventral fin. Origin of anal fin behind end of base of dorsal fin. Pectoral fin not reaching base of ventral fin. Ventral fin extending to anus. Base of adipose fin, in advance of vertical through end of base of anal fin.

A large roundish, forward-directed Dn immediately dorsal to olfactory organ, its size about equal to that of nasal rosette or larger than nasal rosette, reaching median ethmoid crest. Vn very well developed, occupying the anteroventral aspect of orbit, ending posteriorly in front of vertical through anterior margin of pupil, extending anteriorly upwards between olfactory organ and eye, reaching Dn, with which it superficially appears to be united. Ant well developed, appearing triangular and lies anterodorsal to the eye, in contact with the Dn-Vn complex.

PLO midway between base of pectoral fin and lateral line or slightly lower VLO somewhat near to base of ventral fin than to lateral line. SAO on a straight line or nearly so; $SAO_3$ in front of origin of anal fin and less than its diameter below lateral line. $AOa_1$

1.5 - 2.5 times its diameter anterodorsal to $AOa_2$. Pol directly under or slightly in advance of base of adipose fin and its diameter or less below lateral line, $AOp_1$ behind base of anal fin, Prc evenly spaced; $Prc_4$ 2 - 2.5 times its diameter below lateral line. A luminous scale at POL.

**Colour:**

Body colour brownish black in fresh specimens and becoming yellowish during long preservation; lateral line scales forming a silver band in fresh specimens.

**Distribution:**

Tropical Indian Ocean: from Sumatra to Africa, Arabian Sea, Mozambique Channel, Indo-Pacific and Southeast Asian seas.

**Remarks:**

This species mainly seen in Indian Ocean. These species are collected from off Lakshadweep Sea by scoopnets during surveys onboard *MV Titanic* during 2011. The samples are collected from surface water since the net operation was done on late evening hours.

**5. *Diaphus malayanus* Weber, 1913**


**Plate 2.5.** *Diaphus malayanus*

*Diaphus malayanus*: Weber 1913:89, Fig. 30 (Halmahere and Banda Seas); Hartmann and Clarke 1975 (Occurance across central equatorial Pacific); Tsokur 1975:611 (development).

**Common name:**

Malayan lantern fish

**Synonyms:**

*Diaphus tanakae* Gilbert, 1913

*Diaphus meyeri* Fowler, 1934

**Material:**

5 specimens of length range 5.1 to 6.8 cm in total length, obtained from off southwest of India ($8^0$ 81' – $12^0$ 79' N; $75^0$ 58' – $74^0$ 11' E) at a depth range of 250-500 m and 5 specimens of length range 3.8 to 5.1 cm in total length, obtained from off north east coast of India ($18^0$ 50' – $18^0$ 58' N; $85^0$ 22' – $85^0$ 25' E) at a depth range 389 – 535 m.

**Description:**

D.15 (16); A.16 (15); P. 12 (11); GR 6-7 + 1 + 12-13 (14), total 19-21 (22); AO 6 – 7 + 4-5 (6), Total 11 (10-12); lateral-line organs 36- 37.

Origin of dorsal fin slightly in advance of base of ventral fin. Origin of anal fin directly under or a little in front of end of base of dorsal fin. Pectoral fin barely reaching base of ventral fin. Ventral fin not reaching origin of anal fin. Base of adipose fin in advance of end of base of anal fin.

The Vn small, often smaller than the Dn, the two organs usually being entirely separated from each other. The Dn is roundish or roughly heart-shaped and equal in size, or larger than, the nasal rosette. The Vn, though somewhat smaller than the Dn, is equally massive.

PLO about twice as near to base of pectoral fin as to lateral line. VLO midway between base of ventral fin and lateral line or slightly higher. SAO on a straight line or nearly so; $SAO_1$ well above level of $VO_5$; $SAO_3$ on or behind, rarely in front of, vertical through origin of anal fin and in contact with lateral line. First AOa abruptly and highly elevated, last AOa less so. Pol under or somewhat in advance of base of adipose fin and immediately below lateral line. First AOp often over base of anal fin. $Prc_3$-$Prc_4$

interspace enlarged; $Prc_4$ behind $Prc_3$ and about twice its own diameter below lateral line. A small luminous scale at PLO.

**Colour:**

Body colour brownish with bluish tint in fresh specimens and becoming yellowish during long preservation; lateral line scales forming a silver band in fresh specimens.

**Distribution:**

Western Pacific: Australia and New Zealand, Indian Ocean: Japan, South China Sea, South east Asian Seas, Mozambique Channel.

**Remarks:**

This species mainly seen in Indian Ocean. These species are found close to the bottom of shelves and slopes of south west coastal waters of India and off north east waters during the deep-sea trawling surveys onboard *FORV Sagar Sampada* Cruise No. 291 during 2011.

**6. *Diaphus knappi* Nafpaktitis, 1978**

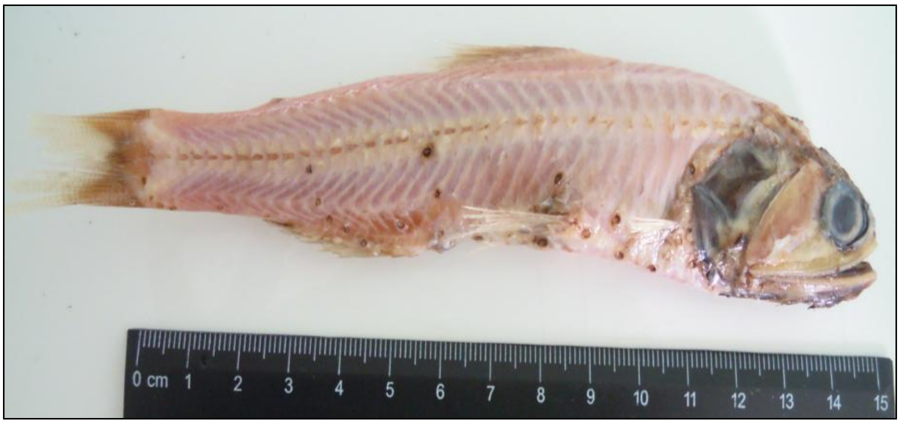


**Plate 2.6.** *Diaphus knappi*

*Diaphus knappi* : Nafpaktitis 1978: 45, Fig. 43. Holotype*:* Female, 90.0 mm; VB 66 TU; 23°36.4´S, 43°31´E; 28 February 1973, 1515-1630 hrs. 450-460 m; MNHN 1977.306.

*Paratypes*: Four specimens, 51.0-67.0 mm; *ANTONY BRUUN* Cruise 9, sta.422;06°51´S,39°54´E; 19 November 1964,LACM 36549.1,2,3,4.

**Common name:**

Namida-hadaka (Japanese)

**Synonym:**

*Diaphus elucens* (Brauer, 1904)

**Material:**

2 specimens of length range 16.1 to 17.8 cm in total length, obtained from Andaman waters $11^0$ 12' N; $92^0$ 25' E at a depth range of 320 - 649 m.

**Description:**

D. 15; A. 15; P. 11; GR 6 +1 + 13 (14); AO 6 + 5; lateral-line organs 36 - 37.

Snout low and long. Operculum sharply pointed posteriorly. Origin of dorsal fin somewhat in advance of base of ventral fin. Origin of anal fin behind base of dorsal fin. Pectoral fin not reaching base of ventral fin. Ventral fin not reaching origin of anal fin. Base of adipose fin slightly in advance of end of base of anal fin.

Dentaries with inner series of large, sharp teeth; small, closely-set teeth on palatines and mesopterygoids, and a few minute teeth on each side of vomer.

A roundish, forward-direction Dn, smaller than body photophore. Vn at anteroventral aspect of eye, superficially connected with Dn by a thin streak of luminous tissue, tapering posteriorly to a point in front of vertical through anterior margin of pupil. Ant developed.

PLO somewhat nearer to lateral line than to base of pectoral fin. Distance between VLO and lateral line about 1.5 times as great as that between VLO and base of ventral fin. SAO on a straight, nearly vertical line, space between $SAO_2$ and $SAO_3$ about 1.5 times as great as that between $SAO_2$ and $SAO_1$ ; $SAO_3$ in advance of origin of anal fin and immediately below lateral line. $AOa_1$ 1 - 1.5 times its diameter anterodorsal to $SAO_2$; penultimate AOa elevated. Pol in advance of base of adipose fin and less than its own diameter below lateral line. First AOp over or just behind end of base of anal fin.

Prc 1.5 - 2 times its diameter below lateral line. A vertically elongated luminous scale at PLO.

**Colour:**

Body colour brownish with bluish tint in fresh specimens and becoming light pink during long preservation; lateral line scales forming a silver band in fresh specimens.

**Distribution:**

Western Indian Ocean: off southwest Madagascar, Saya de Malha Bank and southeast of Zanzibar, Pacific Ocean: Kyushu-Palau Ridge, Taiwan, the Savannah Seamount Chain and South Pacific.

**Remarks:**

This is an occasional species seen in Indian waters. These species were found close to the bottom of shelves and slopes of Andaman waters during the deep-sea trawling surveys onboard *FORV Sagar Sampada* Cruise No. 252 during 2007.

**7. *Diaphus lucidus* (Goode and Bean) 1896**

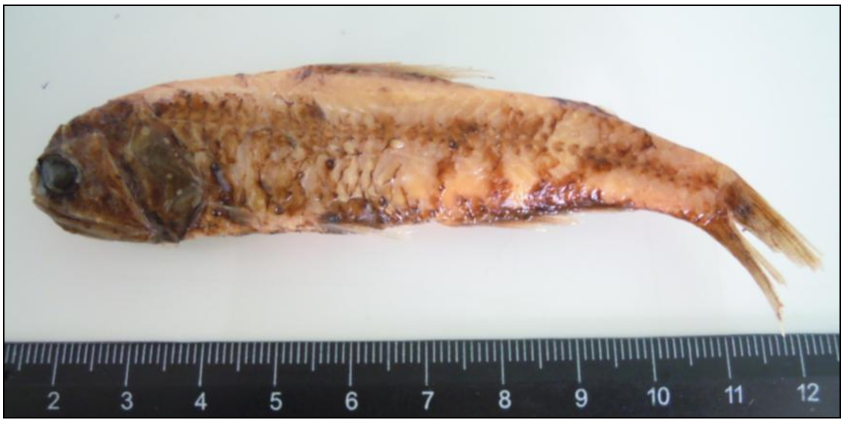



**Plate 2.7.** *Diaphus lucidus*

*Diaphus lucidus*: Taning 1928:61(in key); Parr 1928:141, Fig.31 (characters). Bekker 1967:107 (records from South Atlantic); Nafpaktitis 1968:59. Figs. 35-37 (key, description, distribution in North Athlantic); Kotthaus 1972:12 (record from eastern North Atlantic, characters, photograph of otolith); Krefft and Bekker 1973:178 (synonymy, reference).

**Common name:**

Spotlight lantern fish

**Synonyms:**

*Aethoprora licida* (Goode and Bean, 1896)

*Diaphus monodi* Fowler, 1934

*Diaphus reidi* Fowler, 1934

*Diaphus altifrons* Kulikova, 1961

**Material:**

Single specimen of length 9.5 cm in total length, obtained from Andaman waters $13^0$ 18' N; $93^0$ 25' E at a depth range of 320 - 538 m.

**Description:**

D.17 (18); A.17-18 (19); P. 11-12; GR 5-6 + 1 + 11-12, total 17-19; AO 7 (8) + 4.5 (6), Total 12 (11-13); lateral-line organs 38 ( 37-39).

Operculm with a weakly serrate lobe posterodorsally, tapering posteriorly to a point below PLO. Origin of anal in front of end base of dorsal fin. Base of adipose fin in advance of end of base of anal fin.

Dn round, forward-directed and as large as, or larger than, eye lens. Vn long and narrow, extending along anterior and anteroventral aspect of eye, terminating posteriorly in advance of vertical through anterior margin of pupil.

Body photophores markedly small PLO midway between base of pectoral fin and lateral line or somewhat higher. VLO much closer to lateral line than to base of ventral fin. $SAO_3$ over base of anal fin and its diameter or less below lateral line. $AOa_1$ elevated well above and in front of $AOa_2$. Pol its diameter or less below lateral line. $AOp_1$ often over base of anal fin and distinctly raised . A vertically elongated luminous scale at PLO.

**Colour:**

Body colour brownish black with bluish tint in fresh specimens and becoming brownish yellow during long preservation; lateral line scales forming a silver band in fresh specimens.

**Distribution:**

Indian Ocean: equatorial waters and west of Agulhas Current, Mozambique Channel, Eastern Atlantic, Western Atlantic: USA, Brazil and Argentina, Indo-west-central Pacific: Southeast Asian seas, South China Sea.

**Remarks:**

This is an occasional species seen in Indian waters. These species are found close to the bottom of shelves and slopes of Andaman waters during the deep-sea trawling surveys onboard *FORV Sagar Sampada* Cruise No. 252 during 2007.

Morphometric measurements of the specimens are presented in Table 2.1.

## 2.4. DISCUSSION

In total, seven species of *Diaphus* has been collected from Indian Ocean. This area can be geographically divided into four regions: Arabian Sea, Bay of Bengal, Lakshadweep Sea and Anadaman Seas. The species collected from each area are shown in Fig 2.2. Among the seven species only one species *D. malayanus* shared from south west and north east part of Indian Ocean. Earlier reports of above discussed *Diaphus* spp. in the Indian Ocean are mentioned in Table 2.2.

**Table 2.1.** Body proportions of *Diaphus* spp. in percentage of standard length

| **Character of species** | ***D. watasei*** | | ***D. garmani*** | | ***D. coeruleus**** | ***D. thiollierei*** | |
|---|---|---|---|---|---|---|---|
| | **Range** | **Mean** | **Range** | **Mean** | **Measure** | **Range** | **Mean** |
| Standard length | 1.99 – 14.32 **(cm)** | 9.50 **(cm)** | 4.14 – 7.14 **(cm)** | 5.65 **(cm)** | 7.38 **(cm)** | 4.1 – 4.8 **(cm)** | 4.32 **(cm)** |
| **As percentage of standard length** | | | | | | | |
| Head length | 0.03 – 0.63 | 0.30 | 0.05 -0.18 | 0.10 | 0.03 | 0.05 – 0.07 | 0.85 |
| Head depth | 0.02 – 0.37 | 0.16 | 0.04 – 0.13 | 0.08 | 0.11 | 0.03 – 0.04 | 0.83 |
| Eye diameter | 0.01 - 0.12 | 0.06 | 0.02 – 0.07 | 0.04 | 0.11 | 0.01 – 0.02 | 0.81 |
| Upper jaw length | 0.02 – 0.42 | 0.20 | 0.03 – 0.10 | 0.06 | 0.06 | 0.04 – 0.05 | 0.83 |
| Body depth | 0.02 – 0.39 | 0.19 | 0.04 – 0.16 | 0.09 | 0.22 | 0.03 – 0.04 | 0.83 |
| Caudal depth | 0.01 – 0.28 | 0.11 | 0.02 – 0.06 | 0.04 | 0.25 | 0.02 – 0.02 | 0.82 |
| Predorsal length | 0.04 – 0.87 | 0.43 | 0.08 – 0.26 | 0.15 | 0.16 | 0.07 – 0.09 | 0.86 |
| Preventral length | 0.04 – 0.95 | 0.46 | 0.09 – 0.26 | 0.16 | 0.36 | 0.07 – 0.10 | 0.87 |
| Prepectoral length | 0.03 – 0.62 | 0.31 | 0.05 – 0.18 | 0.10 | 0.45 | 0.05 – 0.07 | 0.85 |
| Preanal length | 0.06 – 1.36 | 0.66 | 0.12 – 0.37 | 0.22 | 0.25 | 0.09 – 0.12 | 0.88 |
| Preadipose length | 0.07 – 1.66 | 0.81 | 0.15 – 0.47 | 0.29 | 0.25 | 0.14 – 0.19 | 0.93 |
| Upper jaw length/E.D | 0.03 – 0.64 | 0.32 | 0.04 – 0.15 | 0.09 | 0.10 | 0.11 – 0.15 | 0.90 |
| H.D/ED | 0.03 – 0.57 | 0.25 | 0.06 – 0.21 | 0.12 | 0.08 | 0.09 – 0.13 | 0.89 |
| Dorsal fin base length | 0.02 – 0.39 | 0.19 | 0.03 – 0.12 | 0.07 | 1.03 | 0.05 - 0.07 | 0.85 |
| Anal fin base length | 0.02 – 0.35 | 0.17 | 0.04 – 0.11 | 0.07 | 1.18 | 0.03 – 0.04 | 0.83 |
| **Meristic counts** | | | | | | | |
| Dorsal fin ray | 13 – 16 | 14 | 15 | 15 | 14 | 15 - 16 | 16 |
| Anal fin ray | 14 – 16 | 15 | 16 | 16 | 16 | 14 - 15 | 15 |
| Pectoral fin ray | 9 – 11 | 10 | 12 | 12 | 11 | 9 - 10 | 10 |
| Gill rakers on first arch | 19 - 20 | 19 | 22 – 23 | 22 | 18 | 20 - 21 | 21 |
| AO photophores | 12 | 12 | 12 | 12 | 12 | 11 | 11 |
| Lateral line scales | 37-38 | 38 | 37 - 38 | 38 | 36 | 37 - 38 | 38 |

*Only single specimen was available

**Table 2.1.** Body proportions of *Diaphus* spp. in percentage of standard length continued…

| Character of species | *D. malayanus* | | *D. knappi* | | *D. lucidus** |
|---|---|---|---|---|---|
| | **Range** | **Mean** | **Range** | **Mean** | **Measure** |
| Standard length | 2.9 - 5.1 **(cm)** | 4.69 **(cm)** | 12.7 – 13.9 **(cm)** | 9.53 **(cm)** | 8.50 **(cm)** |
| **As percentage of standard length** | | | | | |
| Head length | 0.02 - 0.07 | 0.95 | 0.45 - 0.54 | 0.99 | 0.23 |
| Head depth | 0.02 – 0.05 | 0.94 | 0.31 – 0.38 | 0.90 | 0.16 |
| Eye diameter | 0.01 – 0.02 | 0.92 | 0.14 – 0.17 | 0.77 | 0.06 |
| Upper jaw length | 0.02 - 0.06 | 0.94 | 0.30 - 0.36 | 0.89 | 0.15 |
| Body depth | 0.02 – 0.07 | 0.95 | 0.35 – 0.42 | 0.93 | 0.19 |
| Caudal depth | 0.01 – 0.03 | 0.93 | 0.16 – 0.19 | 0.78 | 0.07 |
| Predorsal length | 0.04 – 0.11 | 0.98 | 0.70 – 0.84 | 1.18 | 0.30 |
| Preventral length | 0.03 – 0.10 | 0.97 | 0.51 – 0.61 | 1.04 | 0.22 |
| Prepectoral length | 0.02 – 0.08 | 0.96 | 0.72 – 0.86 | 1.19 | 0.32 |
| Preanal length | 0.06 – 0.18 | 1.02 | 1.11 – 1.33 | 1.48 | 0.45 |
| Preadipose length | 0.06 – 0.18 | 1.02 | 1.33 – 1.60 | 1.64 | 0.64 |
| Upper jaw length/E.D | 0.05 – 0.15 | 1.00 | 0.27 – 0.33 | 0.87 | 0.22 |
| H.D/ED | 0.05 – 0.14 | 1.00 | 0.29 – 0.34 | 0.88 | 0.24 |
| Dorsal fin base length | 0.02 – 0.06 | 0.95 | 0.34 – 0.40 | 0.91 | 0.21 |
| Anal fin base length | 0.02 – 0.05 | 0.94 | 0.31 – 0.37 | 0.89 | 0.20 |
| **Meristic counts** | | | | | |
| Dorsal fin ray | 14 – 16 | 15 | 15 | 15 | 16 |
| Anal fin ray | 15 | 15 | 15 | 15 | 16 |
| Pectoral fin ray | 9 - 11 | 11 | 11 – 12 | 11 | 12 |
| Gill rakers on first arch | 22 | 22 | 19 | 19 | 17 |
| AO photophores | 10 - 12 | 11 | 11 | 11 | 12 |
| Lateral line scales | 37 - 38 | 38 | 38 | 38 | 38 |

*Only single specimen was available

**Table 2.2.** Distribution of seven *Diaphus* species in Indian Ocean

| **Species** | **Area of distribution** | **References** |
|---|---|---|
| *Diaphus coeruleus* | Western Indian Ocean | Nafpaktitis (1984) |
| *Diaphus garmani* | Northern Arabian Sea, Western Indian Ocean, Srilankan waters, African coast, Equatorial region of Arbian sea | Gjosaeter (1977), Nafpaktitiss (1984), Hulley (1986), Dalpadado and Gjosaeter (1993) and Tsarin and Boltachev (2006) |
| *Diaphus knappi* | Western Indian Ocean, Off southwest Madagascar, Southeast of Zanzibar | Nafpaktitis (1984) and Hulley (1986) |
| *Diaphus lucidus* | Western Indian Ocean, EEZ of Arabian Sea, Equatorial region of Arbian sea | Nafpaktitiss (1984), Hulley (1986), Karuppasamy *et al*. (2006, 2010) and Tsarin and Boltachev (2006) |
| *Diaphus malayanus* | Western Indian Ocean, Mozambic Channel, Arabian Sea | Nafpaktitis (1984), Hulley (1986) and Tsarin and Boltachev (2006) |
| *Diaphus thiollieri* | Northern Arabian Sea, Western Indian Ocean, Southeast Asian Seas, Srilankan Waters | Gjosaeter (1977), Nafpaktitiss (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Kinzer *et al*. (1993) and Tsarin and Boltachev (2006) |
| *Diaphus watasei* | Western Indian Ocean, African continental shelf, West coast of Madagascar, EEZ of Arabian Sea | Nafpaktitiss (1984), Hulley (1986) and Karuppasamy *et al*. (2006). |

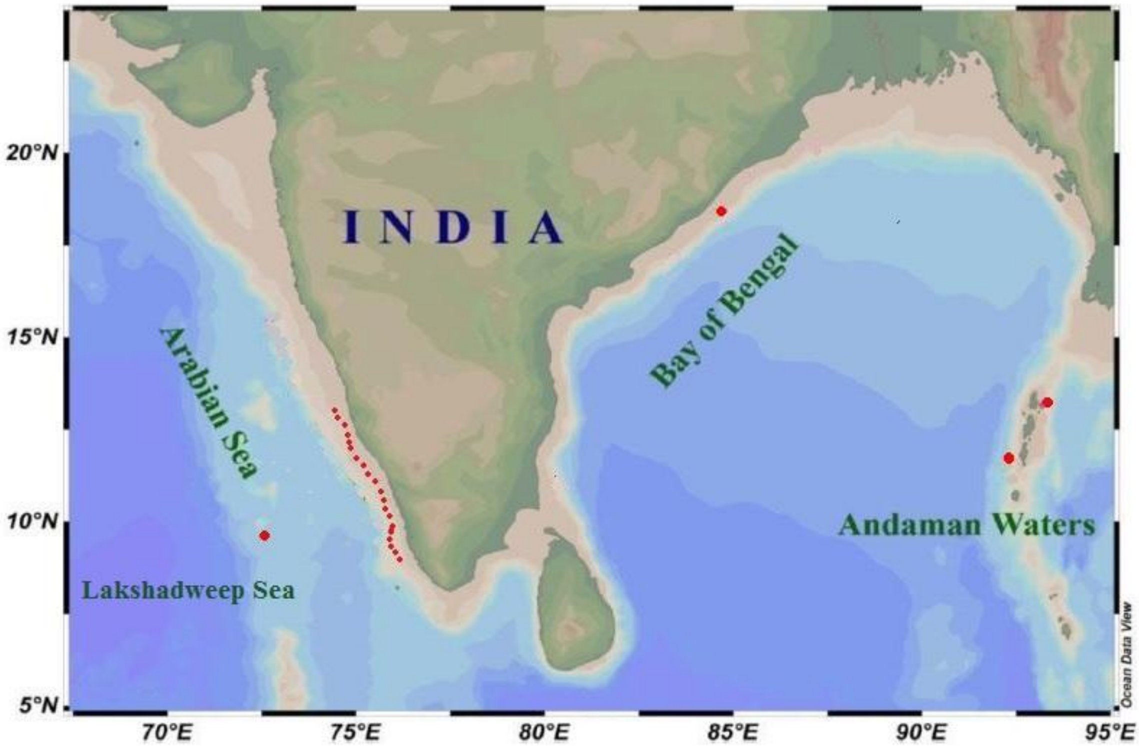



**Fig. 2.2.** Map showing samples surveyed along the Arabian Sea, Bay of Bengal, Andaman waters and Lakshadweep Sea

# CHAPTER 3

# FISHERY

# CHAPTER 3

# FISHERY

## 3.1. INTRODUCTION AND REVIEW OF LITERATURE

Fishes of the family Myctophidae are widely distributed in the world Oceans and occured as bycatch in deep-sea shrimp trawlers. The resources demands only very low price and are often discarded in the sea itself at the time of sorting. Along the south-west coast of India, lantern fish (order myctophiformes) forms a major portion of bycatch in the deep sea shrimp trawler (Bineesh *et al*., 2009; Pillai *et al*., 2009). These fishes, when landed as by catch are mostly used for fishmeal or manure production.

Stock sizes of mesopelagic fishes, in which myctophids are predominant constituents, have been re-estimated as 263 and 102 million t, in the Western Indian Ocean and Eastern Indian Ocean, respectively (Lam and Pauly, 2005). Myctophids are the most common fishes in the world Oceans with an estimated biomass of 600 million t (GjØsaeter and Kawaguchi, 1980 and Hulley, 1994). The Indian Ocean harbours a rich fauna of lantern fishes both in number of species and biomass (Gjosaeter and Kawaguchi, 1980). GLOBEC (1993) estimated 100 million t of myctophids in the Arabian Sea. Recent estimates of FAO (1997) reported 2.3 million t of *Benthosema petrotum*. Wide occurrence of *Diaphus* spp. from the eastern and north-eastern Arabian Sea has been reported (FAO, 1997; Balu and Menon, 2006). In Suruga Bay, Japan, *D. watasei* was abundant in the fishing grounds of the sergestid shrimp (Kosaka *et al*., 1969). A study carried out by the Central Marine Fisheries Research Institute during 1997 - 2002, estimated their biomass as 100,000 t along the Indian EEZ of Arabian Sea and is dominated by *Diaphus* sp. (Balu and Menon, 2006). Sajeevan and Nair (2006) reported 1202 tonnes biomass of *Diaphus* spp. from south west coast of India. They also reported 655 tonnes biomass of neoscopilids from the same depth zone. Studies made by Menon and Venugopal (2004) on DSL of Indian EEZ, signified that myctophid catch was high during night hauls, where more concentrations at $7^0$, $14^0$, $16^0$, $21^0$ with maximum abundance at $19^0$ N of West coast of India. According to their studies myctophids appeared in large shoals in the north west region of Indian EEZ with distribution decreasing from north to south. Aravindakshan *et al*. (1987) reported an average catch of 40650 kg *Myctophum* sp. from Maharashtra coast.

### 3.2. MATERIAL AND METHODS

Data on catch, effort and species composition by weight were collected, following Stratified Random Sampling Method, at weekly intervals from the deep sea shrimp trawlers landed at fishing harbours of Cochin and Kollam. At Cochin, deep sea shrimp trawlers landed at Cochin Fisheries Harbour and Kalamukku Landing Centre. At Kollam, deep sea shrimps landed at Sakthikulangara Harbour. Absence of the multiday trawlers from the port for 12 hours period was taken as one unit effort. The average bycatch and species composition by weight for the observed units were multiplied by the number of units landed on the day to get that days' catch. The total species wise catch and effort were raised to the month by multiplying it with a factor obtained by dividing the actual fishing days by the total number of days in the month.

## 3.3. RESULTS

### 3.3.1. Habitat

They are Oceanic or pseudOceanic, pelagic or epibenthic from Artic to Antartic waters. Some species exhibit diurnal vertical migration between the surface and at 500 m depth. Most species are abundant, some are rarely occuring.

### 3.3.2. Craft and gear

Myctophids were caught as bycatch in multi-day deep-sea shrimp trawlers operated off the Kerala coast. The plank built and steel mechanized crafts of 13 - 16 m OAL, with an engine power of 100 - 120 hp is used (Plate 3.1) Trawl net having a codend mesh size of 25 - 30 mm were used in the fishery.

Fishing operations by multi-day deepsea shrimp trawlers of Kerala extends from off Quilon in Kerala in the south to off Ezhimala in the north. These trawlers stay back at sea for 7 to 14 days for fishing. The fishing areas were 60 nautical miles from the shore. Each boat makes 3 to 4 hauls of 2 - 3 hours duration at a towing speed of 2 knots/hour during day time fishing. The multiday trawl fishing is done targeting mainly for deep-sea prawns. Generally, fishing is carried during the day time but extends to the night hours when day catches dwindle.commencement

### 3.3.3. Fishing season

Generally deep-sea shrimp trawlers commence operation soon after the commensment of monsoon (August) but peak fishing activities are observed during November - February. Fishing is carried on till the end of May. The Government of Kerala has banned the operations of mechanized fishing units during the peak monsoon months (15 June – 31 July) along the Kerala coast.

### 3.3.4. Fishery and fishing area

Deep sea shrimp trawling was carried out between off Quilon and off Ezhimala, along the southwest coast of India ($8^0$ 81’ – $12^0$ 79’ N; $75^0$ 58’ – $74^0$ 11’ E) (Fig. 3.1). Deep sea shrimp trawlers were more concentrated at off Kollam area, where fishers identified this area as Quilon Bank. Fishing was carried out during day time at a depth range of 250 - 500 m. From the echogram of echosounder it was found that the shrimps inhabited in uneven bottom surfaces.

The trawlers specifically targeted for deep sea shrimps like *Aristeus alcocki*, *Heterocarpus gibbosus, Heterocarpus woodmasoni, Metapenaeopsis andamanensis*, *Plesionika quasigrandis*, *Plesionika martia* and *Solenocera hextii*. Among the targeted shrimps, *P. quasigrandis* was the dominant species. Usually in each operation, bycatch contributes about 20 to 40% along with targeted species (Plate 3.2). Sometimes the bycatch exceeded more than 80% and was discarded without being taken onboard vessel. The major components in the bycatch belonged to the families Rhinochimaeridae, Echinorhinidae, Centrophoridae, Squalidae, Stomiidae, Sternoptychidae, Gonostomatidae, Ateleopodidae, Chlorophthalmidae, Ipnopidae, Evermannellidae, Neoscopelidae and Myctophidae.

The average annual catch of myctophids during 2009-11 was 2587 t/yr. (Table 3.1). The year wise catch of myctophids during 2009, 2010 and 2011 were 2421 t, 2610 t and 2729 t respectively with an increasing trend in the catch. Catch per Hour (CPH) ranged from 6.3 to 9.5 kg with an average of 7.9 kg. Myctophids formed 10 – 20% of the total catch.

During 2009, an estimate of 2421 t of myctophids were calculated and it formed 15% of the total deep-sea trawl catch, it was 2610 t in 2010 forming 18% and 2729 t in 2011 forming 20%.

The month-wise catch indicates that myctophids are more abundant in the trawling grounds during November – February. Peak catch was observed in February and minimum in August (Fig. 3.2).

**3.3.5. Species composition**

Myctophid catch in deep-sea shrimp trawlers was supported by five species *viz*., *Diaphus watasei* (74.23%), *Neoscopilus microchir* (20.56%), *Benthosema fibulatum* (1.94%), *Diaphus garmani* (1.69%) and *Myctophum obtusirostre* (1.58%) (Table 3.2 and Fig. 3.3). *Diaphus watasei* was found to be dominant among the myctophids and comprised more than 74% of the total. *Benthosema fibulatum* and *Myctophum obtusirostre* were dominant towards northern part off Kerala. Year wise species composition during 2009, 2010 and 2011 are given in Tables (3.3, 3.4 and 3.5) and Figs. (3.4, 3.5 and 3.6). In all the three years, *Diaphus watasei* was the dominant species in the fishery and contributed by 1767 t, 1949 t and 2048 t in 2009, 2010 and 2011 respectively. The monthly percentage contribution of *D. watasei* to total myctophids landings differed from 0.53 percent (August) to 12.98 percent (February). All the species showed year wise increase in the catch, except the catch of *M. obtusirostre* during 2011 reduced when compared with previous year (Fig. 3.7). All the species are benthopelagic, as the trawlers operating in deeper waters alone are landing myctophids.

### 3.3.6. Catch disposal and utilization

High fat content of myctophids makes the fish not ideal for human consumption. So they are considered as trash fishes and are often discarded at the time of onboard sorting itself. If the catch of targeted resources is low, the trash fishes will be taken to the landing centre and are sun dried for the preparation of fish meal. Some species like *Neopinnula orientalis* were used for human consumption, which only fetches a low price. At Kollam fishing harbour, some amount of trash fishes are used in the bio-processing plant for the production of electricity (Plate 3.3). Some amount of trash fishes were sundried and used for the preparation of fish manure. These sundried fishes were transported to areas of interior Tamilnadu, were it is processed as manure. The high fat content of the fish makes it an ideal raw material in fishmeal plants for extraction of oil and preparation of poultry/fish feed and manure. These plants extract the oil and the residue is used as a protein base for the preparation of poultry/fish feeds.

## 3.4. DISCUSSION

Myctophids are caught as bycatch along the Kerala coast by the multi-day deep sea shrimp trawlers. Fernandez *et al*. (2011) reported 11,484 t of bycatch from deepsea shrimp trawlers operated along south west coast of Kerala. The species exhibits diurnal vertical migration and comes up to the upper 100 m layer at night. The day time habitat is presumed to be near the bottom, since the species is commonly captured in the daytime by commercial deep-sea shrimp bottom trawl at a depth range of 250 – 500 m.

The occurrence of myctophids depends on the intensity of deep sea shrimp fishery, as there is no targeted fishery. Fishers undertake targeted deep-sea shrimp fishing only when there is abundance of commercially important deep sea shrimps observed in the ground and also if paucity in the commercial fin fishes catch. Deep-sea shrimp fishing by the multi-day trawlers operate continuously for ten months in a year with a peak fishing during November - February. During lean months, only selected trawlers will operate for deep-sea shrimps. The annual production of myctophids during 2009, 2010 and 2011 are 2421, 2610, 2729 t respectively. The overall myctophids catch during the years exhibit an increasing trend. However, the estimates are not realistic as many trawlers still discarded myctophids in the sea itself due to less demand and shortage of space on the deck and fishhold. Also midwater species are not encountered in the catch, since reports of Gjosaeter and Kawaguchi (1980) suggests that the key members of myctophids are mesopelagics species. According FAO (1998) mid water trawls is appropriate for myctophids catch, so exclusive studies have to be done on DSL myctophids.

The average catch per unit of myctophids from deep-sea shrimp trawler is 25 kg/haul. Peak period of abundance of myctophids in the Kerala coast extended during November to February (Table 3.1). During southwest monsoon season (June – August) fishermen targets pelagic fishes. Also there will be trawl ban during June - July. From August onwards multiday deep-sea shrimp fishery starts, but intensity of deep-sea shrimp trawling is less compared with the coastal trawling. By November the depth and area of operation intensely changes to deep-sea shrimp fishery and this trend will remain upto February and there after the fishers set out general trawling. This can be attributed the intensity of the myctophids catch during November to February. As more number of multiday deep-sea shrimp trawlers are operating from Kollam, nearly 70% of deep-sea shrimp catch was from Kollam and rest from Cochin harbour. Rajan *et al*. (2001) reported that fishing ground between Kollam and Alapuzha, popularly known as 'Quilon Bank' is a rich ground for deepsea shrimps. Both Cochin and Kollam harbours had similar peak periods of abundance in the respective months. Among the deep-sea shrimp landing centers, Kollam recorded the highest landings of bycatch, because there are demands from biofuel processing plants and fish feed processing units.

Out of the five species obtained, *D. watasei* contributed a major share to the myctophid fishery of Kerala. *Diaphus watasei* was the most dominant species at all the centers. Overall *D. watasei* comprised 74% of the myctophid catch. The second dominant species *Neoscopilus microchir* contributed 20.6% of the total myctophids. *Diaphus garmani* contribute only marginally to the sum of 1.7% of myctophid catch. The other species contributed to the fishery are *B. fibulatum* (1.9%) and the *M. obtusirostre* (1.6%) of the total myctophids. With the introduction of more number of multiday trawlers and together with increasing depth of operation, the catch of myctophids along the Kerala coast is found to increase greatly in the coming years.

In Kerala, myctophids are mainly utilized for fish feed and manure preparation. Some experimental bioprocessing unit was started at Kollam harbour, where discarded species can be used for biogas production which in turn for the electricity production. Though, people prefered some deep sea fishes for consumption, myctophids are not used for direct consumption due to oily taste. Further utilization as value added products, diet supplements and industrial purpose are suggestible.

**Table. 3.1.** Estimated catch (tonnes) of myctophids from the deep-sea shrimp trawlers off Kerala during 2009 -11

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 392 | 444 | 190 | 153 | 120 | 0 | 0 | 15 | 66 | 266 | 393 | 382 | 2421 |
| 2010 | 441 | 433 | 146 | 172 | 9 | 0 | 0 | 22 | 157 | 354 | 457 | 420 | 2610 |
| 2011 | 433 | 480 | 213 | 163 | 181 | 0 | 0 | 19 | 74 | 272 | 487 | 408 | 2729 |
| Average | 422 | 452 | 183 | 163 | 103 | 0 | 0 | 19 | 99 | 297 | 446 | 403 | 2587 |

* No fishing in June and July

**Table 3.2.** Average monthwise species composition (tonnes) of myctophids

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *D. watasei* | 313 | 336 | 136 | 121 | 77 | 0 | 0 | 14 | 73 | 221 | 331 | 300 | 1920 |
| *N. microchir* | 87 | 93 | 38 | 34 | 21 | 0 | 0 | 4 | 20 | 61 | 92 | 83 | 532 |
| *B. fibulatum* | 8 | 8 | 4 | 3 | 2 | 0 | 0 | 0.4 | 2 | 6 | 9 | 8 | 50 |
| *D. garmani* | 7 | 8 | 3 | 3 | 2 | 0 | 0 | 0.3 | 2 | 5 | 8 | 7 | 44 |
| *M. obtusirostre* | 7 | 7 | 3 | 3 | 2 | 0 | 0 | 0.3 | 2 | 5 | 7 | 6 | 41 |

* No fishing in June and July

**Table. 3.3.** Monthwise species composition (tonnes) of myctophids from the deep-sea shrimp trawlers off Kerala during 2009

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *D. watasei* | 286 | 324 | 138 | 112 | 88 | 0 | 0 | 11 | 48 | 194 | 287 | 279 | 1767 |
| *N. microchir* | 74 | 84 | 36 | 29 | 23 | 0 | 0 | 3 | 13 | 51 | 75 | 73 | 460 |
| *B. fibulatum* | 6 | 7 | 3 | 2 | 2 | 0 | 0 | 0.2 | 1 | 4 | 6 | 6 | 38 |
| *D. garmani* | 5 | 6 | 3 | 2 | 2 | 0 | 0 | 0.2 | 1 | 4 | 6 | 5 | 34 |
| *M. obtusirostre* | 5 | 5 | 2 | 2 | 2 | 0 | 0 | 0.2 | 1 | 3 | 5 | 5 | 29 |

* No fishing in June and July

**Table. 3.4.** Monthwise species composition (tonnes) of myctophids from the deep-sea shrimp trawlers off Kerala during 2010

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *D. watasei* | 329 | 324 | 109 | 128 | 6 | 0 | 0 | 16 | 117 | 264 | 341 | 314 | 1949 |
| *N. microchir* | 88 | 86 | 29 | 34 | 2 | 0 | 0 | 4 | 31 | 70 | 91 | 84 | 519 |
| *B. fibulatum* | 9 | 8 | 3 | 3 | 0.2 | 0 | 0 | 0.4 | 3 | 7 | 9 | 8 | 51 |
| *D. garmani* | 7 | 7 | 3 | 3 | 0.1 | 0 | 0 | 0.4 | 3 | 6 | 8 | 7 | 44 |
| *M. obtusirostre* | 7 | 7 | 2 | 3 | 0.1 | 0 | 0 | 0.4 | 3 | 6 | 7 | 7 | 43 |

* No fishing in June and July

**Table. 3.5.** Monthwise species composition (tonnes) of myctophids from the deep-sea shrimp trawlers off Kerala during 2011

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *D. watasei* | 325 | 360 | 160 | 122 | 136 | 0 | 0 | 14 | 55 | 204 | 365 | 306 | 2048 |
| *N. microchir* | 90 | 100 | 45 | 34 | 38 | 0 | 0 | 4 | 15 | 57 | 102 | 85 | 569 |
| *B. fibulatum* | 10 | 11 | 5 | 4 | 4 | 0 | 0 | 0.4 | 2 | 6 | 11 | 9 | 63 |
| *D. garmani* | 8 | 9 | 4 | 3 | 4 | 0 | 0 | 0.4 | 1 | 5 | 9 | 8 | 52 |
| *M. obtusirostre* | 6 | 7 | 3 | 2 | 3 | 0 | 0 | 0.3 | 1 | 4 | 7 | 6 | 39 |

* No fishing in June and July

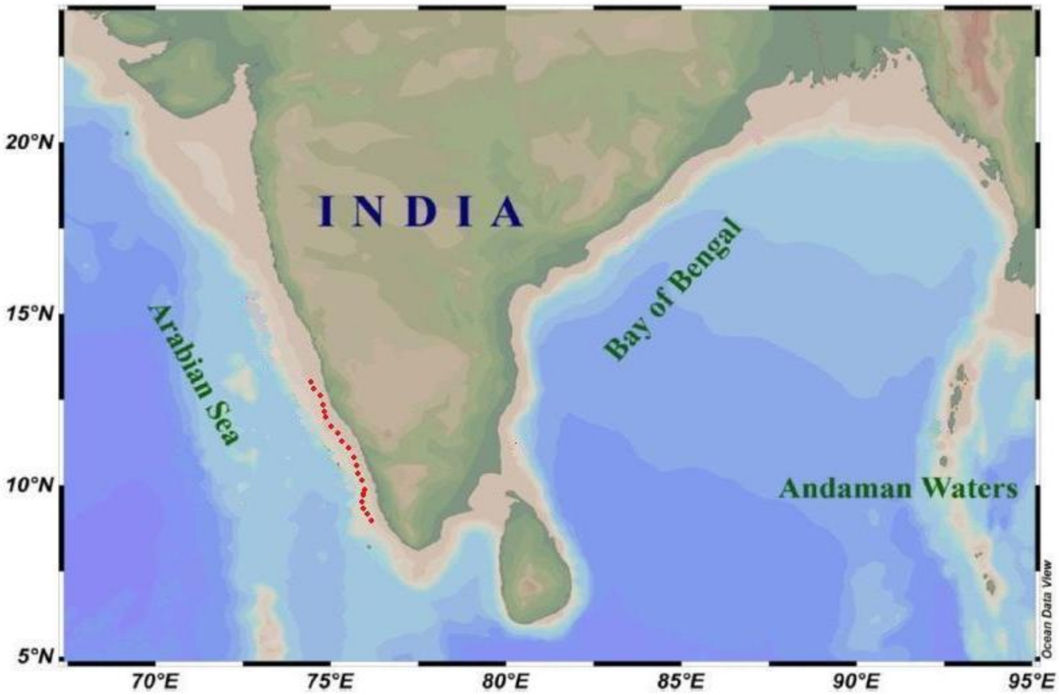
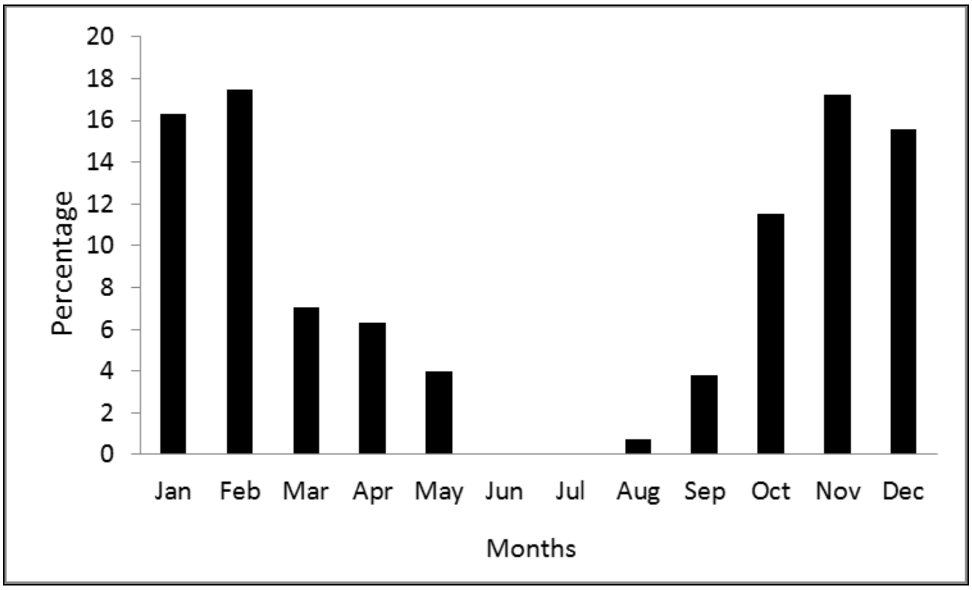



**Fig. 3.1.** Map showing fishing area of myctophids off Kerala




* No fishing operation in June and July

**Fig. 3.2.** Seasonal pattern in the myctophid catch by deepsea shrimp trawlers during 2009-11

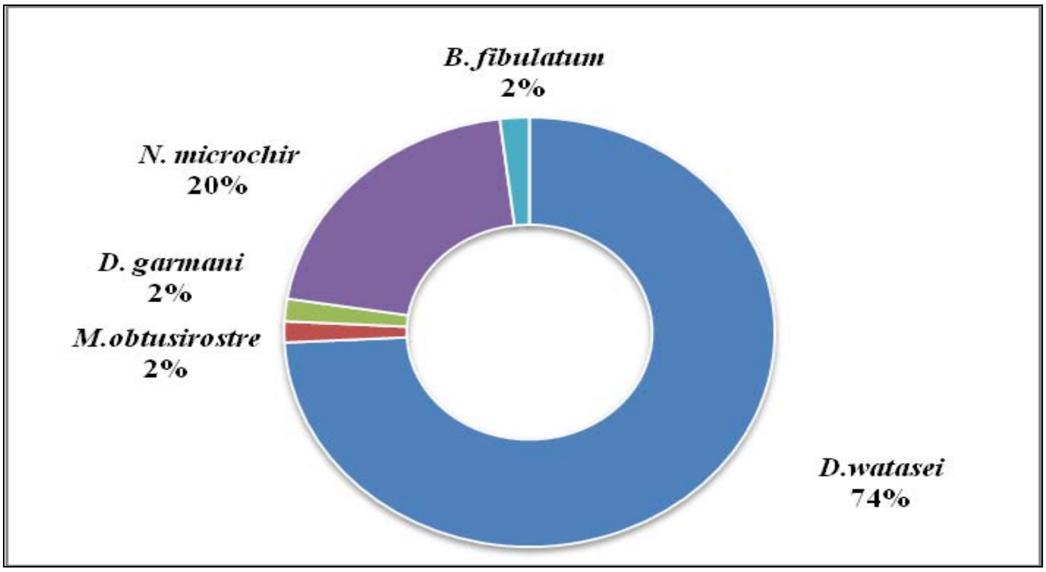



**Fig. 3.3.** Species composition (average) of myctophids by deepsea shrimp trawlers during 2009-11

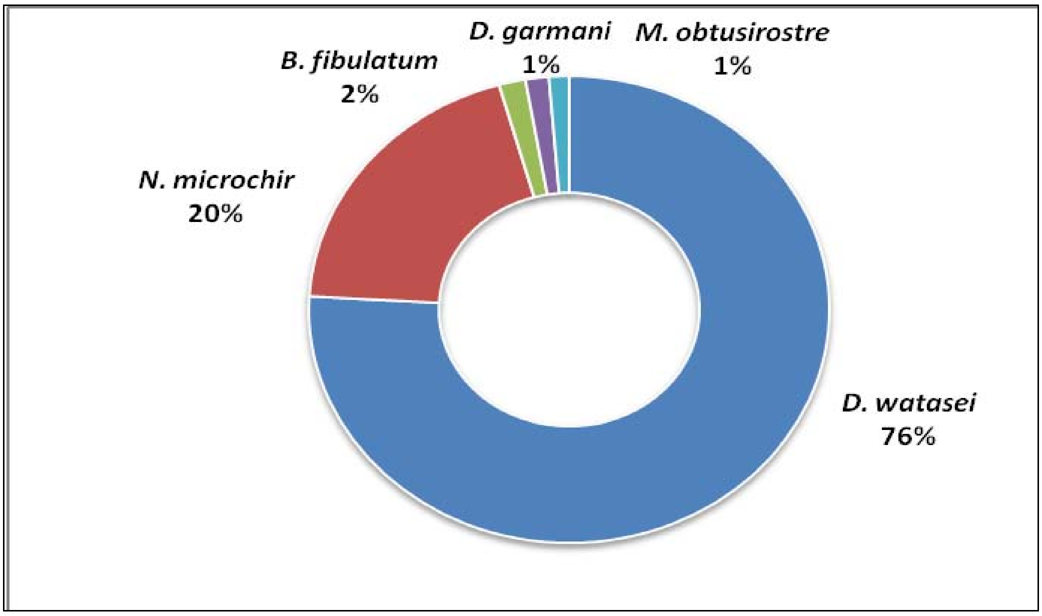



**Fig. 3.4.** Species composition (average) of myctophids by deepsea shrimp trawlers during 2009

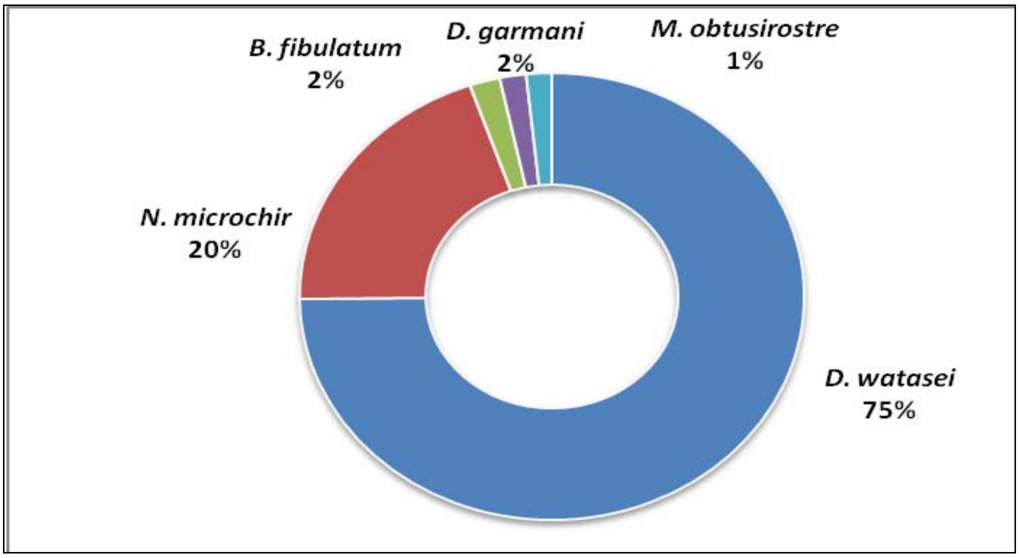



**Fig. 3.5.** Species composition (average) of myctophids by deepsea shrimp trawlers during 2010

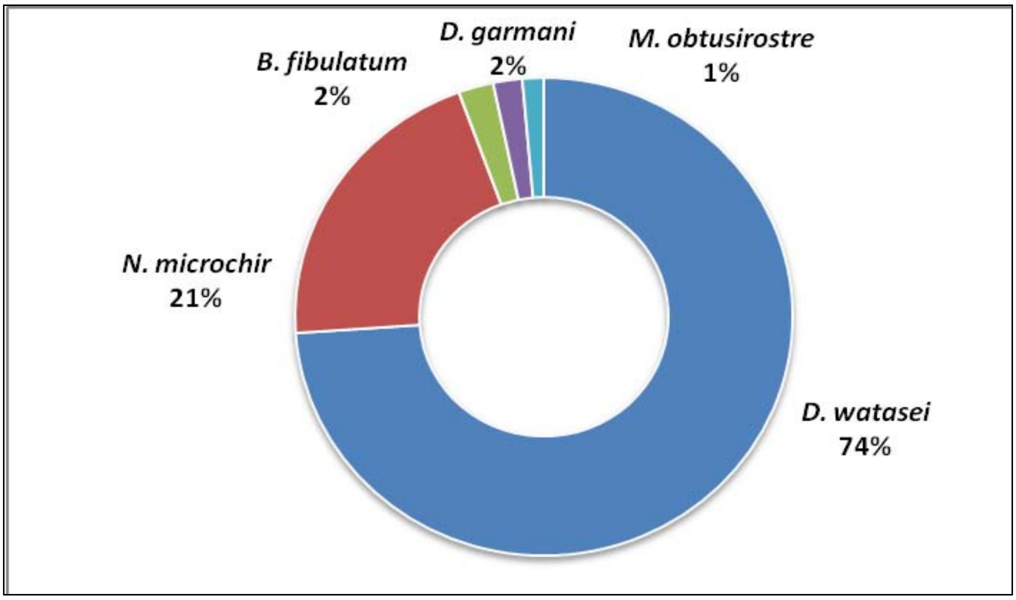



**Fig. 3.6.** Species composition (average) of myctophids by deepsea shrimp trawlers during 2011

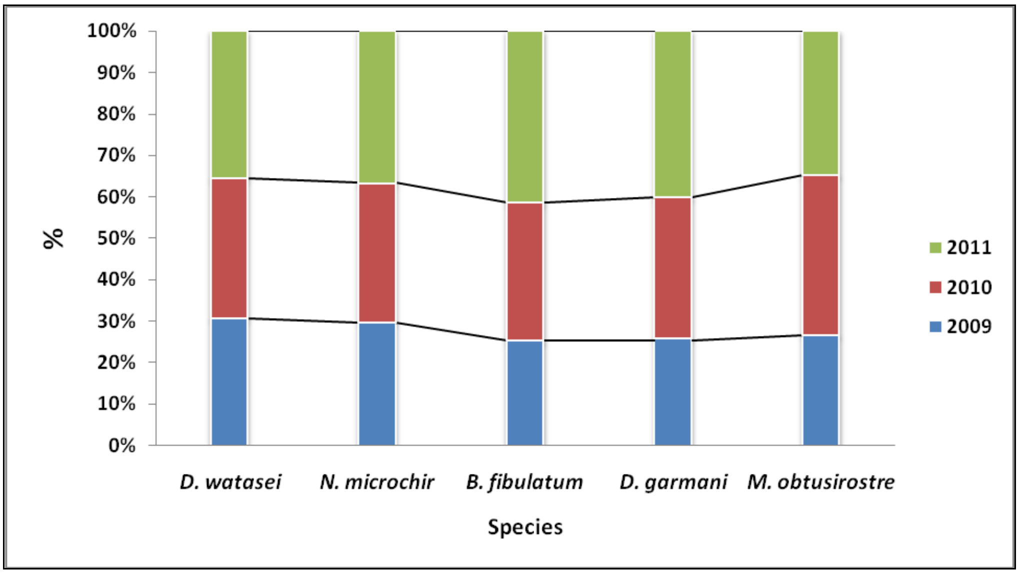



**Fig. 3.7.** Comparison of species composition of myctophids by deepsea shrimp trawlers during 2011

**Plate 3.1.** Deepsea shrimp trawler at Kalamukku Landing Centre

**Plate 3.2.** Deep-sea bycatch sorting

**Plate 3.3.** Bioprocessing plant at Kollam which functions with fish discards

# CHAPTER 4

# AGE AND GROWTH

# CHAPTER 4

# AGE AND GROWTH

## 4.1. INTRODUTION AND REVIEW OF LITERATURE

Information on the age and growth of a species is essential for understanding the stock structure of the resources in the region. The study of growth means basically the determination of the body size as a function of age. Estimating the age, *i.e.* the length/weight the fish gains over a period of time thus forms the basis for population and stock assessment studies and suggests management measures for the optimal exploitation of the resource.

The various methods used for the study of age and growth rate of fishes are:

a. Mark and recapture method
b. Culturing the fishes in confinement and studing their growth periodically
c. Study markings on hard parts such as scales, otoliths, fin rays and skeletal parts
d. Length frequency distribution analysis

Of the above mentioned methods the former two methods are direct methods and over a period of time give accurate estimation of growth. However, these methods cannot be carried out easily for marine fishes as tagging and recapture method is very time consuming and the percentage of recapture especially for migratory fishes being generally low. The second method involves the culture of the marine fish in enclosed areas. Confined culture however, may not yield the true growth picture of the species.

The latter two methods for the estimation of age and growth are indirect means of growth measurement. Of these, the study of hard parts has been found to be very reliable for the study of fishes in the temperate regions (Thompson, 1902; Maier, 1906 and Hederstrom, 1959). The fluctuations in the environmental conditions from summer to winter and *vice versa* can be easily read from the rings formed on the hard parts. These rings seen as widely spaced or opaque zones alternating with narrower and more transparent zones may be of annual, seasonal or monthly nature based on the area of study. Rings are also formed when distinct biological changes like spawning occurs in the fishes. Recent reviews on the studies of hard parts included those by Chugunova (1959), Bagenal (1974), Holden and Raitt (1974) and Pauly (1978), Chilton and Beamish (1982), Casselman (1983) and Jearald (1983).

Age and growth determination is more difficult in tropical than in temperate fishes (De Bont, 1967). The study of the hard parts for the estimation of age is however unsuitable for tropical fishes due to the absence of clear cut seasonal changes in environment. Moreover, most of the tropical pelagic resources have a prolonged spawning period with one or more peaks. So the markings though present on the hard parts are less pronounced and no authentic evidences are available as to their annual or periodic nature. Recently methods have been developed for the counting of daily growth rings. These methods however, require special expensive equipment and a lot of manpower and thus unsuitable for routine analysis.

The length frequency distribution study consists essentially of grouping the lengths of the fish into different groups of convenient class intervals and the modes in the length frequency sample are assumed to represent different year classes. The method was introduced first by Petersen in 1892 and is commonly known as 'Petersen Method'. This method has since been very popular technique for the estimation of age of fishes all over the world. A Common drawback in the application of the Petersen's method is the overlapping of modes representing the older fishes. This happens because the growth rate of fish declines with age. Length frequency distributions have usually been considered less useful for many tropical fishes because of their prolonged spawning periods (Tesch, 1968). However, Pauly (1983) considered that these methods are underutilized for tropical species and that the problems had generally been overemphasized. Graphical methods as described by Cassie (1954), Tanaka (1956), Harding (1964) and Bhattacharya (1967) and computer based methods as demonstrated by Hasselbald (1966), Hasselbald and Tomlinson (1971), Yong and Skillman (1971) and Macdonald and Pitcher (1979) are now used to separate the modes representing the different age groups.

The Bhattacharya method is very useful for splitting a composite distribution into separate normal distributions, each representing a cohort of fish; when several age groups (cohorts) of fish are contained in the same sample. The process involves a number of steps and would take a very long time to do by paper-and-pencil method. The 'BHATTAC' programme of the' LFSA' package of microcomputer programs, the 'MPA' program in the 'COMPLEAT ELEFAN' package and the 'BHATTACHARYA ANALYSIS' in the 'FISAT' package performs the analysis in a short time. With the computer based programs, the analysis can be performed several times to get the best fit and certain drawbacks like the estimation of the number of fish in each cohort is also overcome. Pauly and Caddy (1985) have developed a slightly different version of the Bhattacharya method to make it more objective.

In the 'Model Progression Analysis' method, the peaks in the length frequency samples arranged sequentially in time are connected to follow the progression of modes (peaks) and the growth estimated (George and Bannerji, 1964 and Brothers, 1980). The drawback in using this method is the difficulty in interconnecting the several modes available in the length frequency. The peaks in the length distribution may be the outcome of several broods arising from prolonged or fractional spawning of fish as it happens in tropical waters and hence the various modes occurring in any single length frequency sample cannot be fixed to a definite age group. Due to these drawbacks both the above methods when used as such become highly subjective (Ricker, 1975; Josse *et al*., 1979 and Pauly, 1981 and 1982).

Pauly (1980b and 1983) combined both the above methods and suggested the 'integrated method'. In this a growth curve joining majority of the peaks is drawn directly upon length frequency distribution arranged sequentially in time or on to the same sample repeated over and over along the time axis with a concept that length/growth in fishes is fast in early part of life and then slows smoothly. Devaraj (1982) introduced the 'Scatter diagram technique' of modal progression analysis in which the modal lengths in the length frequency distribution are plotted in the form of a scatter diagram against sequence of time and the trend of progression of modes through time is marked by eye fitted line. A long time series of data pertaining to several months or years is essential to get reliable information. Venema *et al*. (1988) have shown that it is often extremely difficult to obtain an unambiguous interpretation of a data set of length frequencies of tropical fish, in particular when there is only one complex length-frequency sample available and not a time series.

Pauly and David (1981) have attempted a new approach for a rapid reliable and objective method of computer based length frequency analysis called ELEFAN (Electronic Length-Frequency Analysis). The principle involved in this programme is to split the composite length frequency into peaks and troughs and the best growth curve passing through maximum number of peaks avoiding troughs is selected using a goodness of fit by a ratio ESP/ASP (Explained sum of points/ Available sum of points). The value observed when the ESP/ASP ratio is highest is taken as the final estimates of the von Bertalanffy growth parameters. The FiSAT contains the routines to perform the various methods described above.

A number of mathematical models of growth described by Gompertz (1825), Bertalanffy (1934), Bagenal (1955), Rafail (1973) and Udupa (/1976) and some known as logistic (Pearl and Read, 1923) and exponential (Ricker, 1958) are now available for deriving growth information of fish stocks and for further use in the yield models. Ricker (1945), Beverton and Holt (1957) and Ursin (1968) have described the theory of various growth models. Of the available models, the most widely used one is that of von Bertalanffy for which methods of fitting the formula have been given by Beverton and Holt (1957) and Ricker (1958). The model expressions the length 'L' at time 't' as:

$$L_{(t)} = L_{\infty} (1 - e^{-k(t-t0)})$$

Where $L_{\infty}$ = the maximum length the fish can theoretically attain

K = growth coefficient or curvature parameter or the rate at which the fish approaches asymptotic length

$t_0$ = theoretical age of fish at (birth) length zero, provided the fish grows conforming to von Bertalanffy's growth equation and

e = the base of natural logarithm.

The age and growth of myctophids have been studied only by a few workers. The earlier age and growth studies were based on growh increments in otoliths (Gjosaeter, 1987; Young *et al*., 1988; Gartner, 1991; Giragosov and Ovcharov, 1992; Linkowski, *et al*., 1993). Age-based demography and mortality coefficient of *Benthosema glaciale* in the Flemish Cap, North Atlantic Ocean was done by Seoane *et al*. (in print). Age and growth of *Electrona* species were estimated by Linkowski (1987). Age and growth of the lanternfsh *Lampanyctodes* sp. from Tasmania was estimated by Young *et al*. (1988). Life span of the myctophids, *Gymnoscopelus nicholsi* from the western South Atlantic and in Antartic waters was reported by Linkowski (1985). Age and growth of *Electrona* sp. from the Southern Ocean was reported by Greely *et al*. (1999). Growth of juvenile *Diaphus theta* was studied from Pacific Ocean by Moku *et al.* (2001). Age and growth of *Sybolophorus* sp. and *Ceratoscopelus* sp. were done from Japan waters by Takagi *et al*. (2006). Life strategies of five genera of myctophids namely, *Electrona, Gymnoscopelus, Krefftichthys, Lampanyctus* and *Protomyctophum* from Scotia Sea were reported by Lourenço *et al*. (2011).

Growth and yield per recruitment of *B. pterotum* has been estimated from the Gulf of Oman marked the preliminary study from Arabian Sea (Gjosaeter, 1984). Manju *et al*. (2013) studied age and growth of *D. watasei* along the Kerala coast. There is no other information on the age and growth of members of the genus *Diaphus* from this region. The present investigation has been taken up to study the age and growth of *D. watasei* and *D. garmani* of Kerala waters along the southwest coast of India.

## 4.2. MATERIAL AND METHODS

The myctophids for the present study were collected from the by-catch of deep-sea shrimp trawlers operated along the Kerala coast. They were operated from off Kollam to off Ezhimala and catches were landed at Kollam, in the southern part of

Kerala and Cochin, the central part of Kerala. Random samples were collected on a weekly basis during 2009 – 2011 periodand different species constituting myctophids catch were sorted out for detailed analysis. The species were measured in centimeter (cm) for their total length (from tip of snout to the longest caudal ray) and standard length (from tip of the snout to the posterior end of the last vertebra). Standard length was considered for the estimations since the caudal rays are very soft and easily brittle. The fishes were then grouped into different length classes. The data was then raised to get the days catch and subsequently the weekly catch. The weekly catch obtained was then pooled to get the monthly estimated numbers in each class. The data on species composition as well as the fishery of the myctophids collected from the two landing centers were almost similar, and so monthly estimates from the two centers were pooled to get monthwise estimates for the entire Kerala coast. These monthly estimated numbers obtained during the period 2009 to 2011, formed the database for the analysis.

FiSAT (FAO-ICLARM Stock Assessment Tools), a package developed by the FAO and ICLARM (1990) for length based fish stock assessment was used for the analysis of length frequency data. The package is structured around an integration of routines incorporated in LFSA and COMPLEAT ELEFAN package. Monthly length frequency data were estimated and used for the estimation of growth parameters. Initially the length frequency data were analysed using the direct fit of Length-frequency data tools provided in FiSAT. The tool contains the Powell-Wetherall plot and ELEFAN-I.

The Powell-Wetherall plot as modified by Pauly (1986) was used to get an initial estimate of $L_\infty$. Powell (1979) suggested a special application of the equation.

$$Z = K^* \frac{(L_\infty - \bar{L})}{\bar{L} - L'}$$ by which $L_\infty$ an Z/K can be estimated

Where $L_\infty$ = -a/b, $L'$ = value equal to and above the smallest length group under full exploitation and $\bar{L}$ = the mean length of fish of length $L'$ and longer. If the intercept of the straight line is considered as 'a' and its slope as 'b'. The above equation can be turned into a regression as follows with L' as the independent variable: $\bar{L}$ - L' = a+b where Z/K = -(1+b)/b and $L_\infty$ = -a/b.

Thus, plotting $\bar{L}$ - L' against L' gives a linear regression from which a and b can be estimated.

The length data was then analysed using the ELEFAN method. As this programme requires arbitrary values of $L_\infty$ and K as seeded input, the $L_\infty$ value obtained by the Powell-Wetherall method was used for making an initial guess. This procedure was repeated to get suitable values of $L_\infty$ and K at highest $R_n$ value. Optimum values of $L_\infty$ and K with highest $R_n$ value were obtained by using the response surface and scan of K values tools.

The von Bertalanffy plot as suggested by Bertalanffy (1934) was used to estimate K as well as $t_0$. The $L_\infty$ estimated by the above methods was used as the input for the von Bertalanffy growth equation:

$$-\ln(1 - L_{(t)}/ L_\infty) = - K^* t_0 + K * t$$

With age 't' as the independent variable (X) and the $-\ln (1 - L_{(t)}/ L_\infty)$ as the dependent variable (y) the equation defines a linear regression where the slope b = K and the intercept, a = $-K^*t_0$.

### 4.2.1. *Comparison of growth curves*

Munro and Pauly (1983) and Pauly and Munro (1984) have developed a test called the 'phi prime test' to evaluate the reliability of the estimated growth parameters of a species. The test is based on the discovery by Pauly (1979) that phi prime values are very similar within related taxa. As per the phi prime test the overall growth performance of a species is reflected by:

$$\Phi \text{ (phi prime)} = \ln K + 2 * \ln L_\infty$$

Where K is expressed in annual basis and $L_\infty$ in cm. It is generally seen that the Φ is approximately distributed around 3.

## 4.3. RESULTS

### 4.3.1. *Diaphus watasei*

Monthly length frequency data grouped into 0.5 cm interval for three years 2009 to 2011 (Table 4.1) were analysed and growth parameters were estimated. The result obtained by Powell-Wetherall Plot is given in Fig. 4.1. and substituting the values 'a' and 'b' as 3.19 and 0.211 to the equation

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

$L_\infty = -3.19/-0.211 = 15.11$ cm was obtained

The automatic search routine in the ELEFAN – I programme gave the highest Rn value of 0.193 when $L_\infty = 15.06$ cm SL and $K = 0.80$/year (Table 4.5). The maximum length (SL) observed in the fishery was 14.32 cm. The growth curve on the restructured data is given in Fig. 4.3 and the length at age in Table 4.3 and Fig. 4.5.

Age of the species at zero length ($t_o$) was estimated as -0.0284 years. The estimated value of K is relatively small. They are estimated to attain 8.1, 12, 13.7 and 14.4 cm SL respectively by the end of 1$^{st}$, 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ years (Fig. 4.5). It will take more than 4 years to reach the $L_{max}$ (14.5 cm SL).

The von Bertalanffy growth equation of *D. watasei* as estimated by different methods was comparable and the best fit as obtained by ELEFAN can be expressed as:

$L_{(t)} = 15.06[1-\exp(-0.8(t - 0.0284))]$

In the present study the Φ prime value for *D. watasei* was 2.9.

### 4.3.2. *Diaphus garmani*

Monthly length frequency data grouped into intervals for three years 2009 to 2011 (Table 4.2) were analysed and growth parameters were estimated. The result obtained by Powell-Wetherall Plot is given in Fig. 4.2. and substituting the values 'a' and 'b' as 2.65 and 0.363 to the equation

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

$L_\infty$ = -2.65/-0.363 = 7.3 cm was obtained

The automatic search routine in the ELEFAN – I programme gave the highest Rn value of 0.127 when $L_\infty$ = 7.61 cm SL and K = 1.3/year (Table 4.5). The maximum length (SL) observed in the fishery was 7.14 cm. The growth curve on the restructured data is given in Fig. 4.4 and the length at age in Table 4.4 and Fig. 4.6.

Age of the species at zero length ($t_o$) was estimated as -0.0104 years. They are estimated to attain 5.4 and 7 cm SL respectively by the end of $1^{st}$ and $2^{nd}$ years. (Fig. 4.6). It will take more than 2 years to reach the $L_{max}$ (7.14 cm SL).

The von Bertalanffy growth equation of *D. garmani* as estimated by different methods was comparable and the best fit as obtained by ELEFAN can be expressed as:

$L_{(t)}$ = 7.61[1-exp (-1.3(t – 0.0104))]

In the present study the Φ prime value for *D. garmani* was 4.3.

## 4.4. DISCUSSION

The $L_\infty$ obtained by ELEFAN for *D. watasei* and *D. garmani* are 15.06 cm and 7.61 cm respectively. Froese and Pauly (2009) estimated the maximum length of *D. watasei* and *D.garmani* as 17 cm and 6 cm respectively. The annual growth coefficients

(K) of *D. watasei* and *D.garmani* estimated as 0.80/year and 1.3/year respectively. There is no earlier estimates of growth parameters of the above mentioned species from the Indian Ocean as well as from the other Oceans. The only study on growth of myctophids in the Indian Ocean was by FAO (1997) on *B. pterotum* in the Gulf of Oman, and the data suggests a life span of less than one year and that two generations may be produced within a year. According to them, age at maximum size was seven months and ten months from the Gulfs of Aden and Oman respectively.

Length attained by *D. watasei* and *D. garmani* in one year was estimated as 8.1 cm SL and 5.4 cm SL respectively. The estimated age of *D. watasei* to its resultant $L_m$ was more than four years, whereas for *D. garmani* it was more than two years. Age and growth of *Diaphus theta* from south Kurile reported that they grew to a size of 4.05 cm SL in one year and attain a maximum size of 11.7 cm SL in 6 years (Ivanov and Lapko, 1994). The standard length of one year old *D. theta* from north Pacific was calculated as 5.06 cm. Linkowski (1985) estimated the life span of the myctophid fish *Gymnoscopelus nicholsi* from the western South Atlantic and in Antartic waters, where stock consisted of adult fish of 3 to7 years old. The age-based demography of the glacier lantern fish, *Benthosema glaciale* was done by Seoane *et al*. (in print) in the North Atlantic Ocean and the von Bertalanffy growth curves revealed inter-annual differences and the maximum age recorded upto seven. The difference in the $L_\infty$ values for the species from different regions may be due to difference in size structure at different localities caused by difference in the environmental parameters, the type of fishing gears used and methodology adopted for the study of growth parameters. Jones (2002) reported that ambient temperature is one of the key factors controlling fish growth.

The ELEFAN method gave an optimum K value of *D. watasei* and *D. garmani* as 0.8/yr and 1.3/yr respectively in the present study. There may be difference observed in the K value estimated due to the sporadic occurrence of this species in the fishery leading to insufficient availability of data over a longer period of time. The estimate obtained above was used for further analysis of mortality and stock structure.

Based on previous studies of ageing myctophids are fast growing (Childress *et al*., 1980), and have relatively short life spans (Gjosaeter and Kawaguchi, 1980). The growth curve of *Diaphus* spp. was similar to the growth of other small tropical pelagic fishes of Indian coast. Even the growth rate for both *D. watasei* and *D. garmani* was rapid during the first year reaching a total length of 8.5 and 5.4 cm respectively, later it tends to decrease. Childress *et al*. (1980) reported that growth of myctophids occurred mainly during the first six months of life, the growth curve approaching an asymptote quickly, which is the peculiarity of mesopelagics fishes. Gartner (1991) reported that the growth rate of myctophids known to decrease with size which are short-lived. The fishery along the study region was represented mainly of the 1+ year class.

**Table 4.1.** Monthwise length frequency distribution (estimated numbers) of *D. watasei* caught by deep-sea shrimp trawlers off Kerala coast during 2009 – 2011

| S.L (cm) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.5 | 136 | 205 | 156 | 142 | 0 | 0 | 0 | 0 | 0 | 323 | 0 | 422 | 1384 |
| 5 | 910 | 935 | 240 | 426 | 165 | 0 | 0 | 17 | 0 | 0 | 0 | 211 | 2904 |
| 5.5 | 387 | 0 | 798 | 0 | 0 | 0 | 0 | 34 | 0 | 323 | 279 | 2401 | 4222 |
| 6 | 2061 | 503 | 3264 | 876 | 348 | 0 | 0 | 79 | 82 | 852 | 4419 | 15237 | 27721 |
| 6.5 | 2053 | 1028 | 4164 | 1101 | 544 | 0 | 0 | 31 | 0 | 4617 | 6264 | 58256 | 78058 |
| 7 | 3329 | 1807 | 4008 | 5797 | 1672 | 0 | 0 | 57 | 123 | 2274 | 8754 | 15810 | 43631 |
| 7.5 | 4742 | 3655 | 3186 | 5623 | 932 | 0 | 0 | 208 | 183 | 2247 | 3402 | 14373 | 38551 |
| 8 | 3099 | 2653 | 5472 | 3579 | 2060 | 0 | 0 | 318 | 852 | 3353 | 2253 | 28505 | 52144 |
| 8.5 | 2074 | 5235 | 5958 | 3938 | 923 | 0 | 0 | 356 | 675 | 3703 | 1416 | 68882 | 93160 |
| 9 | 2072 | 4024 | 4248 | 1910 | 874 | 0 | 0 | 640 | 1430 | 4438 | 2172 | 41472 | 63280 |
| 9.5 | 1025 | 935 | 1950 | 3788 | 1177 | 0 | 0 | 184 | 1703 | 3559 | 1116 | 83396 | 98833 |
| 10 | 2302 | 1006 | 576 | 4048 | 3429 | 0 | 0 | 263 | 3454 | 4796 | 1926 | 68832 | 90632 |
| 10.5 | 1528 | 1714 | 978 | 2687 | 5921 | 0 | 0 | 528 | 1575 | 6493 | 5595 | 97096 | 124115 |
| 11 | 1907 | 3018 | 1872 | 4364 | 3741 | 0 | 0 | 444 | 2350 | 3332 | 10959 | 41542 | 73529 |
| 11.5 | 3967 | 5328 | 3918 | 2770 | 379 | 0 | 0 | 442 | 1189 | 7310 | 9549 | 70650 | 105502 |
| 12 | 5089 | 3975 | 4896 | 5248 | 562 | 0 | 0 | 134 | 1620 | 3882 | 4737 | 152268 | 182411 |
| 12.5 | 5022 | 3223 | 3354 | 3003 | 959 | 0 | 0 | 62 | 2878 | 3511 | 4377 | 15679 | 42068 |
| 13 | 3069 | 1509 | 648 | 785 | 379 | 0 | 0 | 65 | 551 | 1745 | 1518 | 27792 | 38061 |
| 13.5 | 4114 | 801 | 486 | 217 | 1284 | 0 | 0 | 31 | 183 | 2645 | 300 | 231 | 10292 |
| 14 | 3087 | 1006 | 888 | 0 | 165 | 0 | 0 | 17 | 142 | 2439 | 0 | 211 | 7955 |
| 14.5 | 1161 | 570 | 78 | 0 | 0 | 0 | 0 | 0 | 0 | 1058 | 0 | 0 | 2867 |

**Table 4.2.** Monthwise length frequency distribution (estimated numbers) of *D. garmani* caught by deep-sea shrimp trawlers off Kerala coast during 2009 – 2011

| S.L. (cm) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.2 | 0 | 24 | 81 | 0 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 73 | 202 |
| 4.3 | 25 | 0 | 0 | 74 | 75 | 0 | 0 | 101 | 150 | 25 | 102 | 0 | 551 |
| 4.4 | 0 | 127 | 59 | 76 | 153 | 0 | 0 | 52 | 102 | 51 | 0 | 101 | 721 |
| 4.5 | 105 | 78 | 0 | 129 | 0 | 0 | 0 | 0 | 79 | 105 | 132 | 26 | 654 |
| 4.6 | 0 | 133 | 62 | 106 | 160 | 0 | 0 | 189 | 0 | 53 | 111 | 80 | 893 |
| 4.7 | 137 | 54 | 0 | 107 | 136 | 0 | 0 | 83 | 109 | 109 | 113 | 108 | 957 |
| 4.8 | 141 | 111 | 101 | 55 | 195 | 0 | 0 | 282 | 167 | 111 | 231 | 111 | 1505 |
| 4.9 | 199 | 170 | 262 | 85 | 170 | 0 | 0 | 0 | 86 | 65 | 149 | 169 | 1354 |
| 5 | 88 | 174 | 88 | 287 | 203 | 0 | 0 | 147 | 87 | 152 | 273 | 229 | 1727 |
| 5.1 | 267 | 59 | 39 | 234 | 266 | 0 | 0 | 90 | 267 | 269 | 246 | 58 | 1795 |
| 5.2 | 91 | 0 | 260 | 297 | 271 | 0 | 0 | 275 | 181 | 273 | 188 | 90 | 1927 |
| 5.3 | 245 | 337 | 173 | 363 | 368 | 0 | 0 | 436 | 247 | 140 | 322 | 583 | 3214 |
| 5.4 | 95 | 375 | 207 | 650 | 563 | 0 | 0 | 286 | 566 | 151 | 421 | 470 | 3783 |
| 5.5 | 97 | 732 | 170 | 284 | 701 | 0 | 0 | 583 | 672 | 217 | 491 | 923 | 4869 |
| 5.6 | 590 | 1102 | 387 | 257 | 486 | 0 | 0 | 560 | 521 | 471 | 521 | 682 | 5579 |
| 5.7 | 299 | 1419 | 472 | 622 | 825 | 0 | 0 | 805 | 829 | 524 | 995 | 530 | 7319 |
| 5.8 | 337 | 1242 | 520 | 1132 | 1343 | 0 | 0 | 1265 | 642 | 513 | 768 | 336 | 8098 |
| 5.9 | 207 | 649 | 436 | 542 | 273 | 0 | 0 | 658 | 927 | 233 | 383 | 445 | 4755 |
| 6 | 421 | 590 | 361 | 724 | 869 | 0 | 0 | 812 | 419 | 308 | 289 | 349 | 5141 |
| 6.1 | 285 | 459 | 234 | 456 | 424 | 0 | 0 | 358 | 426 | 143 | 401 | 283 | 3468 |
| 6.2 | 326 | 430 | 181 | 392 | 538 | 0 | 0 | 621 | 650 | 82 | 261 | 216 | 3697 |
| 6.3 | 591 | 510 | 195 | 290 | 474 | 0 | 0 | 704 | 440 | 249 | 414 | 401 | 4270 |
| 6.4 | 450 | 445 | 171 | 332 | 593 | 0 | 0 | 414 | 223 | 270 | 574 | 408 | 3882 |
| 6.5 | 378 | 339 | 262 | 149 | 527 | 0 | 0 | 191 | 113 | 86 | 346 | 526 | 2916 |
| 6.6 | 0 | 152 | 254 | 191 | 306 | 0 | 0 | 390 | 345 | 377 | 357 | 500 | 2873 |
| 6.7 | 196 | 233 | 359 | 77 | 233 | 0 | 0 | 591 | 585 | 231 | 314 | 272 | 3090 |
| 6.8 | 119 | 315 | 0 | 273 | 276 | 0 | 0 | 320 | 237 | 179 | 205 | 118 | 2042 |
| 6.9 | 162 | 159 | 329 | 0 | 160 | 0 | 0 | 242 | 120 | 292 | 493 | 158 | 2117 |
| 7 | 204 | 0 | 228 | 160 | 162 | 0 | 0 | 124 | 366 | 162 | 0 | 246 | 1653 |
| 7.1 | 83 | 164 | 95 | 164 | 164 | 0 | 0 | 334 | 124 | 166 | 128 | 84 | 1507 |
| 7.2 | 0 | 0 | 0 | 124 | 125 | 0 | 0 | 127 | 0 | 0 | 130 | 83 | 589 |

**Table 4.3.** Length at age of *D. watasei* as estimated by ELEFAN – I method

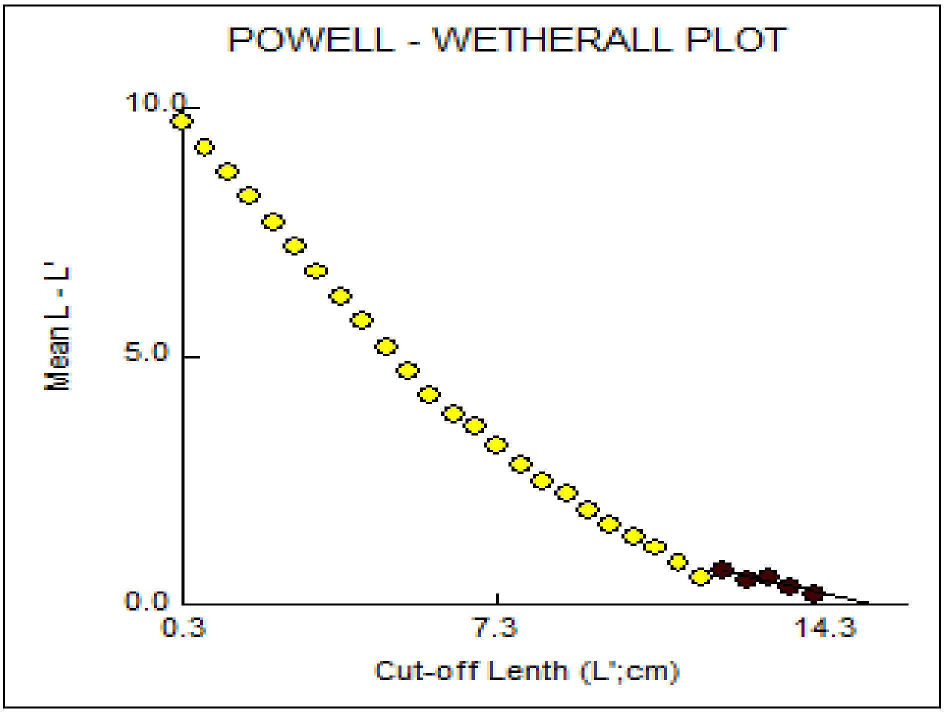
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age (yr)** | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 | 0.9 |
| **Length (cm)** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **Age (yr)** | 1.1 | 1.4 | 1.6 | 2 | 2.5 | 3.3 | 4.1 | 4.4 |
| **Length (cm)** | 9 | 10 | 11 | 12 | 13 | 14 | 14.5 | 14.6 |

**Table 4.4.** Length at age of *D. garmani* as estimated by ELEFAN – I method

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age (yr)** | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 |
| **Length (mm)** | 0.1 | 0.7 | 1.4 | 2.2 | 2.8 | 3.4 | 3.9 | 4.4 |
| **Age (yr)** | 0.8 | 0.9 | 1 | 1.2 | 1.4 | 1.6 | 1.8 | 2.1 |
| **Length (mm)** | 4.8 | 5.1 | 5.4 | 6.0 | 6.3 | 6.6 | 6.9 | 7.1 |

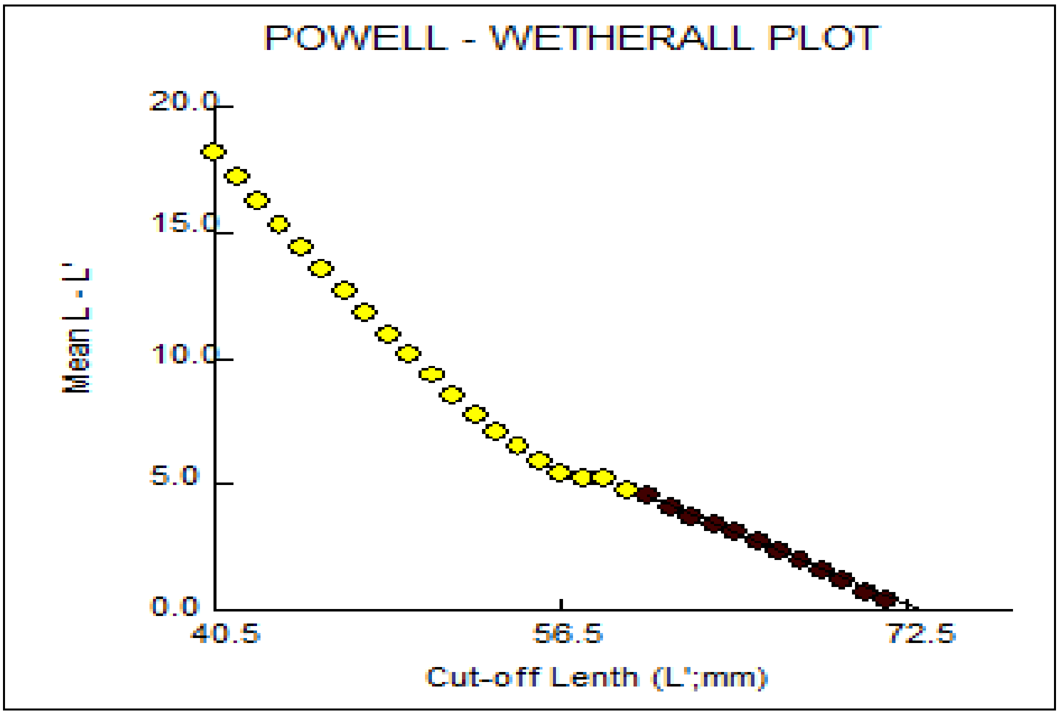
**Table 4.5.** Selected VBGF growth parameters for *D. watasei* and *D. garmani*

| ***Species*** | **$L_\infty$** | **K/year** | **$t_o$** |
|---|---|---|---|
| *D. watasei* | 15.06 | 0.80 | - 0.0284 yr |
| *D. garmani* | 7.61 | 1.3 | - 0.0104 yr |



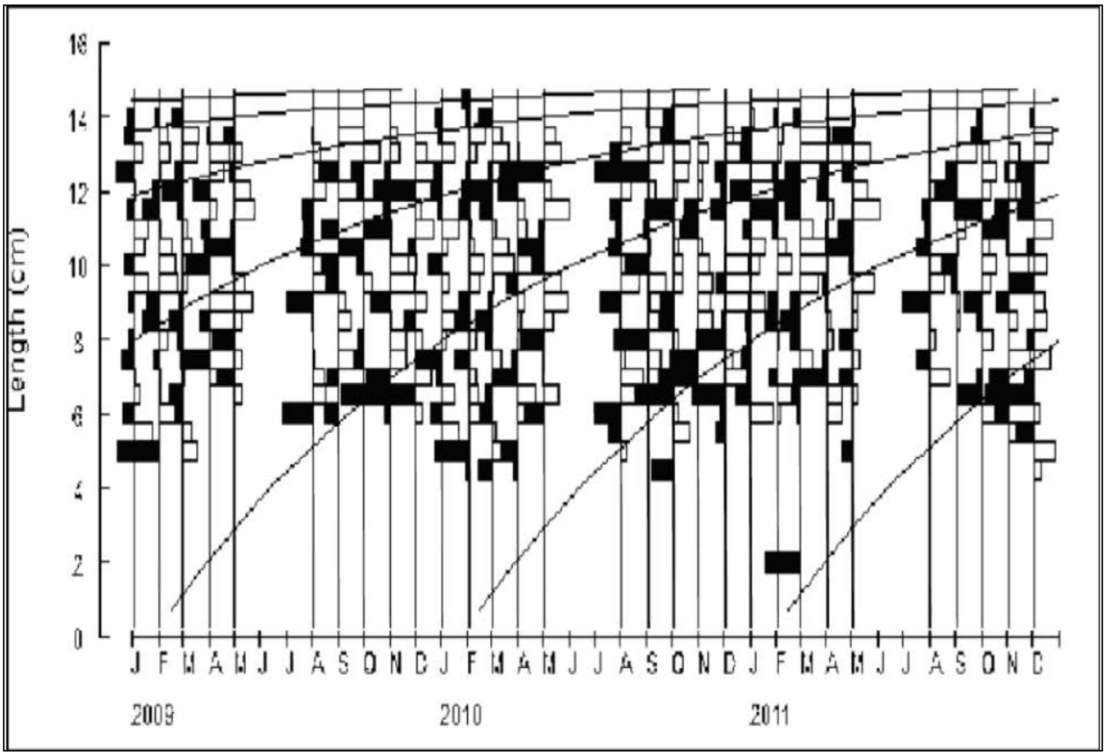

| |
|---|
| Regression Equation: |
| $Y = 3.19 + (-0.211)*X$, $r = -0.907$ |
| Estimate of $L_\infty = 15.06$ cm SL |
| Estimate of $Z/K = 3.887$ |

**Fig. 4.1.** Powell and Weatherall plot for *D. watasei*



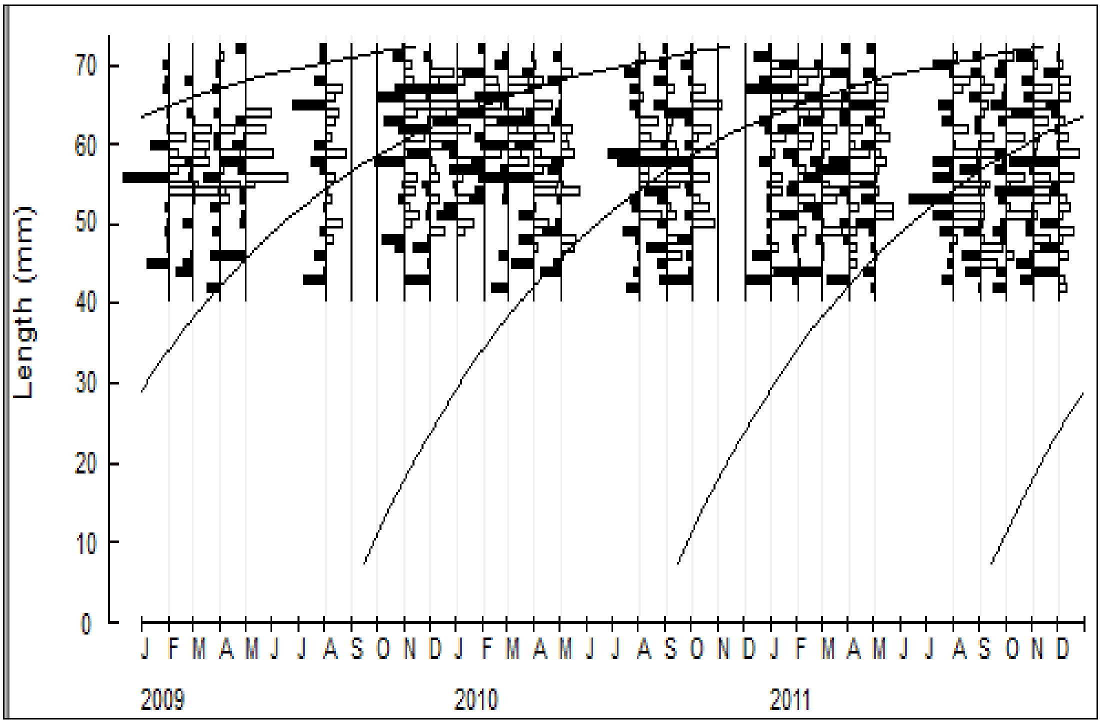

| Regression Equation: |
| --- |
| Y = 26.49+ (-0.363)*X, r = - 0.998 |
| Estimate of $L_\infty$ = 73.02 mm SL |
| Estimate of Z/K = 1.757 |

**Fig. 4.2.** Powell and Weatherall plot for *D. garmani*




L∞ = 15.06 cm SL , K = 0.8, C = 0.00, WP = 0.0, SS = 30, SL = 14.75, Rn = 0.193

**Fig. 4.3.** Rerstructured length frequency distribution with superimposed growth curves of *D. watasei* obtained using ELEFAN –I programme




| |
|---|
| $L_{\infty}$ = 7.61 cm SL, K = 1.3, C =0.0, WP = 0.0, SS = 30, SL = 7.25, Rn = 0.127 |

**Fig. 4.4.** Rerstructured length frequency distribution with superimposed growth curves of *D. garmani* obtained using ELEFAN –I programme

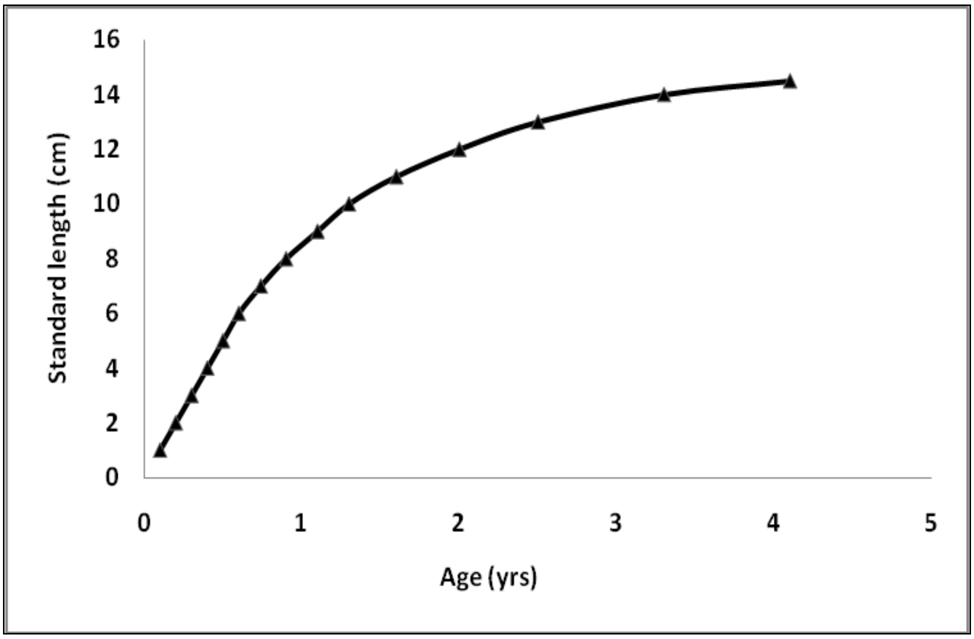



**Fig. 4.5.** Estimated length at age of *D. watasei*


**Fig. 4.6.** Estimated length at age of *D. garmani*

# Chapter 5

# Length - Weight Relationship

# CHAPTER 5

# LENGTH - WEIGHT RELATIONSHIP

## 5.1. INTRODUTION AND REVIEW OF LITERATURE

The study of length-weight relationship forms an integral part of fishery biology, aimed to understand the biological condition of the species. Once the length-weight relationship is established, field studies of the resources need only measuring the total length of the fish. The corresponding weights can be calculated using the relationship. The relationship assumes great significance in establishing almost all aspects of fish growth and its well being. The relationship is useful in assessing the spawning season, minimum size at maturity, variation in weight either due to difference in sex, feeding, maturation and growth. This relationship is also useful in identification of different stocks of the same species (David, 1963). Further, this relationship is vital for carrying out stock assessment studies.

The weight of fish is a function of its length and it is assumed to follow the cube law, $W = cL^3$, where W = weight, L = length, c = constant. However, in fishes the growth is not always isometric and therefore it does not exactly follow the cube law. Le Cren (1951) modified the above into a parabolic equation as $W = aL^b$ where, W = weight, L = length, ‘a’ = a constant equal to ‘c’ and ‘b’ another constant to be derived empirically. This equation explains the relationship between the length and weight of fish better than the cube law. The exponential value of ‘b’ in the parabolic equation is found to vary from 2.5 to 4 (Hile,1936 and Martin, 1949) depending on the fish.

The equation $W = aL^b$ can be transformed into linear function by taking logarithmic values of the length and weight data, and the values of ‘a’ and ‘b’ can be estimated by the regression analysis. The equation now can be rewritten as:

$$\text{Log } W = \log a + b \log L$$

Studies on the length-weight relationship of marine fishes have been carried out since early forties. In India, the length weight relationship of all commercially exploited fin fishes and shellfishes were studied (Bal and Joshi, 1956; Pradhan, 1956; Venkataraman, 1956; Raja, 1967; Shekaran, 1968; Rao, 1988 and 1988a).

Only a few works on length-weight relationship of myctophids were documented worldwide. Length-weight relationship of eight species of myctophids including *D. garmani* were done in EEZ of Brazil (Bernardes and Wongtschowski 2000). The preliminary study of length-weight relationship on myctophids in Indian waters was done by Karuppasamy *et al*. (2008). Length weight relationship of neoscopilids, in Indian waters were done by Thomas *et al*. (2003). Length weight relationship of *D. watasei* in Indian waters were done by Vipin *et al*. (2011) and Manju *et al*. (2013). In the present study the length-weight relationship of *D. watasei* and *D. garmani* exploited from off Kerala were studied.

## 5.2. MATERIAL AND METHODS

Random samples of *D. watasei* and *D. garmani* were collected from the fish landing centres at Kochi and Kollam on weekly basis. The fish was then measured for it standard length (from tip to snout to to the posterior end of the last vertebra) to the nearest millimeter and wet weight to the nearest gram. The fishes were then cut open to determine their sex and stage of maturity. They were then separated into males and females. Regression analysis was performed separately on each group to obtain the values of ‘a’ and ‘b’. Scatter diagrams of length against weight and logarithms of lengths and weights were plotted for these groups separately.

The regression co-efficient or slope of the regression line (b) was computed using the equation

$$b = \frac{\sum XY - (\sum X)(\sum Y) / N}{\sum X^2 - (\sum X)^2 / N}$$

Where N = number of samples, X = length of the fish and Y = weight of fish.
The intercept 'a' was determined by the formula:

$$a = Y - bX.$$

Using these values the linear equation ($y = a + bx$) of length-weight relationship

$$\text{Log } W = \log a + b \text{ Log } L, \text{ was obtained.}$$

Where log W = Y, log a = a and log L = X.

Further converting these logarithmic values into antilogarithms, the exponential form of $W = aL^b$ was obtained.

The significance of variation between the regression co-efficients of both sexes were tested by analysis of co-variance following Snedecor and Cohran (1967).

The estimates of regression co-efficient of males and females were tested for measuring the significance of variation from the expected value of 3 by employing the't' test using the formula:

$$T = \frac{b - \beta}{S_b}$$

Where $\beta$ is equal to 3
The 95% confidence limits of 'b' was calculated using the formula

$$S_b * t\ (n-2)$$

## 5.3. RESULTS

### 5.3.1. Size composition and length weight relationship of *Diaphus watasei*

Catch was supported by fishes ranging in size 4.26 - 14.32 cm, with a mean of 9.56 cm and weight ranged from 1.03 g to 37.83 g, with a mean of 12.37 g. The length-weight relationship established separately for males, females as well as for the pooled data are

Males : $W = 0.013912\ L^{2.953861}$

Females : $W = 0.010052\ L^{3.063181}$

Pooled : $W = 0.011442\ L^{3.023246}$

The same in the logarithmic form is given as :

Males : Log W = - 4.27497 + 2.953861*Log L (r = 0.848153)

Females : Log W = - 4.59997 + 3.063181*Log L (r = 0.957939)

Pooled : Log W = - 4. 4705 + 3.023246*Log L (r = 0.908653)

The length-weight relationship differed significantly between males and females of the species (ANCOVA, $p = 0.005$). The co-efficient indicate that the species follow an isometric growth pattern. The logarithmic forms of relationships are given in Figs. 5.1, 5.2 and 5.3

### 5.3.2. Size composition and length weight relationship of *Diaphus garmani*

Catch of *Diaphus garmani* was supported by fishes ranging in size 4.13 – 7.14 cm, with a mean of 3 cm and weight ranged from 1.2 g to 5.55 g, with a mean of 2.9 g. The length-weight relationship established separately for males, females as well as for the pooled data are

Males : $W = 0.0285\ L^{2.649681}$

Females : $W = 0.019301\ L^{2.860155}$

Pooled : $W = 0.023958\ L^{2.742926}$

The same in the logarithmic form is given as :

Males : $\text{Log } W = -3.55786 + 2.649681 * \text{Log } L$ ($r = 0.736494$)

Females : $\text{Log } W = -3.9476 + 2.860155 * \text{Log } L$ ($r = 0.815509$)

Pooled : $\text{Log } W = -3.73146 + 2.742926 * \text{Log } L$ ($r = 0.785639$)

The length-weight relationship differed significantly between males and females of the species (ANCOVA, $p = 0.005$). The co-efficient indicate that the species follow an allometric growth pattern. The logarithmic forms of relationships are given in Figs. 5.4, 5.5 and 5.6.

## 5.4. DISCUSSION

In the study females attain larger size than males. It is known that females are larger than males in some myctophids (Karnella, 1987; Badcock and Araujo, 1988; Linkowski *et al*., 1993 and Greely *et al*., 1999). The growth pattern in *Diaphus watasei* females was found to be isometric with the regression co-efficient being very close to 3 whereas in males it showed allometric growth. This result correlate with the study of Vipin *et al*. (2011), who reported isometric growth in females and positive allometric growth in males of *D. watasei*. Based on the cube law, an ideal fish maintains a constant shape, $n = 3$ (Allen, 1938). According to Jones (1976) the LWR may change seasonally; thus, the length-weight parameters presented here may be considered as average values. The regression coefficient (b) of *D. garmani* reported from EEZ of Brazil (Bernardes and Wongtschowski 2000), was similar with the present study.

From the studies the growth in relation to length and weight deviate appreciably from the cube law. *D. garmani* and males of *D. watasei* showed a slight negative allometric growth whereas females of *D. watasei* showed nearly an ideal value of 3.

Studies on many deep-sea species exhibited a trend of negative allometric growth (Thomas *et al*., 2003). Their energy consuming characteristic of diurnal vertical migrations as well as their physiological adjustments can be attributed to its variation from the hypothetical cube law. Also there is a significant difference between males and females of the species. Studies on the growth rate of myctophid, *B. pterotum* (Gjosaeter, 1978 and Gjosaeter and Kawaguchi, 1980) from the northern Arabian Sea also reported with linear growth pattern. Hulley (1981), Linowski (1987) and Linowski *et al*. (1993) reported that some myctophids show differences in the growth pattern in males and females. According to them females attain larger size and live longer and the growth in females was found to be linear. In the present study also females were found to attain larger size than males and the growth were nearly linear.

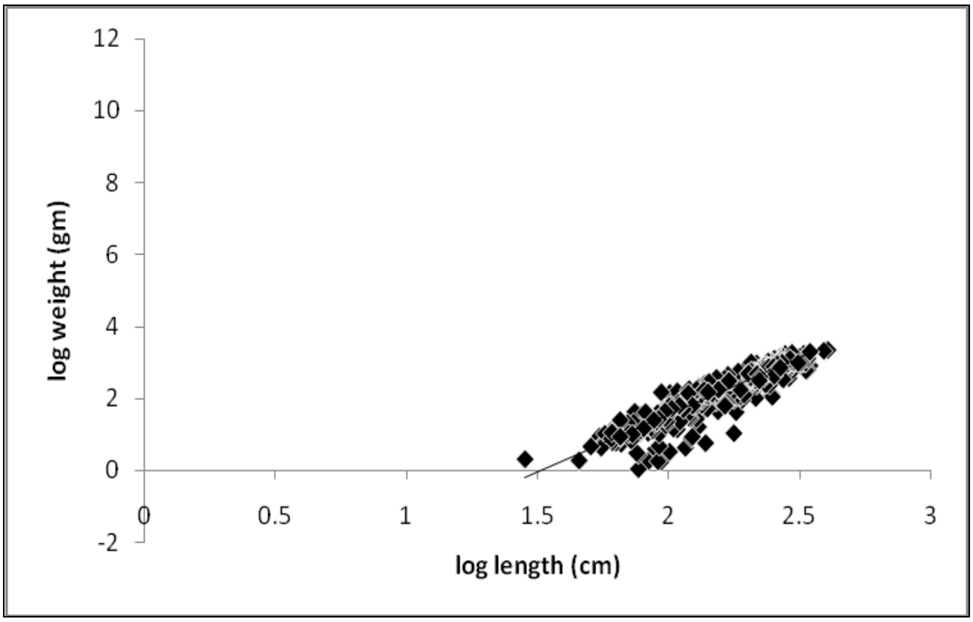



**Fig. 5.1.** Length weight relationship in males of *D. watasei*

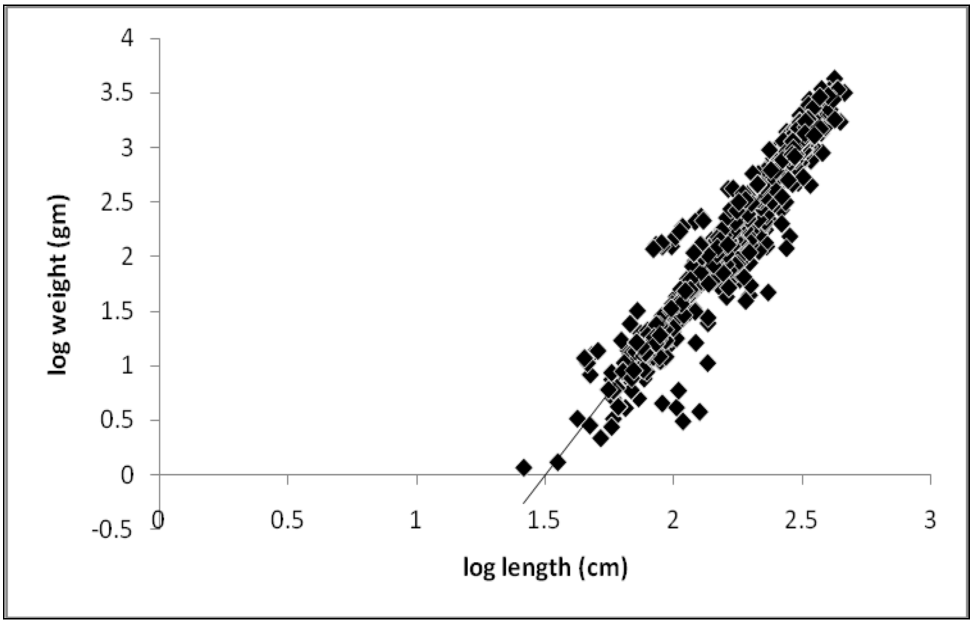



**Fig. 5.2.** Length weight relationship in females of *D. watasei*

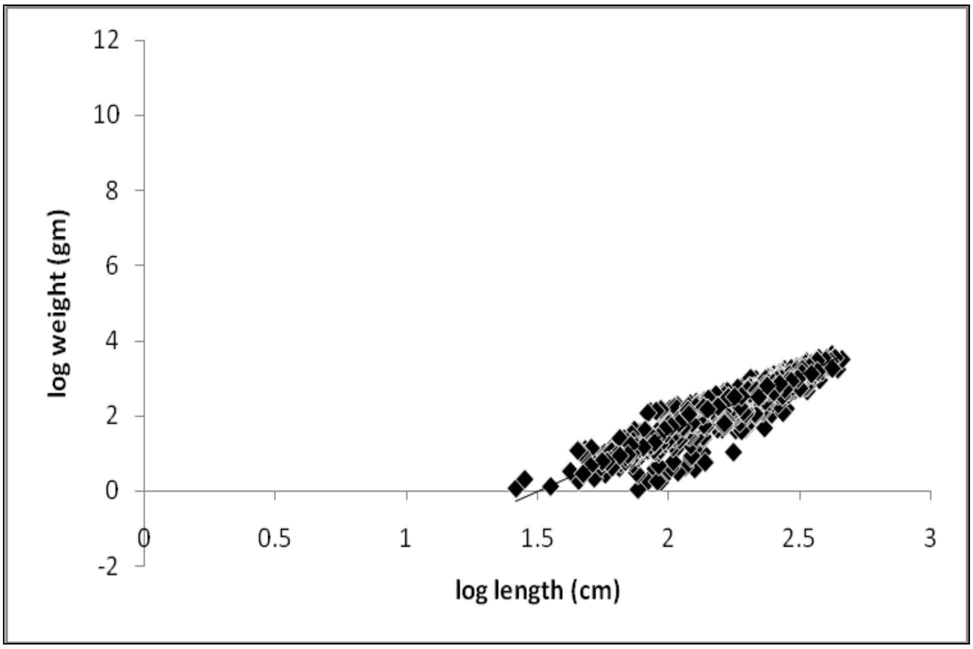



**Fig. 5.3.** Length weight relationship in of *D. watasei* (pooled for males and females)

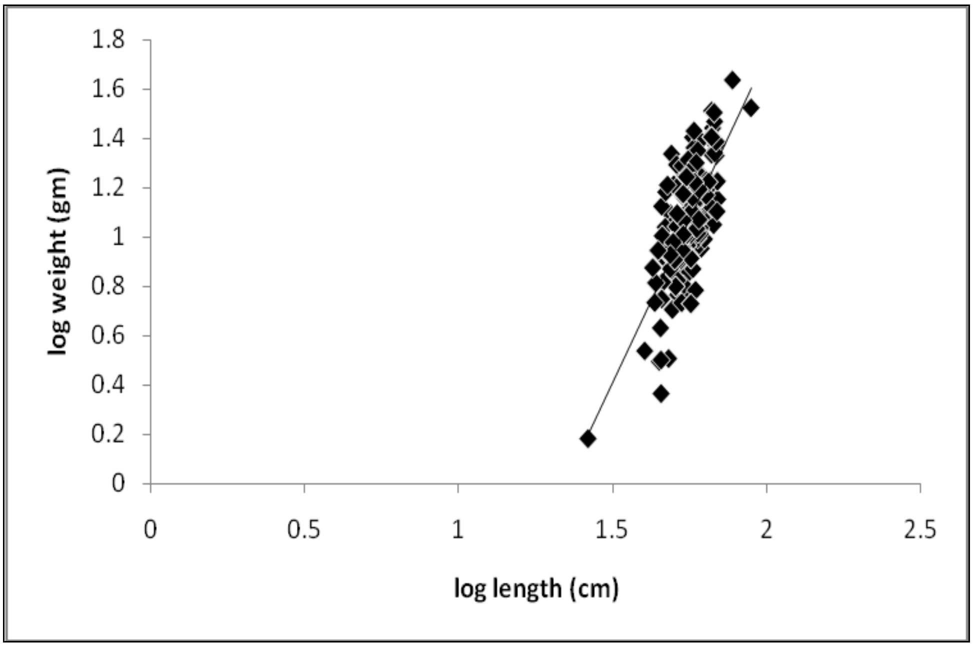



**Fig. 5.4.** Length weight relationship in males of *D. garmani*

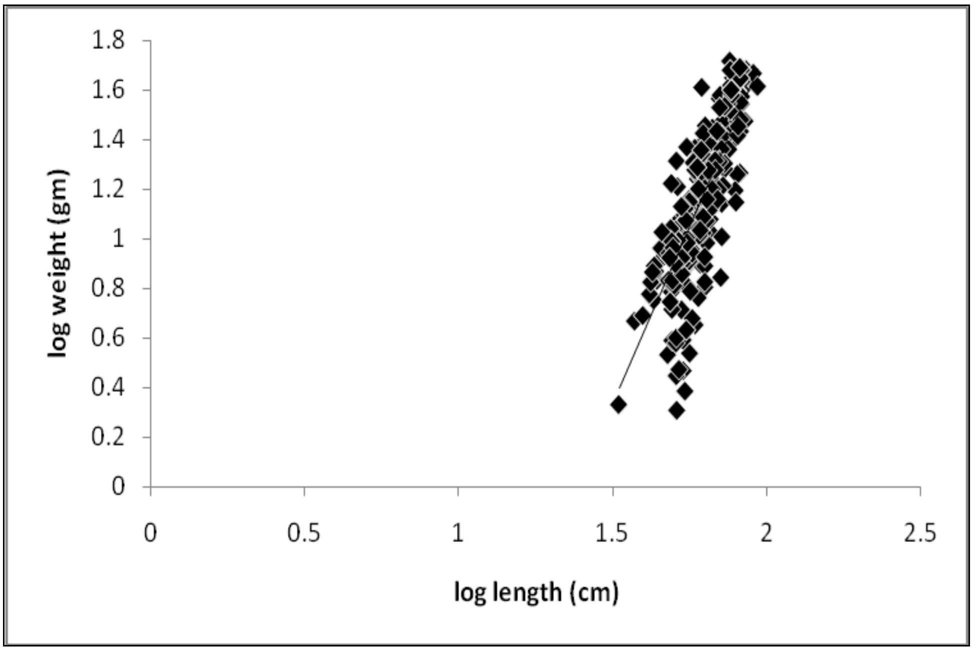



**Fig. 5.5.** Length weight relationship in females of *D. garmani*

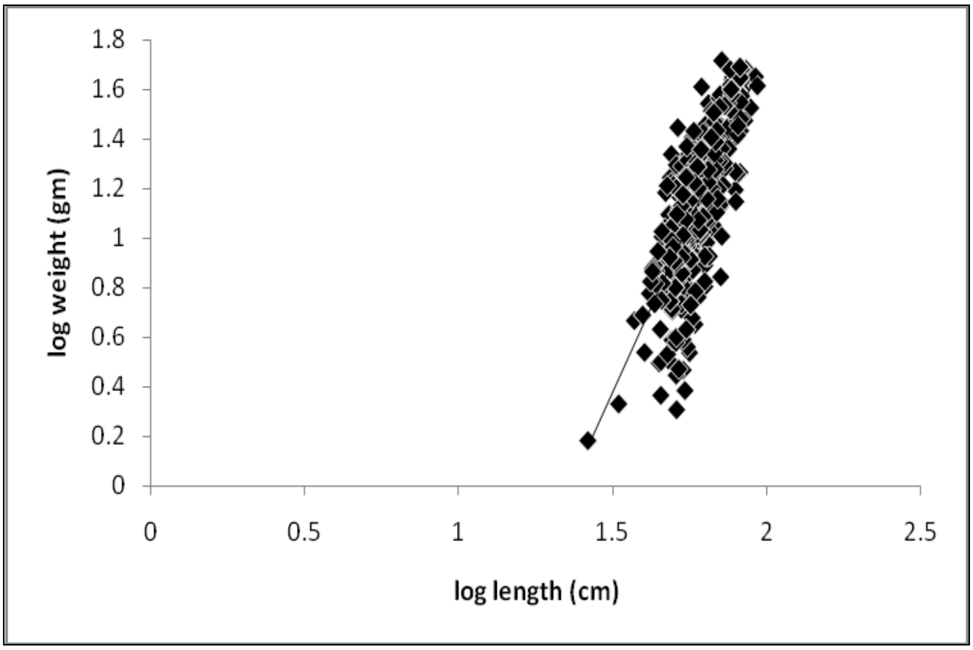



**Fig. 5.6.** Length weight relationship in of *D. garmani* (pooled for males and females)

# CHAPTER 6

# POPULATION PARAMETERS

# CHAPTER 6

# POPULATION PARAMETERS

## 6.1. INTRODUTION AND REVIEW OF LITERATURE

The improvements in the fishing efficiency with the advancement of technology and the introduction of improved crafts and gears have resulted in overexploitation of many fisheries especially in temperate regions. This has necessitated the formulation of management measures to ensure sustainable yields. Several studies have been carried out on the stocks of many fishes from the temperate waters. However, issues of over exploitation related studies on the tropical waters are of recent origin. The uncertainties encountered in the estimation of growth parameters and the erratic fluctuations in the stocks available for exploitation combined with migration have made the assessment of fishes rather difficult. However, several methods have been developed and many of the methods used for the stock assessment of temperate fishes have been adopted to estimate the stock of tropical fishes. Studies on tropical fishes have gained a lot of importance all over the world including India. Stocks of dominant species from different parts of the country have been assessed and a few studies on the multispecies assessment have also been attempted in the last decade.

Management of the available fishery resources is imperative to obtain sustainable yield at economically viable basis. In the present context, non targeted exploitation of the myctophids assumes not much greater importance in optimal management. Utilization of these resources is in initial stage in our country, but researches showed that this resource has immense commercial use for industrial purpose. For successful management of the fishery resources, in-depth knowledge on the dynamics of the population is essential to understand and quantify the stock, which could be harvested in consideration of losses due to fishing as well as natural causes. This information is useful to regulate the exploitation level and for proposing harvesting strategies.

Stock assessment of tropical fish resources gained momentum in the last two decades mainly through the works of Ber (1854), Buckland (1861 and 1864 as cited by Graham, 1948), Danilevskii (1862, 1871 and 1875), Hensen and Apstein (1897), Heincke (1898), Petersen (1895, 1900 and 1903), Barnov (1918), Russel (1931 and 1939), Chugunova (1935), Graham (1935 and 1939), Thompson (1937) and Ricker (1940 and 1944), Nikolskii (1950, 1953, 1956 and 1965) Scheafer (1954), Beverton and Holt (1957), Thompson (1959), Lapin (1961), Paloheimo (1961), Gulland (1965, 1969 1983 and 1988), Ricker (1958), Holden (1974), Powell (1979), Caddy (1980 and 1982), Pauly (1980, 1980a, 1981, 1982, 1983, 1983a, 1984, 1984a and 1987), Pope (1980), Jones and Zalinge (1981), Pauly and David (1981), Garcia and Le Reste (1981), Devaraj (1982 and 1983), Jones (1984), Sanders *et al*. (1984 and 1984a), Alagaraja (1984), Garcia (1985), Pauly and Morgan (1987), Sparre (1987, 1987a and 1991), Cushing (1988) and Sparre and Venema (1992). In India a few stocks have been studied on pelagic resources include those by Bannerji (1973), Murty (1991), Balasubramanian (1997) and Rohit *et al*. (1998).

The dynamics of fish population are concerned with natality, growth and mortality of fish stocks and these processes are governed by their adaptation in relation to environment. Fish stock assessment aims at describing these processes and the changes brought about by fishing activities. Fishing carried out at a sustainable level ensures renewal and continued supply of fish. However, indiscriminate and unrestricted fishing activities, deplete the stock and results in diminished returns. To determine the quantitative effects of fishing and suggest ways and means of sustained fishing levels, two types of models namely 'holistic models' and 'analytic models' have been developed. The former models are used when only limited data are available. The 'Surplus Production Model' – one of the holistic models generally used in fish stock assessment deals with the entire stock, the entire fishing effort and total yield obtained from the stock, without entering into any details such as growth and mortality parameters or the effect of the mesh size on the fish capture etc. Surplus Production Model was proposed by Hjort *et al*., (1933) and later developed into the sigmoid curve theory by Graham (1939 and 1943) and into Surplus Production Model by Schaefer (1954). The model is often referred to as 'Schaefer-models'. The objective of the applications of the above model is to determine the optimum level of effort, which is the effort that produces the maximum yield that can be sustained without affecting the long term production of the stock. The theory behind the Surplus Production Model has been reviewed by several authors (Ricker, 1975; Caddy, 1980; Gulland, 1983 and Pauly, 1984). Though the model is simple, the results obtained however, have proved to be unrealistic wherein information on fish population *ie*., biological characteristics and the environment cannot be incorporated (Gullard, 1977).

The analytical models are developed by Baranov (1918), Russel (1931 and 1939), Thompson and Bell (1934), Beverton and Holt (1957) and Ricker (1958) are "age-structered models" working with concepts such as mortality rates and individual body growth rates. These models are used for estimation of stock and for predicting future yields of a fishery employing mathematical models like

1. Virtual Population Analysis (VPA) or cohort analysis.
2. Thompson and Bell Model
3. Beverton and Holt Model

The first model analyses the effect of fishing on a particular year class or length group. Based on the findings of the first model, the second model describes the effect of different fishing levels in the future (Thompson and Bell). The basis of the first model is on the past historic data. As these models are based on variable parameters describing changes in the stock and yield on a year to year basis with regard to change in the fishing pattern on individual species length or age groups, these are called non-steady models. The third popularly used model is the Yield per Recruit Model of Beverton and Holt (1957). This model assumes a steady state situation describing the state of stock and yield when the fishing pattern remains the same over a long period of time and all recruits during the life are exposed to it (Sparre *et al.*, 1989).

Mortality refers to the death process brought about either by natural causes or by fishing ventures. It is expressed as total mortality or instantaneous total mortality coefficient and the symbol used to denote this is 'Z'. Natural mortality in fishes includes activities such as predation, disease, infection, old age, starvation and also unfavourable environmental conditions. It is expressed as instantaneous rate of natural mortality coefficient and denoted by the sign ‘M’. Fishing mortality is caused by the various fishing activities taking place in a given area. It is expressed as the instantaneous rate of fishing mortality co-efficient ‘F’ and is directly proportional to the fishing intensity (f).

Studies on the population dynamics of myctophids have been carried out only for a few species. Detailed studies have not been carried out in this subject. Age-based demography and mortality coefficient of the glacier lantern fish *Benthosema glaciale* in the Flemish Cap, north Atlantic was carried by Seoane *et al*. (in print). Mortality rate of two myctophids, *Benthosema glaciale* and *Notoscopelus kroeyeri* from Norwegian water was carried out by Gjosaeter (1973 and 1981a). Mortality rate of *Lampanyctodes* sp. from Atlantic Ocean was estimated by Halliday (1970) and from Australia by Young *et al*. (1988). Population biology of the myctophid *Gymnoscopelus nicholsi* in the western South Atlantic and Antartic waters was reported by Linkowski (1985). Population dynamics of five genera of myctophids namely, *Electrona*, *Gymnoscopelus*, *Krefftichthys*, *Lampanyctus* and *Protomyctophum* and their life strategies in the Scotia Sea were reported by Lourenco *et al*. (2011).

Few studies are available on the stock assessment of myctophids from Indian waters. Mortality estimates of myctophids from the Arabian Sea were done by Sanders and Bouhlel (1982). Growth and yield per recruitment of *Benthosema pterotum* from the Gulf of Oman marked the preliminary study from Arabian Sea (Gjosaeter, 1984). Recently, Manju *et al*. (2013) estimated population characters of *D. watasei* exploited along the Kerala coast. The present work has been taken up to study the population dynamics of *D. watasei* and *D. garmani* along the Kerala coast.

## 6.2. MATERIAL AND METHODS

The monthly and annual estimated numbers of fish in different size groups for the period 2009 to 2011 in respect of *D. watasei* and *D. garmani* obtained as described under the material and methods section of the Age and Growth chapter formed the data bases for the present study.

The natural mortality co-efficient (M) was determined by employing Pauly's (1980a) and Srinath's (1990) empirical formula.

For the estimation of total instantaneous mortality co-efficient (Z), Length Converted Catch Curve method (Pauly, 1982) was used.

The fishing mortality (F) co-efficient was obtained by the subtraction of M from Z.

### 6.2.1. ***Natural mortality***

The natural mortality co-efficient rate referred to as 'M' quantifies the death occurring within a population due to natural causes. Natural mortality is linked directly to longevity (Tanaka, 1960; Holt, 1965; Cushing, 1968; Sekharan, 1975; Saville, 1977; Pauly, 1980b and Alagaraja, 1984) and indirectly to growth co-efficient 'K' (Beverton and Holt, 1959 and Srinath, 1990). Growth parameters (Sparrre *et al*., 1989) maturity (Rikhter and Effanov, 1976) gonad weight (Gunderson and Dygert, 1988) and environmental temperature (Pauly, 1980a) also influence the mortality. Though estimation of natural mortality co-efficient 'M' is difficult, several direct as well as indirect methods have been developed. The following methods were used in the present study.

#### 6.2.1.1. Pauly's empirical formula (1980):

The formula as given below uses growth parameters of the stock and mean sea surface water temperature of the actual fishing area/ ground.

$$\text{Log } M = - 0.0066 – 0.279 \text{ Log } L + 0.6543 \text{ Log } K + 0.4634 \log T$$

Where M = the instantaneous rate of mortality per year, $L_\infty$ = asymptotic length in cm, K = annual growth co-efficient and T = average annual sea surface temperature in degree centigrade.

For Pauly's method, the parameters used were $L_\infty$, K and the mean sea surface water temperature as 28.5$^o$ C.

**6.2.1.2. Srinath's empirical formula (1990):**

Srinath (1990) proposed the following empirical formula to estimate the natural mortality

$$M = 0.4603 + 1.4753\ K$$

Where 'K' is the growth co-efficient.

**6.2.2. *Total mortality co-efficient***

The computing procedures and the principles involved in the derivation of 'Z' are given below:

**6.2.2.1. Length converted catch curve method:**

The Length Converted Catch Curve method as described by Pauly (1983a, 1984, 1984a and 1984b) is also known as Linearised Length Converted Catch Curve method. Here, the time taken for an average fish to grow from length $L_1$ (lower limit) to $L_2$ (upper limit) and the age interval and mid points are derived from the inverse von Bertalanffy equation:

$$T(L) = t_0 - \frac{1}{K} \ln \left[1 - \frac{L}{L_\infty}\right]$$

For making use of the equation in length based analysis, it is inserted into cumulative catch curve equation:

$$\ln \left(\frac{C}{\Delta t}\right) = A - Z\ t^*$$

Where C is the numbers caught in a given length class.

$$t^* = \frac{t_1 + t_2}{2}$$

Where $t_1$ represents the age corresponding to lower limit of the length class

$t_2$ represents the age corresponding to the upper limit of length class

Z = total instantaneous mortality

A = a constant

$\Delta t$ = is the time taken to grow from lower limit $L_1$ (lower limit) to $L_2$ (upper limit) in each length class. Taking the above equation

$$Y = \ln\left(\frac{C}{\Delta t}\right) \text{ and } X = t^*$$

Is in the form of Y = a + bx where the slope (b) = - Z with the sign changed, Z is obtained.

Scatter plot of the values of t* against ln (C/Δt) are used to identify the straight portion of the catch curve as the first few length groups representing the ascending limb consists of fish not yet fully recruit to the fishery.

### 6.2.3. *Fishing mortality estimates*

Instantaneous rate of fishing mortality rate (F) was estimated by substraction of M from Z as:

$$F = Z - M$$

### 6.2.4. *Stock assessment*

For the purpose of stock assessment studies, the following parameters are considered:

a) **Exploitation rate (U):** The rate of exploitation (U) is defined as the fraction of fish present at the start of a year that is caught during the year (Ricker, 1975). It is estimated by the equation given by Beverton and Holt (1957) and Ricker (1975) as

$$U = \frac{F\,(1 - e^{-z})}{Z}$$

b) **Exploitation ratio (E):** It refers to the ratio between fish caught and the total mortality (Ricker, 1975) or the exploitation rate or the fraction of deaths caused by fishing (Sparre and Venema, 1992). It is estimated by the equation;

$$E = F/Z = F/(M+F)$$

The ratio gives an indication whether a stock is highly exploited or not, under the assumption that the optimal value of 'E' equals to 0.5 or 'E'≈ 0.5 which in turn is under the assumption that the sustainable yield is optimised when $F \approx M$ (Gulland, 1971).

**c) Yield:** Yield is the fraction of fish population by weight taken by the fishery and is denoted by 'Y'

**d) Standing stock (Y/F):** The standing stock is a concentration of fish population for a given area at a given time. It is measured in terms of numbers, weight and is estimated from the relation: Y/F where 'Y' is the yield and 'F' is the co-efficient of fishing mortality.

**e) Total stock or annual stock or biomass (Y/U):** It refers to the total weight or number of fish population available for a given area at a particular time. It is estimated from the relation Y/U where 'Y' is the yield and 'U' is the exploitation rate.

### 6.2.5. *Probabilities of Capture*

The probability of capture by length (Pauly, 1984b) was calculated by the ratio between the points of the extrapolated descending arm of the length-converted catch curve using the FiSAT software.

### 6.2.6. *Optimum length of exploitation*

The optimum length of exploitation ($L_{opt}$) was estimated from the empirical equation of Froese and Binohlan (2000) using the relationship,

$$L_{opt} = 3 * L_{\infty} / 3 + M/K$$

The mean length at first capture ($L_c$) for the three year period was derived by taking 50% of the length of selection curve (Beverton and Holt, 1957). The $L_c$ and its corresponding age ($t_c$) was calculated by inverse von Bertalanffy equation.

## 6.3. RESULTS

### 6.3.1. Population parameters of *Diaphus watasei*

Growth parameters: $W_{\infty}$ = 41.62 g, K = 0.8 (annual), $t_0$ = - 0.028 years. Of these parameters K and $t_o$ have already been estimated in age and growth chapter.

The smallest fish size of 4.26 cm SL recorded in the fishery during the three-year study period was taken as the length at recruitment ($L_r$) and the age at recruitment ($t_r$) was estimated as 0.4 years (Table 6.7). The smallest size was noted during the year 2009. $L_r$ during 2010 and 2011 was 4.7 cm SL and 4.3 cm SL and its corresponding $t_r$ was five and four months respectively.

$W_{\infty}$ was estimated using the length-weight relationship ($W_{\infty} = aL_{\infty}^{b}$) estimated earlier (chapter 3). The $L_{\infty}$ estimated was 15.06 cm SL and the corresponding $W_{\infty}$ is,

$$W_{\infty} = 0.011442 * 15.06^{3.023246} = 41.62 \text{ g}$$

Size at first capture ($L_c$) of *D. watasei* in trawl was estimated as 11 cm SL. Age corresponding to size at first capture was sixteen months. $L_c$ during 2009, 2010 and 2011 was 8.5 cm SL, 10.9 cm SL and 10.5 cm SL and their corresponding age was 1, 1.6 and 1.5 years. Optimum size of exploitation ($L_{opt}$) was 8.4 cm SL at an age of one year.

Length at maturity ($L_m$) was estimated at 9.8 cm SL and their age ($t_m$) was 1.3 years (Fig. 8.1). TheLength Converted Catch Curves obtained for *D. watasei* is given in Fig. 6.1.

#### 6.3.1.1. Stock, mortality and exploitation rate

Estimates of total mortality (Z) in the population during the period 2009 - 2011 was 2.53, natural mortality (M) being 1.89 and fishing mortality (F) 0.64. Year wise estimates of mortality rates was given in Tables (6.1, 6.2 and 6.3). Total mortality rate estimates during the years 2009, 2010 and 2011 were 2.7, 2.1 and 2.2 respectively. The highest total mortality rate was observed in 2009. Natural mortality was estimated for the whole period of study as 1.9. The highest fishing mortality (0.76) was observed in 2009. The estimate of 'M' obtained by Srinath's empirical formula was 1.18. Exploitation rate for the resource was 0.2. Exploitation ratio was very low being 0.3 (Table 6.4). Total loss from the population due to fishing is only 25% and that by natural causes is 75%. Total stock assessed for the period was estimated as 8348 t.

#### 6.3.1.2. Probabilities of Capture

The results of the length-converted catch curve method were used for the estimation of probabilities of capture (Fig. 6.3). The values obtained by the probability of capture were $L_{25}$ = 10 cm, $L_{50}$ = 11 cm and $L_{75}$= 12 cm of SL for the period. Year wise probability of capture estimates was given in Table (6.8).

### 6.3.2. Population parameters of *Diaphus garmani*

Growth parameters: $W_\infty$ = 6.26 g, K = 1.3 (annual), $t_0$ = - 0.0104 years. Of these parameters K and $t_o$ have already been estimated in age and growth chapter.

The smallest fish size of 4.13 cm SL recorded in the fishery during the three-year study period was taken as the length at recruitment ($L_r$) and the age at recruitment ($t_r$) was estimated as 0.6 years (Table 6.7). The smallest size was noted in 2009 and 2010. $L_r$ during 2011 was 4.6 cm SL and its corresponding $t_r$ was seven months.

$W_\infty$ was estimated using the length-weight relationship ($W_\infty = aL_\infty^{b}$ )estimated earlier (chapter 3). The $L_\infty$ estimated was 7.61 cm and the corresponding $W_\infty$ is,

$W_\infty = 0.023958 * 7.61.^{2.742926} =$ 6.26 g

Size at first capture ($L_c$) of *D. garmani* in trawl was estimated as 5.2 cm SL. Age corresponding to size at first capture was nine months. $L_c$ during 2009 and 2010 was 5.2 cm SL at an age of nine months, $L_c$ in 2011 was 5.5 cm SL, at an age of 1 year. Optimum size of exploitation ($L_{opt}$) as 5.4 cm SL at an age of one year. Length at maturity ($L_m$) was estimated at 5.3 cm SL at an age ($t_m$) of 9 months (Fig. 8.2). The Length Converted Catch Curves obtained for *D. garmani* is given in Fig. 6.2.

#### 6.3.2.1. Stock, mortality and exploitation rate

Estimates of total mortality (Z) in the population during the period 2009 - 2011 was 2.85, natural mortality (M) being 1.65 and fishing mortality (F) 1.2. Year wise estimates of mortality rates was given in Tables (6.1, 6.2 and 6.3). Total mortality rate estimates during the years 2009, 2010 and 2011 were 2.9, 2.8 and 2.5 respectively. The highest total mortality rate was observed in 2009. Natural mortality was estimated for the whole period of study as 1.7. The highest fishing mortality (1.23) was observed in 2009. The estimate of 'M' obtained by Srinath's empirical formula was 2.38. Exploitation rate for the resource was 0.4 for the period. Exploitation ratio was very low being 0.4 (Table 6.5). Total loss from the population due to fishing is only 42% and that by natural causes is 58%. Total stock assessed for the period was estimated as 107 t.

#### 6.3.2.2. Probabilities of Capture

The results of the length-converted catch curve method were used for the estimation of probabilities of capture (Fig. 6.4). The values obtained by the probability of capture were $L_{25}$ = 5.1 cm, $L_{50}$ = 5.2 cm and $L_{75}$= 5.3 cm of SL for the period. Year wise probability of capture estimates was given in Table (6.8).

## 6.4. DISCUSSION

In the present study, the total instantaneous rate of mortality 'Z' was estimated using Length Converted Catch Curve method, gave a result of 2.53 in *D. watasei* and 2.85 in *D. garmani*.

Several methods are available for the estimation of natural mortality 'M'. However, the estimation of 'M' is very difficult in areas where multigears exploit multispecies during the fishing seasons. In the present study the methods namely Pauly's method and Srinath's empirical formula were used for the estimation of M. In the case of *D. watasei* 'M' values ranged from 1.18 (Srinathh's Method) to 1.89 (Pauly's Method). The value obtained by Pauly's method was used for all further studies. In *D. garmani* 'M' values ranged from 1.65 (Pauly's Method) to 2.38 (Srinathh's Method). The value obtained by Pauly's method was used for all further analyses.

The fishing mortality was calculated by subtracting the value of M form Z. *D. garmani* was subjected to more intensive fishing mortality (F = 1.2) as compared to *D. watasei* (F = 0.64). The catch is dominated by *D. watasei*, indicating that this species has more stock in this area when compared to *D. garmani*. So the fishing effort in the same niche will have more effect on *D. garmani* resulted in high fishing mortality. Furthermore the natural mortality was found to be higher for *D. watasei* as compared to *D. garmani*.

In *D. watasei*, total stock (the stock size at the beginning of the year) was estimated at 8348 t and standing stock (Y/F) = 3000 t. as against the yield of 1920 t. The present yield is realized at an exploitation rate of 0.3. This shows that the population of the species at present is exploited at a marginally lower rate than the optimum. Hence, there is considerable scope to increase the yield by judicious exploitation.

For *D. garmani* the Z was 2.9, F = 1.2 and M = 1.7, the average total stock and the standing stock was 107 t and 37 t respectively. The present yield is 44 t.

The natural mortality (M) is related to age and size of the fish. Since ‘M’ is linked to longevity and latter to the von Bertalanffy curvature parameter K, ‘M/K’ ratio is found constant among closely related species and sometimes within the similar taxonomic group (Beverton and Holt, 1959 and Bannerji, 1973). The M/K ratio is known to range from 1 to 2.5 (Beverton and Holt, 1959). The estimated annual K values in the study for *D. watasei* and *D. garmani* were 0.8 and 1.3 respectively. The respective M values were 1.89 and 1.65 respectively. The M/K ratio was worked out as 2.36 for *D. watasei* and 1.26 for *D. garmani* and falls within the known limit. The mortality rate of *B. glaciale* has been estimated in Norwegian waters as 0.74 with an annual mortality of 52% (Gjosaeter, 1973 and 1981). Halliday (1970), reported an annual mortality of 83% of the same species *B. glaciale* from the Atlantic Ocean, indicates that mortality may be highly variable within same species of myctophids.

The age at first capture ($t_c$) in respect of *D. watasei* was 1.6 years as against the optimum age of exploitation ($t_y$) of 1 year. In *D. garmani* the $t_c$ and $t_y$ values were 0.9 year  and 1 year respectively. It shows that in *D. garmani*, $t_y$ is higher than the present $t_c$. So inorder to satisfy the optimum harvest condition the present age at first capture may be enhanced to near the ‘$t_c$’. This would allow the stock to grow and reach the maximum marketable age. The present size at first capture is 11.3 cm and 5.20 cm respectively for *D. watasei* and *D. garmani*. Studies on the maturation and spawning of these species show that minimum size at first maturity is 9.8 cm SL and 5.3 cm SL for *D. watasei* and *D. garmani* respectively. As the lengths are higher than the present length for first capture, the *D. garmani* is being exploited before it matures and spawns even once in its life. Estimate of the size at maturity of *D. garmani* was larger than the size at first capture, but since the exploitation rate is very low, there is no immediate threat to the stock, if this situation prevails will lead to recruitment overfishing.

The present study shows that the stock of *D. watasei*, which contributes 74% of the myctophids catch, is being exploited at a level of E = 0.3. The other species *D. garmani* is being exploited at a level of E = 0.4. Although by increasing the fishing effort, it may be possible to enhance the production of the above species, further increase in effort in a multispecies multigears system would lead to over exploitation of some of the targeted groups existing in the same fishing grounds. The stock assessment studies of various individual fish stocks inhabiting the same fishing ground will be useful in formulating an overall strategy for the management and conservation of the resources. The present investigation would be a preliminary step for developing viable measures for sustainable harvest of the resources in future from the fishing grounds of the region.

**Table 6.1.** Estimates of total mortality by Length Converted Catch Curve method for *D. watasei* and *D. garmani*

| Species | 2009 | 2010 | 2011 | Pooled |
|---|---|---|---|---|
| *D. watasei* | 2.65 | 2.09 | 2.24 | 2.53 |
| *D. garmani* | 2.88 | 2.77 | 2.46 | 2.85 |

**Table 6.2.** Estimates of natural mortality by Pauly's Method for *D. watasei* and *D. garmani*

| Species | 2009 | 2010 | 2011 | Pooled |
|---|---|---|---|---|
| *D. watasei* | 1.89 | 1.89 | 1.89 | 1.89 |
| *D. garmani* | 1.65 | 1.65 | 1.65 | 1.65 |

**Table 6.3.** Estimates of fishing mortality of *D. watasei* and *D. garmani*

| Species | 2009 | 2010 | 2011 | Pooled |
|---|---|---|---|---|
| *D. watasei* | 0.76 | 0.20 | 0.35 | 0.64 |
| *D. garmani* | 1.23 | 1.12 | 0.81 | 1.2 |

**Table 6.4.** Estimates of exploitation ratio (E), exploitation rate (U), total stock (Y /U) standing stock (Y/F) of *D. watasei* for 2009, 2010, 2011 and pooled year

| Year | E | U | Yield Y (t) | Total Stock Y/U (t) | Standing Stock Y/F (t) |
|---|---|---|---|---|---|
| 2009 | 0.29 | 0.27 | 1797 | 6656 | 2364 |
| 2010 | 0.10 | 0.08 | 1937 | 24213 | 9685 |
| 2011 | 0.16 | 0.14 | 2025 | 14464 | 5789 |
| Pooled | 0.25 | 0.23 | 1920 | 8348 | 3000 |

**Table 6.5.** Estimates of exploitation ratio (E), exploitation rate (U), total stock (Y /U) standing stock (Y/F) of *D. garmani* for 2009, 2010, 2011 and pooled year

| **Year** | **E** | **U** | **Yield Y (t)** | **Total Stock Y/U (t)** | **Standing Stock Y/F (t)** |
|---|---|---|---|---|---|
| 2009 | 0.43 | 0.40 | 41 | 102 | 33 |
| 2010 | 0.40 | 0.38 | 44 | 116 | 39 |
| 2011 | 0.33 | 0.27 | 46 | 170 | 57 |
| Pooled | 0.42 | 0.41 | 44 | 107 | 37 |

**Table 6.6.** Estimates of length at first capture ($L_c$) and its corresponding age of first capture ($t_c$) of *D. watasei* and *D. garmani*

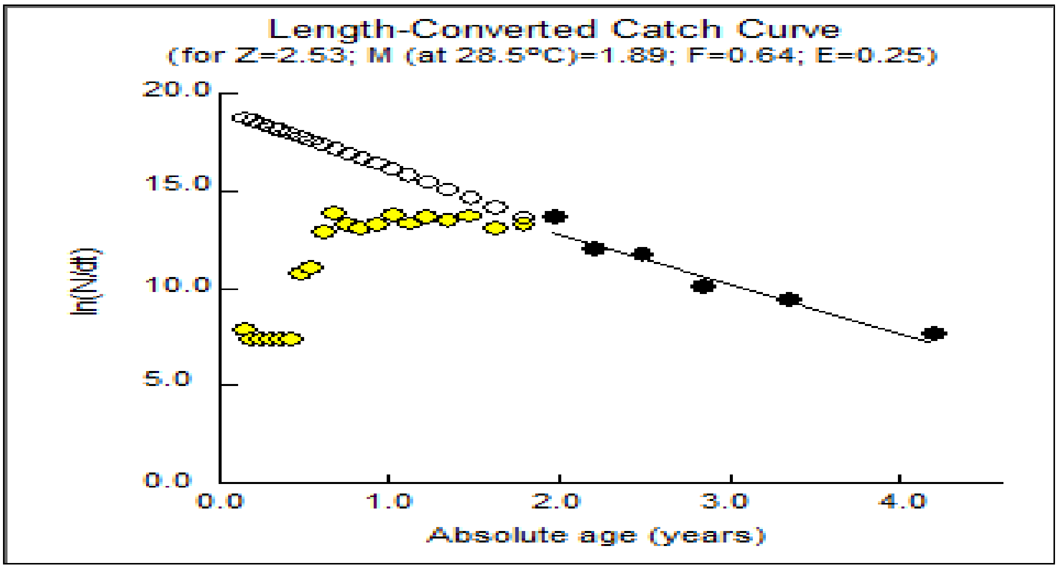
| **Years** | ***D. watasei*** | | ***D. garmani*** | |
|---|---|---|---|---|
| | **$L_c$ (cm SL)** | **$t_c$ (yrs)** | **$L_c$ (cm SL)** | **$t_c$ (yrs)** |
| 2009 | 8.49 | 1 | 5.21 | 0.9 |
| 2010 | 10.87 | 1.6 | 5.19 | 0.9 |
| 2011 | 10.47 | 1.5 | 5.47 | 1 |
| Pooled | 11.03 | 1.6 | 5.20 | 0.9 |

**Table 6.7**. Estimates of length at recruitment ($L_r$) and its corresponding age at recruitment ($t_r$) of *D. watasei* and *D. garmani*

| **Years** | ***D. watasei*** | | ***D. garmani*** | |
|---|---|---|---|---|
| | **$L_r$ (cm SL)** | **$t_r$ (yrs)** | **$L_r$ (cm SL)** | **$t_r$ (yrs)** |
| 2009 | 4.26 | 0.4 | 4.13 | 0.6 |
| 2010 | 4.71 | 0.5 | 4.13 | 0.6 |
| 2011 | 4.31 | 0.4 | 4.57 | 0.7 |
| Pooled | 4.26 | 0.4 | 4.13 | 0.6 |

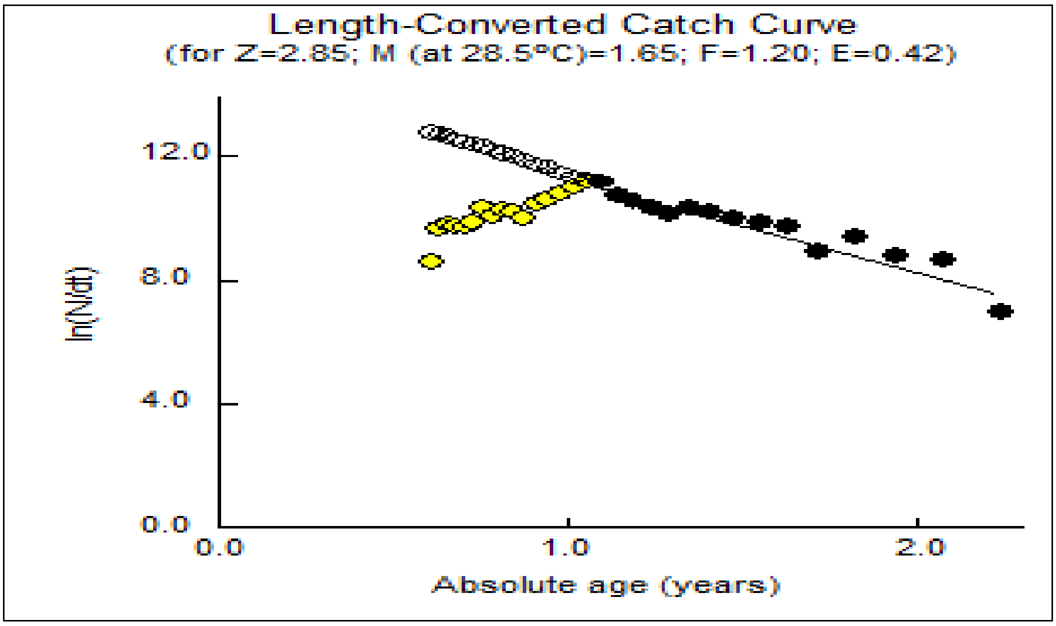
**Table 6.8.** Estimates of probability of capture of *D. watasei* and *D. garmani*

| **Lengths (cm SL)** | ***D. watasei*** | | | | ***D. garmani*** | | | |
|---|---|---|---|---|---|---|---|---|
| | **2009** | **2010** | **2011** | **Pooled** | **2009** | **2010** | **2011** | **Pooled** |
| $L_{25}$ | 8.08 | 10.29 | 10.04 | 9.95 | 5.12 | 5.03 | 5.27 | 5.10 |
| $L_{50}$ | 8.49 | 10.87 | 10.47 | 11.03 | 5.21 | 5.19 | 5.47 | 5.20 |
| $L_{75}$ | 8.92 | 11.35 | 10.91 | 11.64 | 5.30 | 5.29 | 5.59 | 5.30 |




| |
|---|
| Z from catch curve = 2.53<br>Growth parameters: $L_\infty$ = 15.06 cm SL, K = 0.8, C = 0, WP = 0, $t_0$ = 0.0284 |

**Fig. 6.1.** Estimation of 'Z' by length Converted Catch Curve method of *D. watasei*




| |
|---|
| Z from catch curve = 2.72<br>Growth parameters: $L_\infty$ = 7.61 cm SL, K = 1.3, C = 0, WP = 0, $t_0$ = 0.0104 |

**Fig. 6.2.** Estimation of 'Z' by length Converted Catch Curve method of *D. garmani*

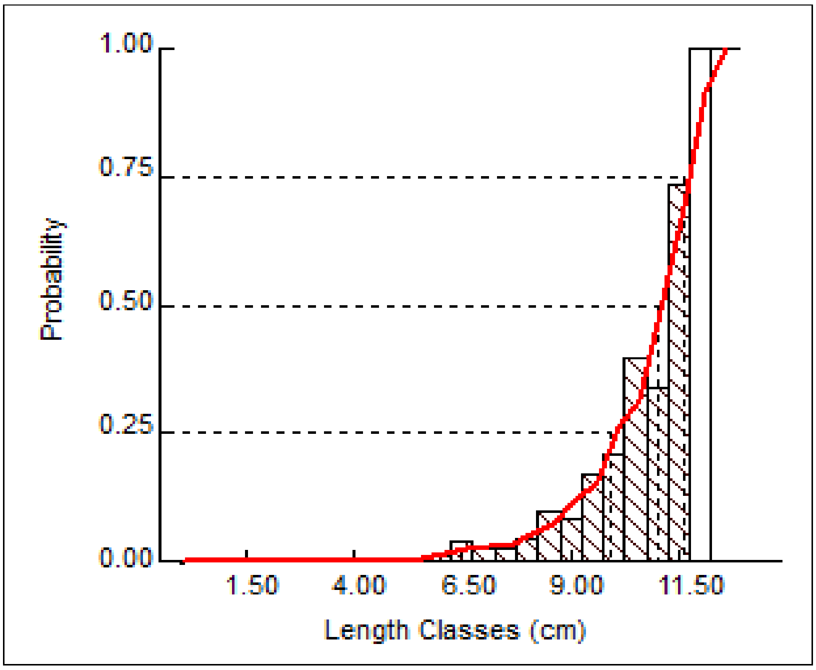



**Fig. 6.3.** Probability of capture of *D. watasei* during 2009- 2011

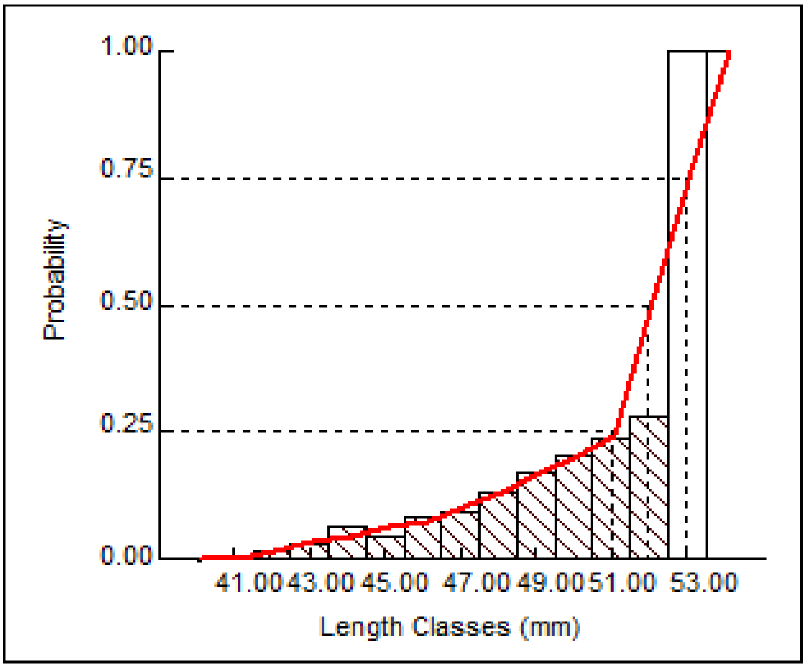



**Fig. 6.4.** Probability of capture of *D. garmani* during 2009- 2011

# CHAPTER 7

# FOOD AND FEEDING

# CHAPTER 7

# FOOD AND FEEDING

## 7.1. INTRODUCTION AND REVIEW OF LITERATURE

The study of food and feeding habits of fishes helps in proper understanding of the biology and their ecological realm. The study provides a clear indication of the feeding habits of the fish, its feeding behavior, growth, the ecological niche it occupies in the sea and also migration, if any undertaken by the fish. In the present context of competitive multispecies-multigear fishing, the study on food of fishes and their position in the food web becomes more significant in the judicious exploitation of fish stocks.

Several workers have reported on the food and feeding habits of fishes. The earlier studies include those of Day (1882), Hederman and Corbin (1892). Other significant studies include those of Scot (1902), Johnston (1906), Le Bour (1919), Hardy (1924), Neill (1938), Swynnerton and Worthingon (1940), Frost (1946), Hynes (1950) and Maitland (1965).

Pioneering studies on the food and feeding habits of marine pelagic species from the Indian waters include those by Hornell and Nayadu (1924), Devanesen (1932), Chacko (1949), Bhimachar and George (1952), Datar (1954), Venkataraman (1960), Tandon (1960a and b), Kuthalingam (1961), James (1967), Qasim (1972) and Muthiah (1994).

Internationally, most mid water trophic studies have dealt with the numerically dominant myctophids by Tyler and Pearcy, 1975; Kawaguchi and Mauchline, 1982; Robinson, 1984; Hulley, 1985; Dalpadado , 1988; Dalpadado and Gjosaeter, 1993; Sameoto, 1988; Kinzer *et al*., 1993; Pakomov *et al*., 1996; Rodriguez-Grana *et al*., 2005; Kosenok *et al*., 2006; Tanimata *et al*., 2008; Uchikawa *et al*., 2008.

Feeding habits and diet composition of *Diaphus* spp. from several areas were published by Tyler and Pearcy, (1975); Gordon *et al*. (1985); Moku *et al*. (2000) Sassa and Kawaguchi (2005) and Kosenok *et al*. (2006).

Only a few reports are available on the food and feeding of myctophids from Indian waters. The earliest report was by Gjosaeter (1977) on the feeding ecology of *B. pterotum* and *B. fibulatum*. Later Dalpadado and Gjosaeter (1988) described the feeding biology of *B. pterotum*.

In the present study the food and feeding habits of *D. watasei* and *D. garmani* along off Kerala coast have been studied in detail. This study aimed to understand the trophic behavior of myctophids along this region, which can be of much use especially when the time of exploitation of these resources becomes real. The detailed study on *Diaphus* spp. is the first of its kind from Kerala as well as from India.

Several methods such as occurrence method, point's method, volumetric method and gravimetric method are available for analyzing the food contents of fishes (Hynes, 1950; Borutsky *et al*., 1952; Pillai, 1952; Lagler, 1956; Windell, 1968; Windell and Bowen, 1978). However, the choice of method to be adopted depends on the feeding habit of the fish to be investigated. The prevailing high temperature in tropical waters accelerates the digestion process, the food remains in recognizable state more in the stomach than the gut. Hence the analysis of the food in the stomach gives a clear picture of the food contents of the fish (Qasim, 1972). Of the different methods, the volumetric method is the best suited method for carnivorous fishes and the gravimetric method for plankton feeders (James, 1967a). While reviewing the available methods for analyzing fish stomach contents, Hyslop (1980) has concluded that the best measure of dietary importance is the one where both the amount and the bulk of food category are recorded. Natarajan and Jhingran (1962) have suggested a composite index known as 'the index of preponderance' wherein the volume as well as the occurrence of each item found in the stomach is accounted. This index being a combination of the volumetric and numerical method gives a better picture of food contents than when any of these methods are applied in isolation.

## 7.2. MATERIAL AND METHODS

Weekly collected myctophids samples were brought to the laboratory, washed and the different species were sorted out. The individual fishes were then measured for their total length and wet weight. The fishes were then dissected to study the stomach condition and content. Based on visual examination of the distention of the stomachs and the amount of food contained in them they were graded as gorged, full, ¾ full, ½ full, ¼ full, trace and empty to study the intensity of feeding. The stomachs were removed from the fish for detailed analysis of the food contents. The stomach was cut open and the contents were emptied into a Petri dish. The food items were identified as far as possible and their individual weights were measured. The fishes with gorged, full and ¾ full stomachs were categorized as actively fed, ½ full as moderately fed and ¼ full and trace as poorly fed. Diet analysis was done in relation to months. The monthwise data from the two centers were pooled together for arriving at a gross picture of the diet. The index of preponderance method of Natarajan and Jhingran (1962) as expressed as:

$$I = \frac{W_i * O_i}{\sum W_i * O_i} * 100$$

was employed for the food analysis where $W_i$ and $O_i$ are the gravimetric weight and occurrence indices of food items respectively presented in percentage.

## 7.3. RESULTS

Both species of *Diaphus* studied were carnivores, feeding on crustaceans, molluscs, fishes and detritus

***Diaphus watasei:*** annually the shrimps formed the major component in the food of *D. watasei* with the Index of Preponderance (IP) being 49.07 followed by the digested matter (38.09), squids (6.99), euphausids (3.45), detritus (1.96), fishes (0.41), and crabs (0.03) (Table 7.1). In the stomachs of *D. watasei*, crustaceans were the most dominant group during all months (Plate 7.1). Among the crustaceans, shrimps were the major group. Other crustaceans mainly comprised of euphausids, small crabs and negligible amount of zoea. Squids represented the molluscs content in the stomach. Stomach with fully digested food matter was very common. Unidentified digested matters were also observed.

***Diaphus garmani:*** crustaceans followed by digested matter, molluscs, detritus and fishes were the dominant component in the food of *D. garmani* (Table 7.2 and Plate 7.2). The respective index being 85.61, 11.54, 2.37, 0.32 and 0.16. The crustaceans component in the stomach were represented by euphausids (67.32) and shrimp (18.29). Squids represented the molluscan food. Only traces of fish were observed in the diet.

**7.3.1. Diet composition in relation to months**

Crustaceans comprised the principal food item in myctophids, they dominated the stomach content almost round the year (Table 7.3 and 7.4).

In *D. watasei* the highest index of crustaceans was observed in January (83.86) and the least during March (78.59). The principle food item among the crustaceans was shrimps. During all months the index of shrimps was high. The index ranged between 78.09 in March and 83.13 in January. Digested matter was the second dominant item in the stomach contents, with an highest index (15.53) observed in August and the lowest (12.6) in February. Squid was the third important component which recorded the highest index of 4.55 in September and the lowest of 1.67 in November. Crabs and zoea were observed in the stomach occasionally in small quantities.

The *Diaphus garmani*, also had a similar trend with the crustacean component forming the main diet during all the months (Table 7.4). The highest index was observed in September (97.4) and the lowest in May (92.67). Among the crustaceans, euphausids formed the main diet during January, August, September, October, November and December; and shrimps formed the main diet during rest of the months. The index of euphausids ranged from 38.54 (May) to 72.73 (September) and that of shrimp from

24.46 (December) to 54.13 (May). Fish remains were observed in the stomach occasionally in small quantities.

### 7.3.2. Feeding condition

In *D. watasei* the empty, poor, moderate and active feeding conditions comprised of 57 %, 19 %, 14 % and 10 % respectively (Table 7.5 and Fig. 7.1). Active feeding condition was maximum during May (18%) and minimum during September (5.72%). Empty stomachs were minimum during May (50%) and maximum during October (71%).

In *D. garmani*, the empty, poor, moderate and active feeding conditions comprised 55 %, 20 %, 14 % and 11 % respectively (Table 7.6 and Fig. 7.2). Active feeding was observed maximum in August and November (16 %) and minimum in January (6.46). Empty stomachs were minimum during May (46%) and maximum during November (63 %).

## 7.4. DISCUSSION

The study shows that the *Diaphus* spp. are carnivores in feeding habit, which feeds predominantly on crustaceans. The crustacean diet consisted mainly of shrimps, euphausids, crabs and zoea. In *D. watasei* shrimps were the dominant group of food item, whereas in *D. garmani* euphausids dominate. The study area from where the myctophids caught were rich in deep sea shrimp, therefore the difference in the diet is more related to the preferential feeding. Most of the studies reported that myctophids are opportunistic feeders, which mainly feeds on zooplanktons like copepods, euphausids, ostracods, amphipods, fish eggs, fish larvae etc (Tyler and Pearcy, 1975; Hulley, 1985; Dalpadado and Gjosaeter 1993; Pakhomov *et al*., 1996 and Sassa and Kawaguchi, 2005). Only one of the myctophid species *Ceratoscopelus warmingii* was reported with occasional herbivory diet (Robinson, 1984). Molluscs were also an important food item for both species. Magnuson and Heltz (1971) explained that the change in food was dependent on the area of filtration formed by the gill apparatus. In small sized fishes gill rakers are closely set with small gaps in between and more smaller organisms were sieved; whereas in larger fishes with comparatively larger gaps in between the gill rakers, larger organisms are retained. Moreover, Sreenivasan (1979) has concluded that the small sized fishes cannot move so swiftly as to prey upon fast moving organisms and therefore need to rely on the plankters. Fishes were least preferred by both of the *Diaphus* spp. Small amount of detritus, which includes radiolarians and foraminiferans were also found in the stomach.

*Diaphus watasei* preferred shrimps, followed by squids, euphausids, detritus, fishes and crabs as their food. Whereas *D. garmani* preferred euphausids followed by shrimps, squids, detritus and fishes. Baird *et al*. (1975) reported that the most prevalent food item in the diet of the *Diaphus taaningi* was larvaceans. Kosenok *et al*. (2006) reported that the developed *Diaphus theta* from the Pacific waters prefer on euphausids as food. Feeding intensity of both of the species revealed that majority with empty stomachs. This may be due to the regurgitation of food at the time of capture. Some fishes were encountered with food items in the mouth; this occurrence may be unintentional at the time of capture. The stomach fullness might have been related by the hydrological conditions and range of vertical diurnal migrations of the fish (Kosenok *et al*., 2006). Dalpadado and Gjosaeter (1988) stated that regurgitation of food at the time of capture might influence the food and feeding study. Anderson (1967) and Holton (1969) the gut fullness and index were more during night, however Paxtron (1967) reported, that myctophids fed throughout the diel period. In the present study data is insufficient to separate these possibilities.

These myctophids are found to form forage for many ecologically important fishes. They are considered as a vital link between the zooplankter and their highly valued predators and thus play a remarkable role in the energy transfer from the deep Ocean.

**Table 7.1.** Index of preponderance of food items of *D. watasei* from Kerala coast during 2009-11

| Food items | I |
|---|---|
| **FISHES** | 0.41 |
| **CRUSTACEANS** | 52.55 |
| Shrimp | 49.07 |
| Euphausids | 3.45 |
| Crab | 0.03 |
| Zoea | * |
| **MOLLUSCS** | |
| Squid | 6.99 |
| **DETRITUS** | 1.96 |
| **DIGESTED MATTER** | 38.09 |

*negligible quantities

**Table 7.2.** Index of preponderance of food items of *D. garmani* from Kerala coast during 2009-11

| Food items | I |
|---|---|
| **FISHES** | 0.16 |
| **CRUSTACEANS** | 85.61 |
| Shrimp | 18.29 |
| Euphausids | 67.32 |
| **MOLLUSCS** | |
| Squid | 2.37 |
| **DETRITUS** | 0.32 |
| **DIGESTED MATTER** | 11.54 |

**Table 7.3.** Monthwise average index of preponderance of different food items in *D. watasei*, caught off Kerala coast

| Food items | Jan | Feb | Mar | Apr | May | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|
| **FISHES** | 0.2 | 0.2 | 0 | 0.4 | 0.2 | 0.23 | 0.6 | 0.3 | 0.75 | 0.3 |
| **CRUSTACEANS** | 83.86 | 82.82 | 78.59 | 82.28 | 81.29 | 79.5 | 80.29 | 82.41 | 83.51 | 83.15 |
| Shrimp | 83.13 | 82.27 | 78.09 | 80.32 | 79.78 | 78.7 | 79.44 | 81.47 | 83.01 | 82.35 |
| Euphausids | 0.73 | 0.55 | 0.46 | 1.96 | 1.5 | 0.8 | 0.85 | 0.94 | 0.5 | 0.8 |
| Crab | - | - | 0.04 | - | - | - | - | - | - | - |
| Zoea | - | - | - | - | 0.01 | - | - | - | - | - |
| **MOLLUSCS** | | | | | | | | | | |
| Squid | 2.01 | 3.54 | 5.64 | 3.19 | 3.29 | 4.47 | 4.55 | 2.34 | 1.67 | 2.17 |
| **DETRITUS** | 0.68 | 0.84 | 0.9 | 0.59 | 0.84 | 0.27 | 1.37 | 1.15 | 1.09 | 1.04 |
| **DIGESTED MATTER** | 13.25 | 12.6 | 14.87 | 13.54 | 14.38 | 15.53 | 13.19 | 13.8 | 12.98 | 13.34 |

**Table 7.4.** Monthwise average index of preponderance of different food items in *D. garmani*, caught off Kerala coast

| Food items | Jan | Feb | Mar | Apr | May | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|
| **FISHES** | 0.87 | 0.79 | 0.88 | 0.36 | 0.15 | 0.46 | 0.1 | 0.52 | 0.06 | 0.8 |
| **CRUSTACEANS** | 94.77 | 95.44 | 95.1 | 95.39 | 92.67 | 94.94 | 97.4 | 94.24 | 96.46 | 94.61 |
| Shrimp | 32.67 | 50.47 | 50.1 | 51.5 | 54.13 | 26.94 | 24.67 | 25.95 | 27.04 | 24.46 |
| Euphausids | 62.1 | 44.97 | 45 | 43.89 | 38.54 | 68 | 72.73 | 68.29 | 69.42 | 70.15 |
| **MOLLUSCS** | | | | | | | | | | |
| Squid | 1.15 | 1.18 | 1.46 | 1.67 | 2.67 | 1.68 | 1.05 | 1.5 | 0.75 | 1.29 |
| **DETRITUS** | 0.65 | 0.94 | 0.38 | 0.61 | 0.97 | 0.76 | 0.39 | 0.77 | 0.59 | 0.43 |
| **DIGESTED MATTER** | 2.56 | 1.65 | 2.18 | 1.97 | 3.54 | 2.16 | 1.06 | 2.97 | 2.14 | 2.87 |

**Table 7.5.** Monthly average feeding codition of *D. watasei* from Kerala coast during 2009-11

| Feeding intensity | Jan | Feb | Mar | Apr | May | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|
| Active | 9.44 | 10.8 | 14 | 12.9 | 17.46 | 7.16 | 5.72 | 8.61 | 10.59 | 6.84 |
| Moderate | 15.84 | 10.75 | 8 | 15.66 | 16.86 | 14.61 | 19.62 | 9.75 | 15.12 | 18.09 |
| Poor | 20.54 | 20.65 | 25.61 | 18.15 | 15.64 | 16.51 | 22.94 | 11.06 | 19.86 | 14.35 |
| Empty | 54.18 | 57.8 | 52.39 | 53.29 | 50.04 | 61.72 | 51.72 | 70.58 | 54.43 | 60.72 |

**Table 7.6.** Monthly average feeding condition of *D. garmani* from Kerala coast during 2009-11

| Feeding intensity | Jan | Feb | Mar | Apr | May | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|
| Active | 6.46 | 10.81 | 7.11 | 11.35 | 12.64 | 15.61 | 11.64 | 9.51 | 15.61 | 9.29 |
| Moderate | 11.61 | 10.43 | 7.37 | 14.19 | 18.49 | 19.84 | 14.77 | 15.16 | 9.64 | 20.95 |
| Poor | 22.59 | 25.32 | 26.51 | 21.22 | 22.65 | 15.82 | 22.15 | 16.49 | 11.54 | 12.98 |
| Empty | 59.34 | 53.44 | 59.01 | 53.24 | 46.22 | 48.73 | 51.44 | 58.84 | 63.21 | 56.78 |

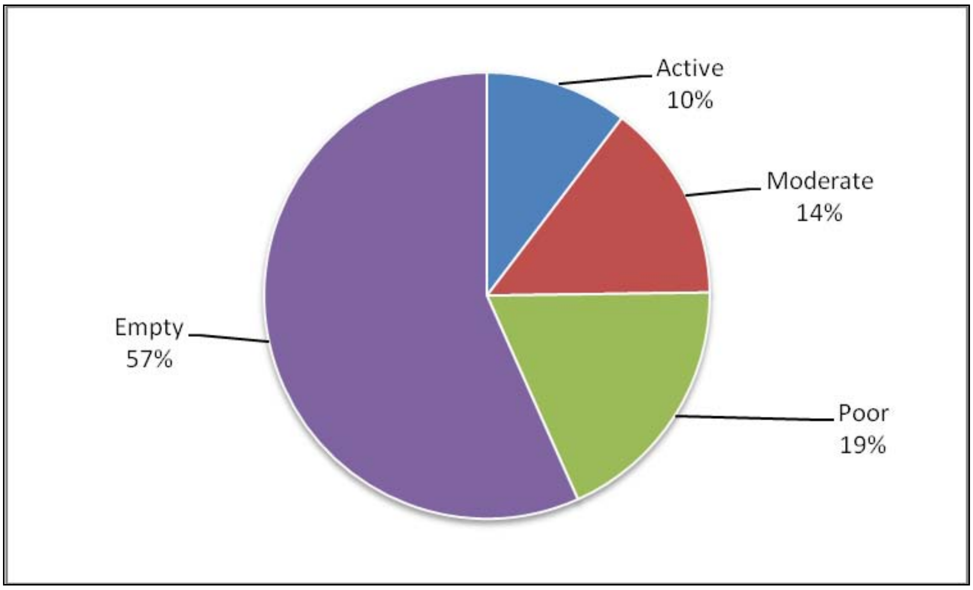



**Fig. 7.1.** Feeding condition of *D. watasei* caught from off Kerala coast

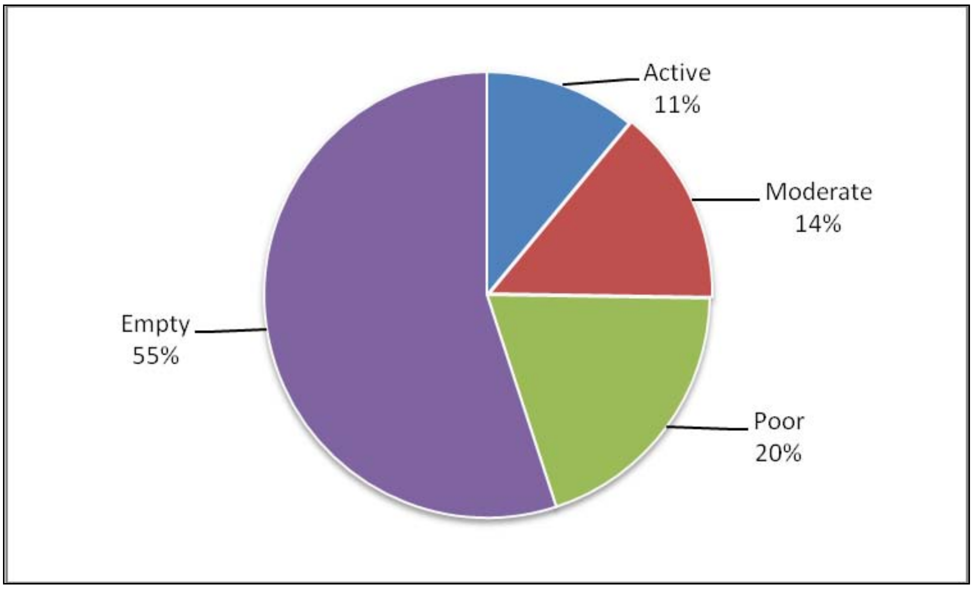



**Fig. 7.2.** Feeding condition of *D. garmani* caught from off Kerala coast

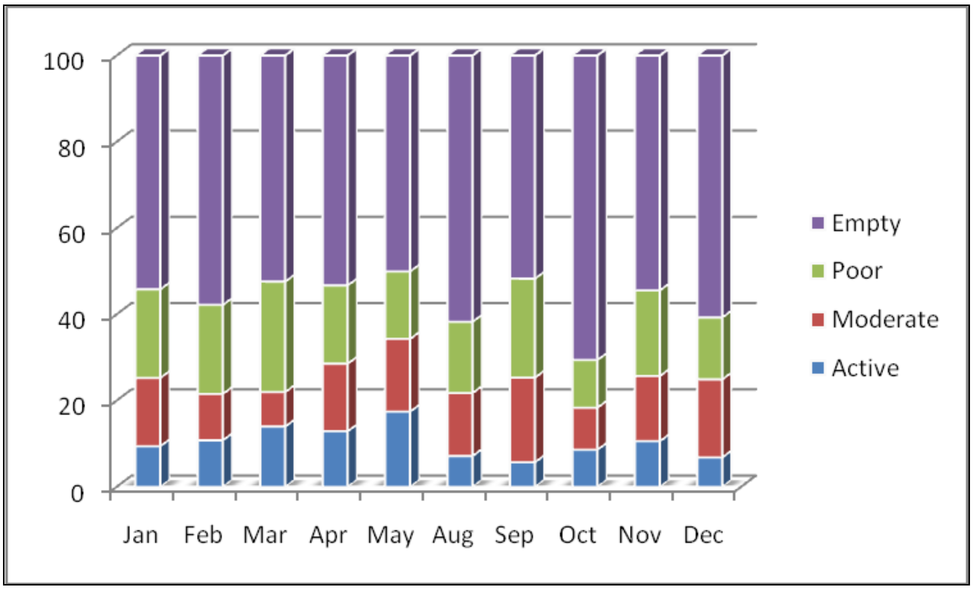



**Fig. 7.3.** Monthly feeding condition of *D. watasei* caught along off Kerala coast during 2009-11

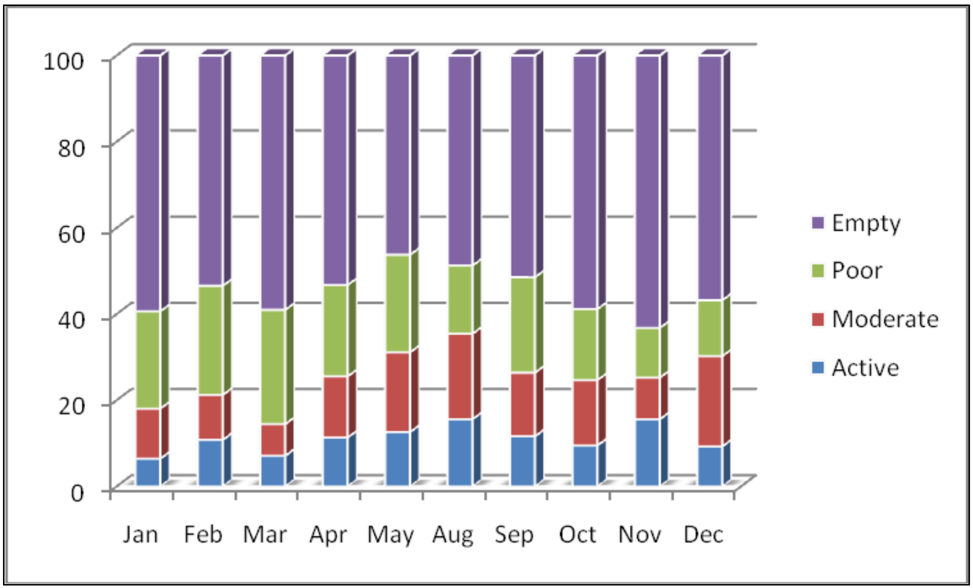



**Fig. 7.4.** Monthly feeding condition of *D. garmani* caught along off Kerala coast during 2009-11

**Plate 7.1.** Gut contents observed in *D. watasei*

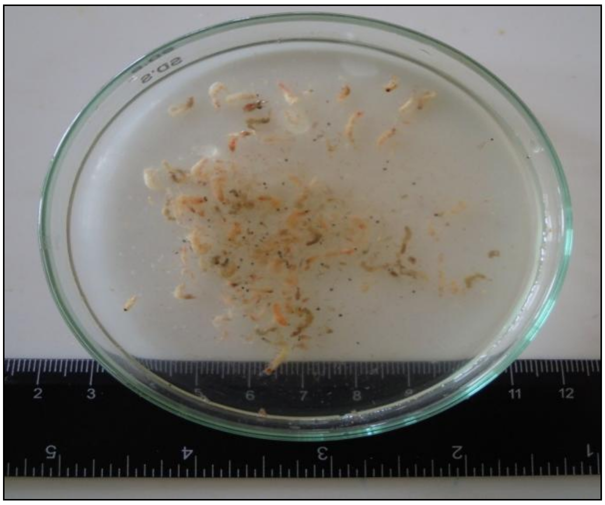


**Plate 7.2.** Gut contents observed in *D. garmani*

# CHAPTER 8

# REPRODUCTION

# CHAPTER 8

# REPRODUCTION

## 8.1. INTRODUCTION AND REVIEW OF LITERATURE

Reproduction is a process, which ensures the very existence and continuity of generations and in particular the species it represents. In fishes, the reproductive capacity has a direct bearing on the population strength and size of the stock that is available for fishing. Fishes follow different reproductive strategies, evolved to suit their living habitat and to ensure sufficient numbers in the next generation. Studies on the reproductive biology of fishes includes their sex ratio, size at first maturity, fecundity, spawning seasons, spawning periodicity etc.

The study of the reproductive characteristics of fishes is essential to understand its replenishment capabilities and the strategies adopted for maintaining their stock abundance in a competitive habitat with heavy predation pressure.

The reproductive biology of several fishes have been studied at different parts of the world by several workers, some of the important works include those of Fulton (1898), Clark (1934), Hickling and Reutenberg (1936), De Jong (1940), Le Cren (1951), June (1953), Bunag (1956), Bagenal (1957), Mac Gregor (1957), Otsu and Uchida (1959), Yoshida (1964), Chigrinskiy (1970), Macer (1974), Crossland (1977), Baglin (1982), Williams and Clarke (1982), Davis (1985), Hunter and Macewiez (1985), Parrish *et al*. (1986), Bengtson *et al*. (1987), Greeley *et al*. (1987), Jons and Miranda (1997), Shoesmith (1990) and West (1990).

The important works on the reproductive biology of Indian species include those by Hornell and Nayadu (1924), Pannikar and Aiyar (1939), Pradhan and Palekar (1956), Prabhu (1956), Qasim and Qayyum (1961), Rao (1963), Raja (1964), James (1967), Parulekar and Bal (1971), Qasim (1973), Devaraj (1977), James and Baragi (1980) and Muthiah (1986 and 1994).

The reproductive biology of myctophids was studied by Fast (1960); Odate and Ogawe (1961); Lipskaya (1967); O'Day and Nafpaktitis (1967); Paxton (1967); Nafpakttitis (1968); Halliday (1970); Smoker and Pearcy (1970); Goodyear *et al*. (1972); Zurbrigg and Scott (1972); Clarke (1973); Pertseva and Ostroumova (1973); Badcock and Merret (1976); Go *et al*. (1977); Karnella and Gibbs (1977); Robertson (1977); Childress *et al*. (1980); Gjosaeter and Kawaguchi (1980); Gjosaeter and Tilseth (1988); Gjosaeter (1981, 1984); Clarke (1983); Oven (1983); Dalpadado (1985, 1988); Gorelova and Prut'ko (1985); Lisovenko and Prut'ko (1987, 1987a); Olivar (1987); Gibbs and Krueger (1987); Young *et al*. (1987); Dalpadado (1988); Andrianov and Bekker (1989); Prosch (1991) and Gartner (1993).

Investigations on the reproductive biology of *Diaphus* spp. were those by Go *et al*. (1977); Gorelova and Prut'ko (1985); Olivar (1987); Lisevenko and Prut'ko (1987, 1987a); Olivar and Beckley (1995) and Moku *et al.* (2002).

The important works carried on myctophids in Indian waters were those by Valsa (1979); Gjosaeter and Tilseth (1988); Hussain and Ali Khan (1987, 1988); Dalpadado (1988) and FAO (1997). Reproductive biology of *Diaphus suborbitalis* in the Indian Ocean was studied by Lisevenko and Prut'ko (1987, 1987a).

There is no study and information on the reproductive biology of myctophids from the present study area. The present investigation provides detailed information on the reproductive biology of *D. watasei* and *D. garmani* off the Kerala coast.

## 8.2. MATERIAL AND METHODS

Weekly samples of *D. watasei* and *D. garmani* were collected as detailed in the earlier chapter. Standard length (cm) and total weight (gm) of the fish were taken after removing moisture from the body surface. The fishes were then dissected and their sex as well as stage of maturity was noted. The gonads were removed, weighed and preserved in 5% formalin.

Macroscopic staging based on changes in the size and appearance of the gonad is used in the present reproductive studies as by West (1990). Fresh gonads were examined macroscopically for the general external characteristics and their organization. The maturity stages of the gonads were fixed as per International Council for Exploration of the Sea (ICES) scale (Wood, 1930 and Lovern and Wood, 1937). Accordingly, the ovaries and the testis were categorized into seven stages, based on easily discernable external features such as shape, size, colour, the volume occupied and the microscopic structure of the ova.

The testes were subject only to macroscopic examinations, as they are generally difficult to stage than females; may give a less well defined estimate of the spawning season and often do not show much large changes in gonad weights (Fairbridge, 1951; June, 1953; Crossland, 1977 and Forberg, 1982). The ovaries were further subjected to detailed microscopic study. Maturation of ova, duration and frequency of spawning were studied by measuring ova diameter following Clark (1934), Hickling and Rutenberg (1936), June (1953), Prabhu (1956), Mac Gregor (1957), Raja (1964) and James and Baragi (1980). The monthly percentage occurrence of different stages of gonad development was analysed to find out the peak spawning season. Ova diameter measurements from matured ovaries in stages IV to VII were made. The distribution of ova diameter frequency from different parts of the matured ovary revealed that there were no marked variations in the number and size of ova between the anterior, middle and posterior portions of right and left lobes of the ovary, so samples were drawn from the middle portion of the ovary for further studies. Ova measuring less than 6 $\mu$ m were not measured, as they were present in large numbers in all the ovaries. The diameter of the egg was measured under microscope with measuring software. Ova diameter frequency from the ovaries of identical stage of maturity was pooled for plotting the graph.

Fecundity estimates were made by counting a sub sample of the ovary in stage IV, V and VI. The gonads were weighed using electronic balance to the nearest 0.001 g after removing the moisture. A sub sample of the ovary was separated and weighed to the nearest 0.001 g. The sample portion was teased and all matured ova were counted and the fecundity estimated employing the formula:

$$\frac{\text{Total weight of the ovary}}{\text{Weight of the sample}} * \text{No. of ova in the sample}$$

The relationship between fecundity and different variables like fish length, fish weight and ovary weight was worked out by the least square method:

$$F = a\,X^{b}$$

Where F = fecundity, X = fish length or fish weight or gonad weight and b = regression co-efficient. The exponential relationship was transformed based on logarithms by the following equation

$$\text{Log fecundity} = \log a + b \log x$$

**Size at first maturity**

The smallest length at which the fish matures for the first time in its life is the size at first maturity. For all practical purpose the size at first maturity is considered as the length at which 50 % of the fishes attain maturity. Fishes with gonad at stage III and above were considered as mature and their percentages in each length group were plotted against mid-length of the size group. Maturity curves were drawn on the scatter plotted so as to estimate, the length at which 50 % of fish mature.

## 8.3. RESULTS

Both *D. watasei* and *D. garmani* have paired reproductive organs (testis and ovaries) (Plates. 8.1 and 8.2) are almost equal in size and each attaches separately to the dorsal wall of the coelomic wall with a thick mesovarium. The two lobes of the gonad are free in the anterior end, but joined posteriorly to a common genital aperture. On attaining full sexual maturity the gonads occupy the entire body cavity. The mature testes of both of the species are thick, broad and milky white in colour and the milt is released on application of slight pressure. The mature ovaries of *D. watasei* are creamy yellow colour and eggs are visible to the naked eyes; whereas in *D. garmani* it is slight pinkish yellow in colour. Eggs are extruded on application of slight pressure on the abdomen.

### 8.3.1. Maturity

A preliminary examination of distribution of ova diameter frequency from different parts of the ovary showed that there was no marked variation in the number and size of ova between the anterior, middle and posterior portions of right and left lobes of ovary. The macro and microscopic structures of the gonads in the two species of *Diaphus* did not differ, so a general description for both the species is given below:

**Males:**

Stage I: Immature

Testes very small, thread like, colourless, placed distally very close to the genital aperture.

Stage II: Immature

Testes are little longer and broader than stage one, pale white in colour and occupy less than one fourth of body cavity.

Stage II: Maturing

Testes broader and longer, whitish in colour and occupy more than1/3$^{rd}$ of the body cavity.

Stage IV: Mature

Thicker, broader and longer whitish in colour with firm texture but milt oozes on applying hard pressure. Occupy more than 2/3$^{rd}$ of the body cavity.

Stage V: Gravid

Thicker, broader and longer than in stage IV. Occupy nearly entire body cavity. Milt easily extrude on pressure.

Stage VI: Ripe

Testes very thick, broad and long. Occupy entire body cavity. Whitish in colour, milt flows out easily with slight pressure.

Stage VII a: Partially spent

Texture of testes not firm, loose to touch, milt still oozes easily on pressure. Colour grayish on upper half and the distal portion blood short. Occupy less than $3/4^{th}$ of the body cavity.

Stage VII b: Fully spent

Testes have an appearance of loose sacs, blood shot in colour and shrunken in appearance. Milt does not flow on applying pressure. Occupy less than $1/4^{th}$ of the body cavity.

**Females:**

Stage I: Immature

Ovaries small, thread like, broader than testes in stage I, creamy colour, lies close to the genital aperture, ova not visible to the naked eyes; under microscope the ova appear irregular, transparent with a central nucleus, yolkless, ova not easily separable.

Stage II: Immature

Ovaries small, tubular, fleshy, cream coloured lobes; ova still not visible to naked eye. Occupy nearly ¼ of the body cavity. Under microscope they appear as transparent, irregular shaped eggs with nucleus clearly visible.

Stage III: Maturing

Broader and longer than stage II, occupy nearly 1/2nd of the body cavity; creamy in colour; ova not visible through ovarian wall. Yolk deposition has commenced and ova look yellowish and granular in the centre and getting transparent towards periphery.

Stage IV: Mature

Ovaries well developed occupying nearly 3/4th of the body cavity; bright yellow in colour for *D. watasei* and pinkish cream colour for *D. garmani*; ovary wall thin, yolked ova visible to naked eye. Ova are yolk laden, granular, round and appear as dark bodies under the microscope.

Stage V: Gravid

Ovaries bright yellow in colour for *D. watasei* and pinkish cream in colour for *D. garmani*; occupy nearly entire body cavity, eggs round, transparent, loosely arranged with a single oil globule, Eggs extruded on applying pressure.

Stage VI: Ripe

Ovaries occupy the entire body cavity creamy yellow in colour for *D. watasei* and pinkish cream in colour for *D. garmani*, ovary wall very thin and eggs easily extruded on slight pressure. Ova round, transparent with a single oil globule, swelled up.

Stage VII a: Partially spent

Ovaries flaccid, blood stained with strong venation; occupies 3/4th to 1/4th of body cavity. Ova translucent with single oil globule, eggs released on application of pressure.

Stage VIIb: Fully spent

Ovaries shrunken, flaccid with blood shot appearance, occupy 1/4th of the body cavity. Some large eggs disintegrating; transparent and opaque eggs also present.

### 8.3.1. *Size at first maturity*

In *D. watasei*, 50 % of fish attained maturity at 9.8 cm standard length when the fish is 1.3 years old (Fig. 8.1). The size of first maturity of *D. garmani* was 5.3 cm standard length at an age of 9 months (Fig. 8.2). From the age and growth curves (Figs. 4.5 and 4.6), it shows that *D. watasei* mature and spawns after one year old, whereas *D. garmani* mature and spawn much early before they reach one year old.

### 8.3.2. Spawning season

The monthly percentage occurrence of different maturity stages of gonad of *D. watasei* and *D. garmani* is given in Tables 8.1 and 8.2.

*Diaphus watasei* has a prolonged and almost continuous spawning season with all stages of maturity occurring round the year (Fig. 8.5). Peak spawning (when stages IV – VI were abundant) was observed during May – August and November – December. Intermediate and immature fishes (Stages I – II) were abundant during September – October and February – April. It is observed that spawning commences early August and peaks during the September.

The spawning season in *D. garmani* is also prolonged (Fig. 8.6). Active spawning is during October – December. Though *D. garmani* were not available in the catch during monsoon months, the presence of young fishes in pre-monsoon months indicated that they also spawn during post-monsoon months.

### 8.3.3. Ova diameter

The ova diameter frequency of *D. watasei* and *D. garmani* at stages IV to VI are shown in Figs. 8.3 and 8.4. The ova were spherical, translucent with a prominent oil globule. In *D. watasei* the ova diameter ranged between 30 µm and 483 µm with majority measuring 330 µm (Plate 8.3). The ova diameter in *D. garmani* ranged between

13 μm and 212 μm with majority of 130 μm. There were different batches of eggs having different size present in each ovary indicating that they are batch spawners.

### 8.3.4. Sex ratio

The distribution of males and females of *Diaphus* spp. during different months were represented in Table 8.3. Analysis of monthwise sex ratio of *D. watasei* indicated the dominance of female with an average sex ratio of 1 : 1.5 (male : female) where dominance of males were observed only in October and December. In *D. garmani* dominance of female was observed with an average sex ratio of 1: 1.3 (male : female) where dominance of males were observed only in April, September and December.

### 8.3.5. Fecundity

Fecundity of *D. watasei* ranged from 9826 to 49659 no. in fishes having a length range of 11.5 – 13.1 cm SL. Relative fecundity of *D. watasei* ranged from 434 no/gm body weight to 1443 no/gm body weight. The wet weight of the fish ranged from 18.8 g to 34.4 g and the gonad weight ranged between 0.66 g – 1.62 g. In case of *D. garmani* the fecundity ranged from 5864 to 9358 no. in fishes having a length range of 6.1 – 6.8 cm SL. Relative fecundity of *D. garmani* ranged from 1668 no/gm body weight to 2491 no/gm body weight. The wet weight of the fish ranged from 3.2 g to 4.2 g and the gonad weight ranged between 0.17 g – 0.33 g.

The regression equation for the relationship of length of fish (L) and fecundity (F) can be expressed as:

*D. watasei* : $\text{Log } F = 2.237796 + 0.027477 \text{ Log } L$

*D. garmani* : $\text{Log } F = 2.119665 + 0.972874 \text{ Log } L$

The relationship between weight of fish (W) and fecundity (F) is:

*D. watasei* : Log F = 0.569787 + 0. 265109 Log W

*D. garmani* : Log F = 2.119665+ 1.37608 Log W

The regression between ovary weight (OW) and and fecundity (F) is:

*D. watasei* : Log F = -2.00483 + 0. 206483 Log OW

*D. garmani* : Log F = 3.264134 + - 0.51717 Log OW

## 8.4. DISCUSSION

The present study showed that both species of *Diaphus* have prolonged spawning period with species taking turns in spawning during different months. Immature and mature fishes comprised the fishery almost throughout the year. Like most of the other pelagic fishes occurring along the Kerala coast, spawning in *D. watasei* is active during the monsoon months (June – August) and the young ones are abundantly available during the post-monsoon months (September – November). Though there was no landing during June and July, but the occurrence of spent fishes in the post-monsoon months indicate that spawning is active during the monsoon months. The abundance of young fishes in September to November further reaffirms that spawning is active during the monsoon months. A second spawning season was observed during November – December period.

In *D. garmani* fishes in later stages of maturity were very less compared with the other stages. According to Dalpadado (1985 and 1988) the lesser number of spawn fishes in most areas may indicate that these fishes spawn just once and sink out of the sampled depth layers after spawning, on the other hand, it could be that spawners recover extremely rapidly and leave no trace of previous spawning. The scare availability of fishes in running stages may be due to the migration of the fish into deeper waters after attaining the penultimate stage of maturity as suggested by Bapat *et al*. (1982) and Sousa (1988). Fishing by mechanized units along the Kerala coast during the peak monsoon months (15th June to 31st July) is banned. The traditional crafts operate in shallow waters, do not land myctophids. In case of *D. garmani* active spawning occurs during post monsoon (October - December). Also the occurrence of young ones during January – March confirms the spawning season as post monsoon. The present study confirms that *Diaphus* spp. along the Kerala coast follow a prolonged spawning in two peaks. It is known that many myctophid species from the tropical zone of the world Oceans spawn through out the year, although its intensity differs in different seasons (Pertseva – Ostroumova, 1972, 1973; Oven, 1983; Gjosaeter, 1981 and Lisovenko and Prut'ko, 1987). According to Gjosaeter and Kawaguchi (1980), myctophids in temperate regions spawn mainly from late winter to summer, spawning apparently coincidewith seasonal maxima in zooplankton production. Clarke (1973) postulated that reproductive cycles in mid water fishes, particularly myctophids, were timed to coincide with the spring bloom. In sub Arctic and sub Antarctic waters, however, spawning in some species of myctophids are confined to winter (Smoker and Pearcy, 1970; Robertson, 1977 and Young *et al*., 1987). According to Gjosaeter and Kawaguchi (1980) winter spawning in high latitudes may be an adaptation to low water temperatures, since hatching takes place much longer than in low latitudes. Kawaguchi and Shimizu (1978) reported ripe eggs of *D. watasei* with from Sulu Sea, indicating that it breed in the South east Asian Seas.

The ova diameter studies in both the species of *Diaphus* indicate that they have a prolonged spawning period and fish in spawning condition have different size of developing oocytes in their ovaries. The maturation of ova in both species displays asynchronous type of development as classified by Marza (1938) and can be grouped under asynchronous ovaries as classified by Wallace and Selman (1981). Fulton (1898) observed that in species with pelagic eggs, there was no sharp demarcation between large and smaller yolked oocytes and the condition was associated with prolonged spawning seasons. De Vlaming (1983) considers that most species with asynchronous oocyte development have protracted spawning seasons with multiple spawning.

Most myctophids have ovaries which contain oocytes of the next spawning and cells of protoplasmic growth as well as the intermediate cells (Gjosaeter, 1981; Alekseeva and Alekseev, 1983; Oven, 1983; Lisovenko and Prut'ko, 1987) and hence these species has continuous oogenesis and spawning in many batches. Multiple (usually bimodal) oocyte size frequencies in myctophids have been reported by earlier authors (Oven, 1986; Young et al., 1987; Dalpadado, 1988; Gartner, 1993). Some authors like Oven (1986) and Lisovenko and Prut'ko (1987a) used the term 'continuous wave oogenesis' to describe the constant sequential production of oocyte batches in myctophids, which is an apt portrayal of oocyte reproduction processes in these long term spawners.

Smoker and Pearcy (1970) argued that the presence of smaller mode of gametes in the myctophid *Stenobrachius leucopsaurus* did not necessarily imply multiple spawning as the immature gametes could either be expelled into the plankton or restored. Gartner (1993) identified two major reproductive strategies observed among myctophids. They include species that attain sexual maturity at small sizes and spawn repeatedly during all the seasons. While the other category include fishes that spawn fewer times and are more seasonally restricted.

In the present study, females dominate in the population of both *D. watasei* and *D. garmani*. The biase towards females in this study may be due to factors such as spatial segregation of sexes (Klingebeil, 1978), depth distribution (Badcock and Merrett, 1976) and differential avoidance of nets (Klingbeil, 1978). The present study indicates that *D. watasei* has a wide range in fecundity where as *D. garmani* has a nominal range of fecundity, this may be due to the size difference between the species as *D. watasei* attain much larger size than *D. garmani*. The fecundity is directly proportional to the fish length, wet weight and gonad weight. Sreenivasan (1987) reported that the fecundity of the fish was directly proportional to the length, fish weight and ovary weight.

**Table 8.1** Monthly occurrence (%) of *D. watasei* in different stages of maturity

| **Stage of maturity** | **I** | **II** | **III** | **IV** | **V** | **VI** | **VIIa** | **VIIb** |
|---|---|---|---|---|---|---|---|---|
| **Month** | **%** | **%** | **%** | **%** | **%** | **%** | **%** | **%** |
| January | 0 | 23.68 | 10.53 | 15.79 | 7.89 | 5.26 | 0 | 36.84 |
| February | 5.77 | 23.08 | 7.69 | 13.46 | 13.46 | 7.69 | 0 | 28.85 |
| March | 1.20 | 24.10 | 26.51 | 16.87 | 18.07 | 3.61 | 1.20 | 8.43 |
| April | 3.45 | 36.78 | 13.79 | 8.05 | 11.49 | 10.34 | 6.90 | 9.20 |
| May | 0 | 8.11 | 27.03 | 16.22 | 40.54 | 8.11 | 0 | 0 |
| August | 0 | 0 | 0 | 29.27 | 53.66 | 15.85 | 0 | 1.22 |
| September | 0 | 58.70 | 13.04 | 4.35 | 2.17 | 4.35 | 0 | 17.39 |
| October | 0 | 28.95 | 36.84 | 7.89 | 21.05 | 5.26 | 0 | 0 |
| November | 0 | 17.39 | 15.22 | 13.04 | 28.26 | 13.04 | 0 | 13.04 |
| December | 0 | 5.00 | 37.50 | 30.00 | 17.50 | 7.50 | 0 | 2.50 |

**Table 8.2** Monthly occurrence (%) of *D. garmani* in different stages of maturity

| **Stage of maturity** | **I** | **II** | **III** | **IV** | **V** | **VI** | **VIIa** | **VIIb** |
|---|---|---|---|---|---|---|---|---|
| **Month** | **%** | **%** | **%** | **%** | **%** | **%** | **%** | **%** |
| January | 6.45 | 35.48 | 3.23 | 12.90 | 35.48 | 0 | 0 | 6.45 |
| February | 6.00 | 14.00 | 32.00 | 18.00 | 10.00 | 4.00 | 4.00 | 12.00 |
| March | 0 | 20.00 | 26.67 | 13.33 | 13.33 | 26.67 | 0 | 0 |
| April | 0 | 13.51 | 24.32 | 21.62 | 29.73 | 10.81 | 0 | 0 |
| May | 0 | 10.26 | 30.77 | 12.82 | 33.33 | 10.26 | 2.56 | 0 |
| August | 0 | 7.14 | 16.67 | 21.43 | 33.33 | 16.67 | 0 | 4.76 |
| September | 0 | 4.35 | 17.39 | 23.91 | 34.78 | 19.57 | 0 | 0 |
| October | 0 | 3.23 | 16.13 | 12.90 | 32.26 | 32.26 | 3.23 | 0 |
| November | 0 | 5.56 | 5.56 | 11.11 | 33.33 | 44.44 | 0 | 0 |
| December | 0 | 13.33 | 26.67 | 23.33 | 6.67 | 30.00 | 0 | 0 |

**Table 8.3.** Monthly distribution of sex ratio in *D. watasei* and *D. garmani* during 2009-11

| **Month** | ***D. watasei*** | ***D. garmani*** |
|---|---|---|
| | **M:F** | **M:F** |
| January | 1 : 1.9 | 1 : 1.3 |
| February | 1 : 1.5 | 1 : 2.7 |
| March | 1 : 1.7 | 1 : 1.1 |
| April | 1 : 1.9 | 1 : 0.8 |
| May | 1 : 2.2 | 1 : 1.4 |
| August | 1 : 1.4 | 1 : 1.1 |
| September | 1 : 1.8 | 1 : 0.9 |
| October | 1 : 0.9 | 1 : 1.3 |
| November | 1 : 1.7 | 1 : 3.8 |
| December | 1 : 0.8 | 1 : 0.8 |
| Total | 1 : 1.5 | 1 : 1.3 |

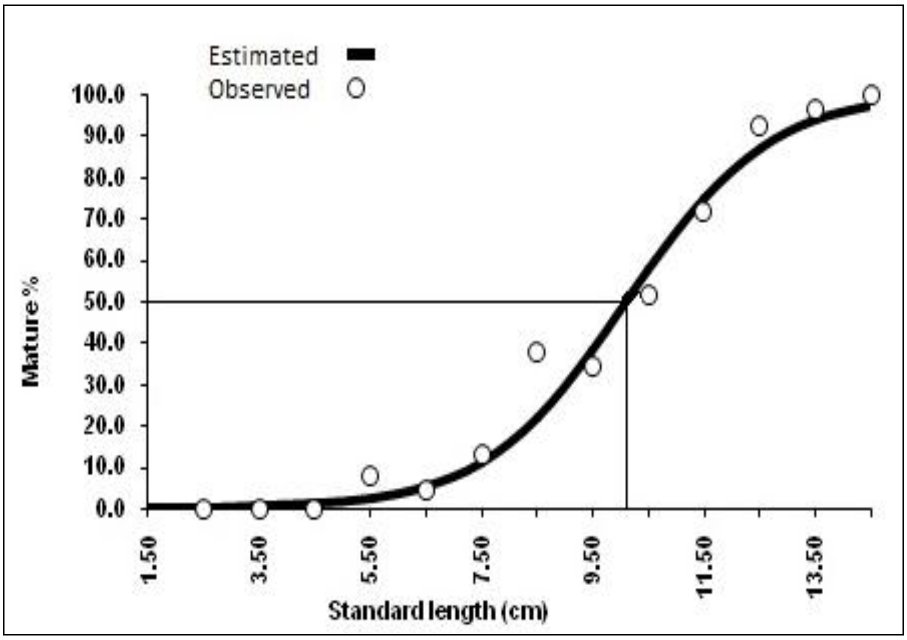



**Fig. 8.1.** Logistic curve showing size at first maturity of *D. watasei*

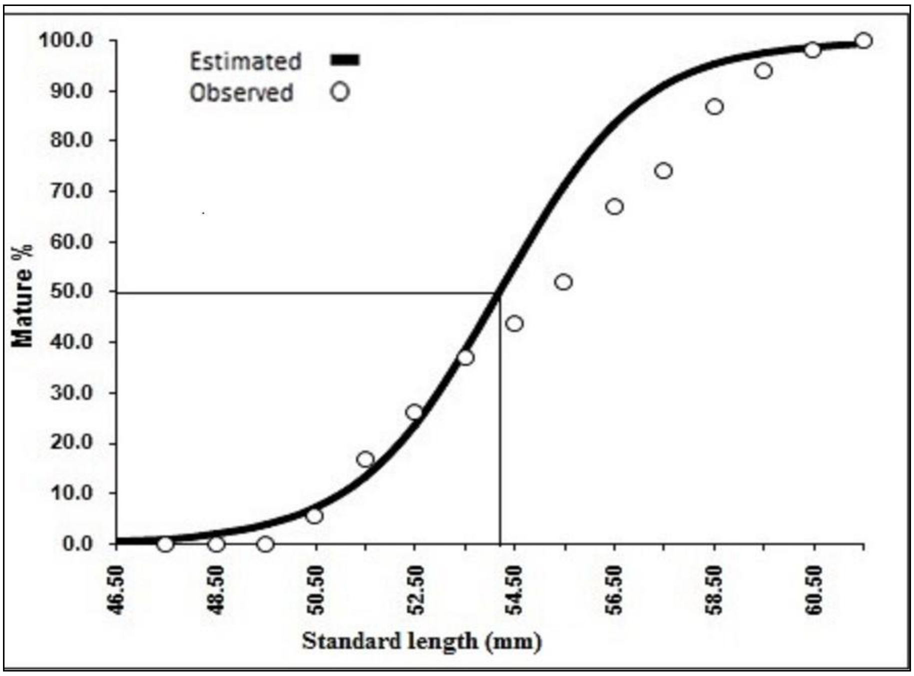



**Fig. 8.2.** Logistic curve showing size at first maturity of *D. garmani*

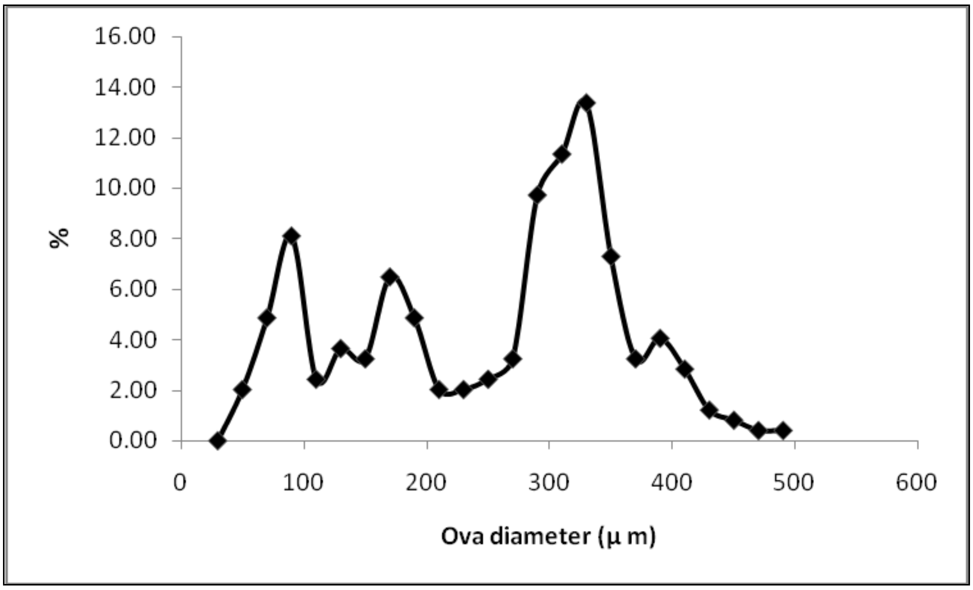



**Fig. 8.3.** Ova diameter frequency of *D. watasei* showing different batch of eggs

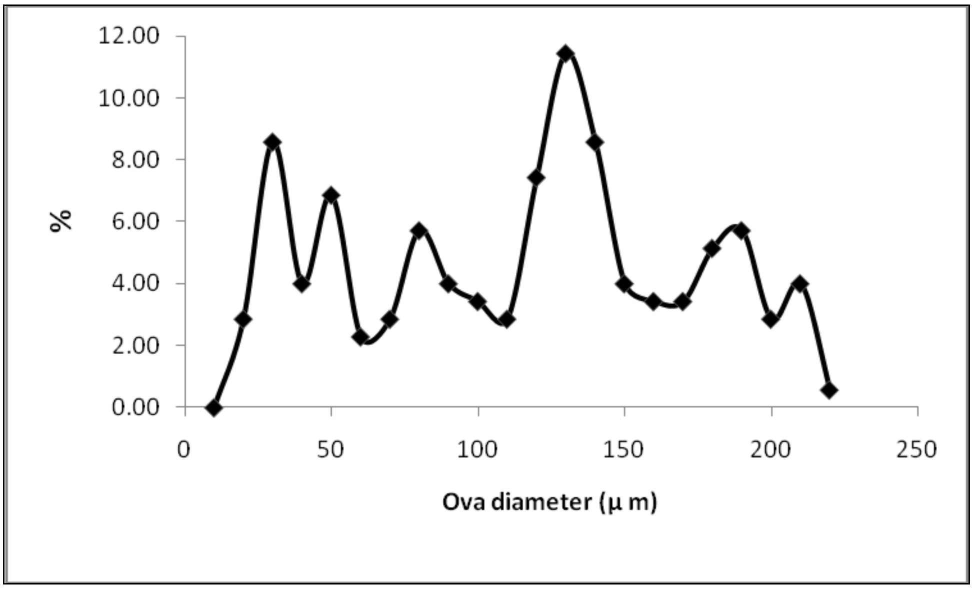



**Fig. 8.4.** Ova diameter frequency of *D. garmani* showing different batch of eggs

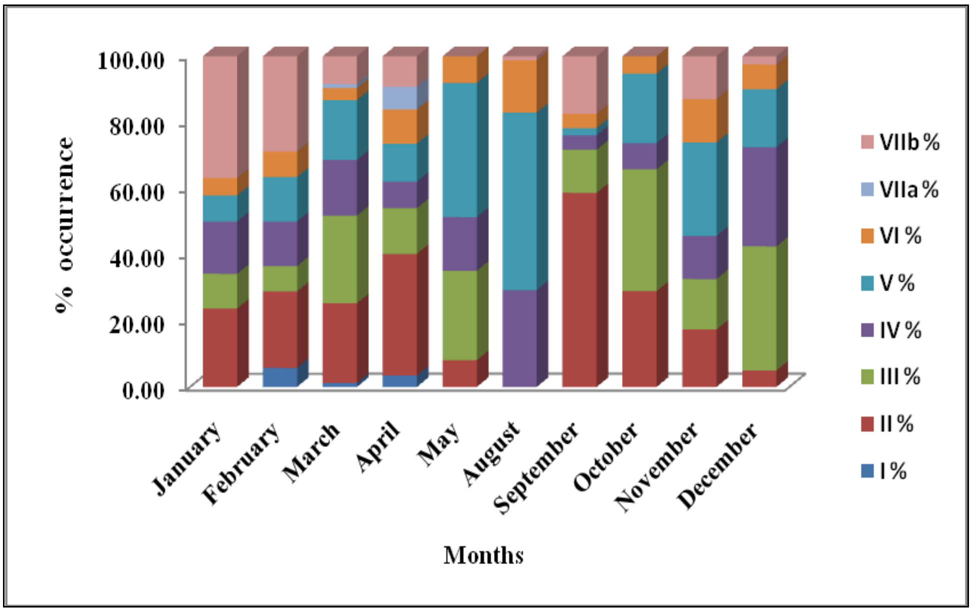



**Fig. 8.5.** Monthly percentage occurrence of maturity stages of *D. watasei*

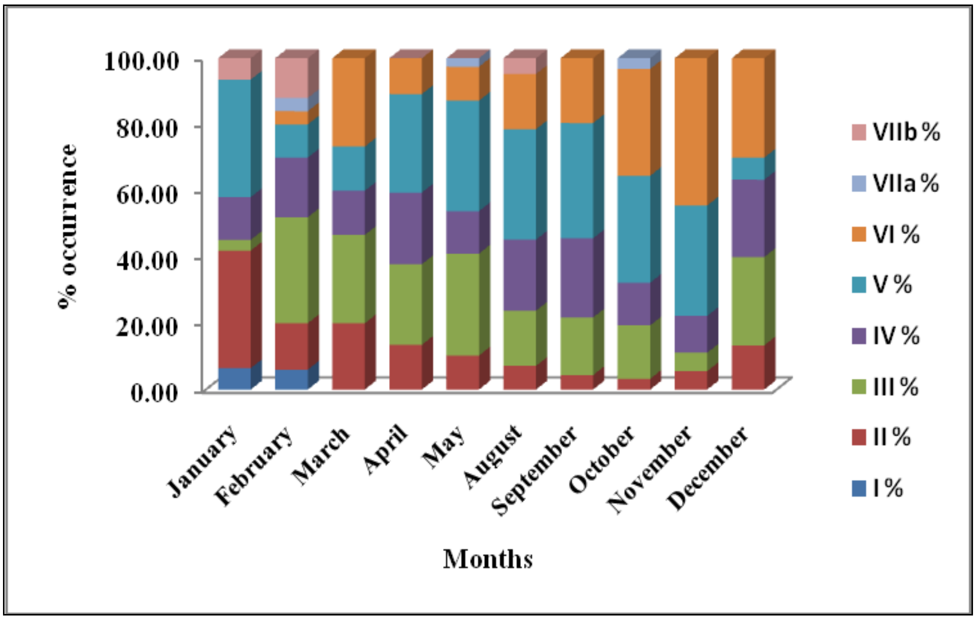



**Fig. 8.6.** Monthly percentage occurrence of maturity stages of *D. garmani*

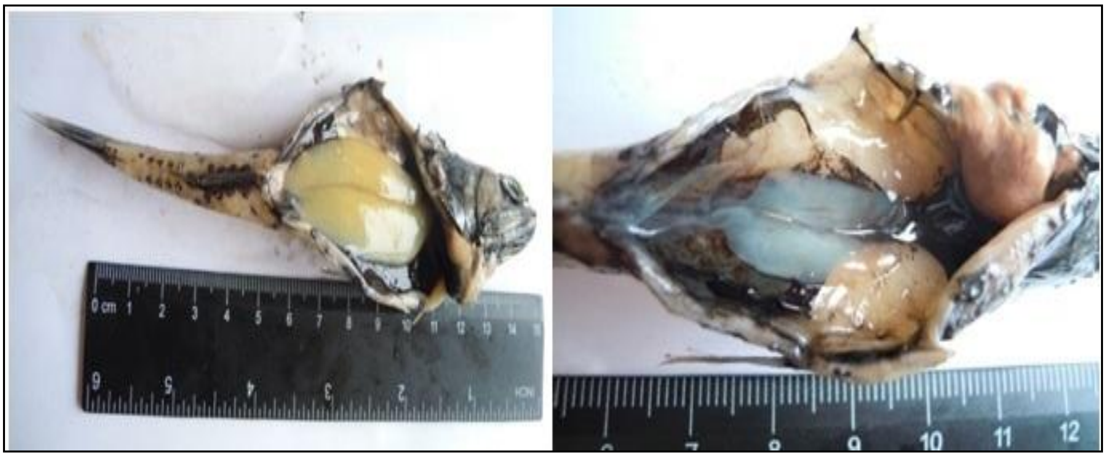


**Plate 8.1.** Gravid ovary and testis of *D. watasei*

**Plate 8.2.** Gravid ovary and testis of *D. garmani*

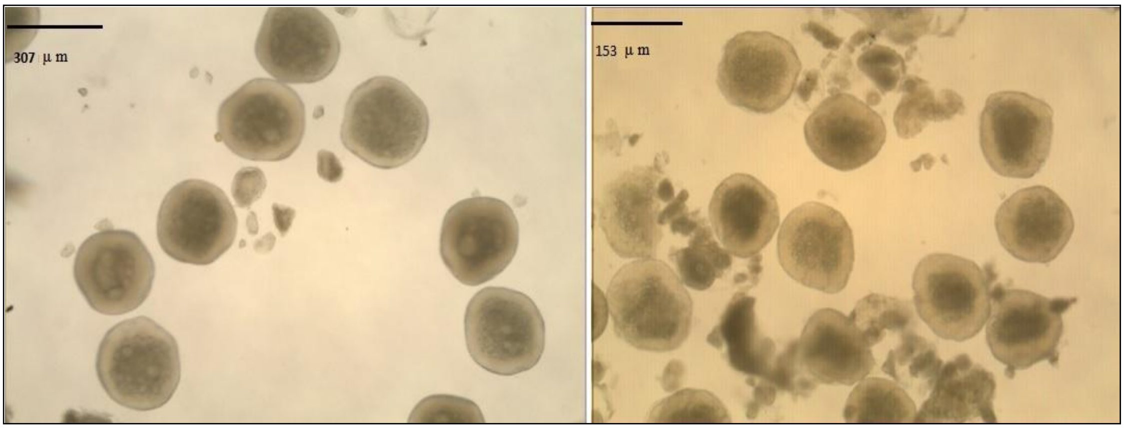



**Plate 8.3.** Maturing eggs of *D. watasei* and *D. garmani*

# CHAPTER 9

# BIOCHEMICAL COMPOSITION

# CHAPTER 9

# BIOCHEMICAL COMPOSITION

## 9.1. INTRODUCTION AND REVIEW OF LITERATURE

As the demand for alternate conventional fishery resource has been increasing, several mesopelagic fishes can be considered as an alternative resource. Polyunasaturated fatty acids (PUFAs) are important structural components of cell membranes, and are useful in growth and development of human beings (Chakraborty *et al*., 2010). PUFAs, especially of longer chain length, *viz.*, EPA and DHA were reported to be found in abundance in marine fish, and have beneficial properties for the prevention of atherosclerosis and other diseases. Therefore newer species of marine fishes need to be explored as potential healthy food items for better nutrition and health.

Mesopelagic fishes constitute a major portion of the deep-sea shrimp trawl by catch, which, demands only very low price and are often discarded in the sea at the time of sorting; these by-catches, when landed are mostly used for fishmeal or manure production. Several attempts were made in India to utilize fish from the shrimp trawler bycatch, effectively by formulating various products acceptable to consumers (Gopakumar *et al*., 1976). According to Gopakumar *et al*. (1983) myctophids resemble most marine fish with regard to its biochemical constituents and can be used for formulation of various food products for both man and animals. Various studies by Nair *et al*. (1983), Lekshmy *et al*. (1983), Noguchi (2004), Olsen *et al*. (2010), Manju *et al*. (2011) and Rajamoorthy *et al*. (2013) shows that myctophids can be utilized for the production of commercial fishery products like fish meal, fish oil, fish silage, surimi, seasoning products, feed for cultured fish, nutrient resource in the formulation of poultry feed as well as crop fertilizers and products like lubricating oil, cosmetics and wax. Rajamoorthy *et al*. (2013) reported the proximate composition of *Diaphus watasei* and point out the nutritional potential of this species for human consumption. Fernandez *et* *al*. (2014) compared proximate composition of myctophids with edible marine fishes, which shown that myctophids have comparable quantity of protein and fat with food fishes and that in *Diaphus effulgens*, the protein content was higher than in *Sardinella longiceps*.

Studies are limited on the nutritional profile of myctophids from Arabian Sea and their nutritional value and use as healthy food items. An understanding of the proximate composition, fatty acids and amino acids of the component species is important, particularly during processing and product development. Most of the species have limited commercial exploitation, but potentially important for production of fish oil and fish meal. The study presents the proximate composition and fatty acid profile of *D. watasei* and *D. garmani*, collected from Kerala coast.

## 9.2. MATERIAL AND METHODS

Samples of *D. watasei* and *D. garmani* were collected and transported to laboratory in refrigerated containers and maintained at -22º C. The samples were cleaned in water and scales and skin were removed before analysis. Skeletal muscles from dorsal fin to caudal fin of the body were collected and minced well in a mixer to get a homogenous sample.

***Proximate composition analysis*:** Moisture content of the flesh samples was analysed by drying the samples of known weight at $60^0$C in hot air oven overnight until a constant weight, followed by drying for 2 h in hot air oven at $100^0$C (AOAC, 2006). Total nitrogen content (crude protein) was determined by micro Kjeldhal method and the result was multiplied by 6.25 to arrive the crude protein percentage. Ether (petroleum ether, 60-$80^0$C boiling point) extracts the oil content of sample using a Soxhlet apparatus and the difference in weight due to crude fat accumulation in the round bottom flask was recorded. Crude fiber were determined following the fraction remaining after refluxing with standard solution of $H_2SO_4$ (1.25% w/v) and NaOH (1.25% w/v) for 30 min, under controlled condition. Crude ash was obtained by igniting the charred sample at about

$600^0$ C in muffle furnace. Acid insoluble ash was estimated by mixing the charred material with 36% HCl and nitrogen free extract (soluble carbohydrate) was determined with methods described by AOAC (2006).

***Fatty acid analysis*: **The fatty acid composition of the flesh sample was determined based on standard procedure described by Bligh and Dyer (1959) with suitable modification (Chakraborty *et al*., 2007). Triglycerides were extracted using $CHCl_3$/MeOH (2:1, v/v), and the lipids thus obtained were saponified with petroleum etherdiethyl ether (1:1 v/v) and trans-esterified yielding fatty acid methyl esters (FAME) by reaction with a methylating mixture ($BF_3/CH_3OH$) under an inert atmosphere of $N_2$ that was later extracted with n-hexane/$H_2O$ (1:2, v/v). After removal of the aqueous layer, the n-hexane layer was passed through $Na_2SO_4$, concentrated *in vacuo*, reconstituted in petroleum ether, and stored at -20°C until required for analyses. A Perkin Elmer Auto System XL, Gas chromatograph (Perkin Elmer, USA) equipped with a flame ionization detector (FID) analyzed the composition of the fatty acids. The esterified fatty acid content was analyzed by gas liquid chromatography with FID detector with comparison to fatty acid methyl ester standard (Supelco FAME 37 standard).

## 9.3. RESULTS

### 9.3.1. Proximate composition

The average meat yield of *Diaphus* species were given in Fig. 9.1. and proximate compositions in Table 9.1. *D. watasei* is having high meat yield (47.25% wet weight) compared to *D. garmani* (44.48% ww). The proximate composition of *D. watasei*, *viz*., moisture, fat, protein and ash content are 72%, 12%, 16% and 0.47% ww and for *D. garmani* are 81, 4, 14 and 0.38% ww respectively. Both the species have a normal range of proximate compsition compared to common edible marine species.

### 9.3.2. Fatty acid composition

The fatty acid profile shows that the flesh contain more unsaturated fatty acids than saturated fatty acids (Fig. 9.2). Fatty acids present in the fish muscle are given in Table 9.3. In *D. watasei* monounsaturated fatty acids (MUFA) form the major fatty acids followed by saturated fatty acid (SFA) and polyunsaturated fatty acid (PUFA) *viz*., 37%, 33% and 26% respectively, whereas in *D. garmani*, SFA form the major fatty acid followed by MUFA and PUFA *viz*., 39%, 29%, 24% respectively (Fig. 9.3). In *D. garmani* the weight percentage of monoenes was much high followed by hexaenes and pentaenes of total fatty acids whereas in *D. watasei* monoenes followed by hexaenes and trienes were more abundant (Table 9.2). The most abundant fatty acids were oleic acid, palmitic acid, docosahexaenoic acid, eicosapentaenoic acid, stearic acid, palmitoleic acid; of the total fatty acids. Palmitic acid (C16:0) was found to be the most prominent in *D. garmani*. SFA has the principal component as palmitic acid. Oleic acid (C18: 1n9) is the major component of MUFA. Docosahexaenoic acid (DHA) (C22:6n3), eicosapentaenoic acid (EPA) (C20:5n3) and $\gamma$ linolenic acid (GLA) (C18:3n6) constitute the principal components of PUFA (Fig. 9.4). *Diaphus* sp. contain a range of 18.9 – 19.5% of $\omega$-3 fatty acids and 4.96 – 7.45% of $\omega$-6 fatty acids. $\omega$-3 PUFA contributed nearly 70.83 – 79.34 % of the total PUFAs and 18.94 – 20.67 % of total fatty acids. The most important $\omega$-3 PUFAs, namely EPA and DHA contributed to 72.74 – 93.07 % of the total $\omega$-3 poly unsaturated fatty acids. Fishes had a higher $\omega$-3/$\omega$-6 ratio ranged from 2.42 to 3.84.

## 9.4. DISCUSSION

Proximate components of the two myctophids studied were within the normal range as of other edible marine species. Myctophids are essentially a crustacean zooplankton feeder (Pakhomov *et al*., 1996), and the environmental conditions *viz*., temperature, salinity, availability of food in different seasons etc. have significant influence on the proximate composition of fish. High moisture content was recorded in

*D. garmani* (81.26 % ww). Fat content was comparatively high in *D. watasei* (11.71 % ww). Protein content and mineral content was more in *D. watasei* (15.62 % ww and 0.47 % ww respectively). When comparing two species *D. watasei* showed a high quantity of fat, protein and minerals. Comparing the two species, *D. garmani* had lesser amount of fat. When comparing the present study with the study of Fernandez *et al*. (2014), protein content of *D. watasei* (16% ww) and *S. longiceps* (16% ww) are almost similar, but *D. watasei* has more fat content (12% ww) than *S. longiceps* (7.93% ww). Rajamoorthy *et al*. (2013) reported the proximate composition of *Diaphus watasei*, *viz*., moisture, fat, protein and ash content as 63.19, 15.13, 21.40 and 1.33% ww respectively which clearly indicate the nutritional potential of this species for human consumption and formulation of novel foods. *Diaphus theta* was reported to have lipid contents of over 10% of their body weight, which is predominated by triglycerides (Neighbors and Nafpaktitis, 1982). Though myctophids are included under trash fish, they are rich in protein and other minerals. Since they being an important component of mesopelagic and benthopelagic resources, they can be utilized as an important protein source.

Nicholas *et al*., (1994) mentioned that the oils derived from Southern Ocean myctophids might have some industrial uses and have potential similar to jojoba oil, which has been used as a replacement for sperm whale oil. Noguchi (2004) evaluated the refined fractions of myctophids wax as equal in quality to commercial purified wax of orange roughy. Chemical composition of myctophids and other mesopelagic fishes were assayed by several workers (Ayyappan *et al*., 1976; Menon, 1976; Neighbors and Nafpaktitis, 1982; Gopakumar *et al*., 1983; Ackman, 1990; Suriah *et al*., 1995; Seo *et al*., 1996, 2001 and Phleger *et al*., 1999) indicates that from nutritional point of view, myctophids are high in proteins, variable in lipids and uniformly low in carbohydrates. Studies shows that lipid content of vertically migrating myctophids include both triglycerides, serve primarily as an energy store, and wax esters, used for buoyancy (FAO, 1997). Lekshmy *et al.* (1983) reported that most of the mesopelagic fishes contain high amount of wax which when consumed in large quantities can cause diarrhea and seborrhea in animals. Gopakumar *et al*. (1983) attempted the prime work from the Arabian Sea and estimated biochemical composition of, *B. pterotum* from the Gulf of

Oman and Aden and reported 16.1 g/100g wet weight of protein and 3.4 g/100g wet weight of fat and commented that lantern fish resembles most marine fish with regard to its biochemical composition and can be used as food for both human and animals after proper processing. Haque *et al*. (1981) made a comparative study of growth rate and feed consumption in chicks with myctophid meal and found out a significant improvement in feed utilization indicated that myctophid can be utilized for fishmeal production. Seo *et al*. (1996) analysed lipids level as 0.5 - 21.7% of total weight. Whereas in the present study lipids level ranged from 3.73 – 11.71 % of wet body weight. Suda (1973) reported myctophids had an oil extraction efficiency of 110 liters/ton. Ayyappan *et al*. (1976) estimated protein, lipid and ash content of miscellaneous edible fish from shrimp trawlers and recorded protein levels as 16.02 - 20.77%, lipid 0.3 - 5.31% and ash 3.2 - 5.6% and most of the species recorded high lipid content and low moisture content. In the present study the protein composition comes within the range of edible fish (13.71 – 15.62 % ww), and mineral content was meager (0.38 – 0.47 % ww).

On the basis of fat content fishes are often classified into lean (fat content below 5%), medium fat (5 -10%) and fatty fish (>10%) (Suriah *et al*., 1995). According to Ackman (1990) fishes can be classified as high fat fish where average fat content is more than 8%. Based on these study, *D. watasei* can be grouped under fat fish whereas in *D. garmani* fat contents set in the range of other marine edible fishes. There may be slight difference in the lipid levels and fatty acid content in the same species depending on the sex, age, size, maturity, season, food availability, geographical variation, salinity and water temperature (Stansby, 1981; Piggott and Tucker, 1990). Phleger *et al*. (1999) stated that most of the body lipids were stored in the flesh of the fish (68 – 92%). Earlier works (Seo *et al*., 1996; Saito and Murata, 1996; Phleger *et al*., 1999) revealed that have high content of monoene fatty acids in the lipids and the present study also supports this.

In the present study, palmitic acid is the major fatty acid in *D. garmani* followed by oleic acid which is similar with the study by Gopakumar *et al*. (1983) and Seo *et al*. (1996). Whereas in *D. watasei* oleic acid is the major one followed by palmitic acid. Saito and Murata (1996) also stated the dominance of oleic acid in *D. watasei*. Study by

Seo *et al*. (1996) proved that palmitic acid and DHA were the major fatty acids in tropical water where as oleic acid and palmitic acid were predominant in the temperate water species, though oleic acid was the major fatty acid of total lipids. Fatty acid profile of *D. theta* and *D. gigas* (Saito and Murata, 1996) from the northern Pacific Ocean, showed high levels of MUFA followed by SFA and PUFA but both of the species showed comparatively low level of PUFA (*D. theta*, 20.7% and *D. gigas*, 9.6% of total fatty acids) as compared with that of the present study with an average PUFA of 24.77%. This is disparate with the report by Ackman (1989) that the tropical and sub-tropical species are reported to contain lower levels of PUFA than temperate species.

In the present study *D. watasei* was predominated with 36.66% MUFA followed by 33.28% SFA and 25.54% PUFA where as *D. garmani* predominated with 39.2% SFA followed by 28.9% MUFA and 24.0% PUFA. These differences can be due to the difference in the feeding pattern in accordance with the species and depth. The total ω-3 fatty acids were found to be higher than the ω-6 where, this is factual in most of the marine fishes especially DHA and EPA (Wang *et al.,* 1990). As usual in case of marine fishes these species are also rich in DHA, EPA and ALA, which are the major components of omega 3 fatty acid which is the one essential nutrient mainly missing in our modern diet.

Myctophid is a good source of protein and fat, hence it could well be a potential source of alternative protein and fat. At present myctophid is not commercially exploiting in India, although it is used when landed along with other fresh fishes for preparing fish meal by some local populations. In view of the nutritive value, myctophid is suitable for value added products, if the wax esters are removed through processing. Myctophids are one of the most promising groups available in the Arabian Sea. Since most myctophids goes to non-predatory mortality, with the biomass ending up with decomposition (Catul *et al*., 2011), attempts can be made to encourage targeted exploitation of these valuable resources, which can be utilized as a source of cheap animal protein. Also oil derivatives of myctophids can be used for industrial purposes.

**Table 9.1.** Proximate composition of meat from *D. watasei* and *D. garmani*

| **Parameters *(% wet tissue weight)** | ***Diaphus watasei*** | ***Diaphus garmani*** |
|---|---|---|
| Moisture | 72 | 81.26 |
| Crude protein | 15.62 | 13.71 |
| Crude fat | 11.71 | 3.73 |
| Crude ash | 0.47 | 0.38 |
| Crude fibre | 0.01 | 0.1 |
| Acid insoluble ash | ND | 0.02 |
| Soluble carbohydrate | 0.28 | 0.82 |

*AOAC (2006)

ND: Not detectable

**Table 9.2.** Composition of saturated fatty acids of *D. watasie* and *D. garmani* from Kerala coast

| **Myctophids** | **Monoenes** | **Dienes** | **Trienes** | **Tetraenes** | **Pentaenes** | **Hexaenes** |
|---|---|---|---|---|---|---|
| *D. watasei* | 36.66 | 1.49 | 7.77 | 1.66 | 5.29 | 9.33 |
| *D. garmani* | 28.92 | 2.12 | 2.52 | 0.63 | 6.76 | 11.98 |

**Table 9.3.** Fatty acid composition of *D. watasie* and *D. garmani*

| **Fatty Acids (%)** | ***D. watasei*** | ***D. garmani*** |
|---|---|---|
| **Saturated fatty acids (SFA)** | | |
| C14:0 Myristic acid | 4.42 | 4.62 |
| C15:0 Pentadecyclic acid | 0.47 | 0.81 |
| C16:0 Palmitic acid | 18.3 | 26.93 |
| C17:0 Margaric acid | 0.77 | 0.69 |
| C18:0 Stearic acid | 9.22 | 5.71 |
| C20:0 Arachidic acid | ND | 0.24 |
| C22:0 Behenic acid | 0.05 | 0.13 |
| C24:0 Lignoceric acid | ND | 0.08 |
| Total SFA | 33.23 | 39.21 |
| **Monounsaturated fatty acids (MUFA)** | | |
| C14:1 Myristoleic acid | 0.1 | 0.06 |
| C15:1 Pentadecanoic acid | ND | 0.01 |
| C16:1n7 Palmitoliec acid | 3.68 | 5.16 |
| C17:1 Heptadecanoic acid | ND | 0.24 |
| C18:1n7 Vaccenic acid | ND | 0.18 |
| C18:1n9 Oleic acid | 32.03 | 22.34 |
| C20:1n11 cis-11- Eicosenoic acid | ND | 0.65 |
| C24:1 Nervonic acid | 0.85 | 0.28 |
| Total MUFA | 36.66 | 28.92 |
| **Polyunsaturated fatty acids (PUFA)** | | |
| C18:2n6 Linoleic acid | 1.05 | 1.36 |
| C18:3n6 γ Linolenic acid | 3.97 | 2 |
| C18:3n3 α Linolenic acid | 3.47 | 0.13 |
| C20:2n6 Eicosadienoic acid | 0.44 | 0.76 |
| C20:3n6 Methyl eta | 0.33 | 0.21 |
| C20:4n6 Arachidonic acid | 1.66 | 0.63 |
| C20:3n3 Homo-γ-linolenic acid | ND | 0.18 |
| C20:5n3 Eicosapentaenoic (EPA) acid | 3.83 | 5.75 |
| C22:5n3 Docosapentaenoic (DPA) acid | 1.46 | 1.01 |
| C22:6n3 Docosahexaenoic (DHA) acid | 9.33 | 11.98 |
| **Total PUFA** | 25.54 | 24.01 |
| Others | 4.57 | 7.86 |

*ND – Not Done

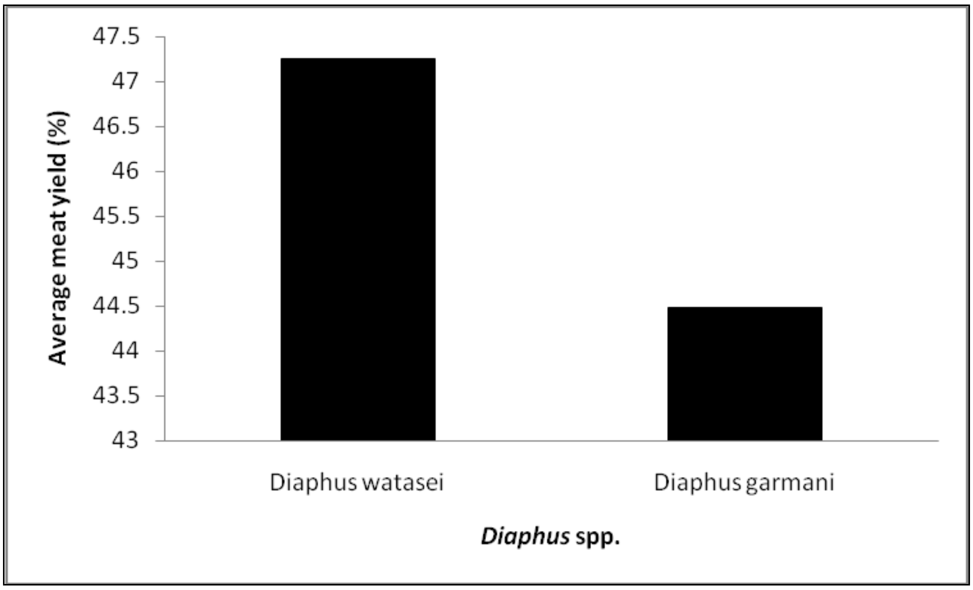



**Fig. 9.1.** Average meat yield from *D. watasie* and *D. garmani*

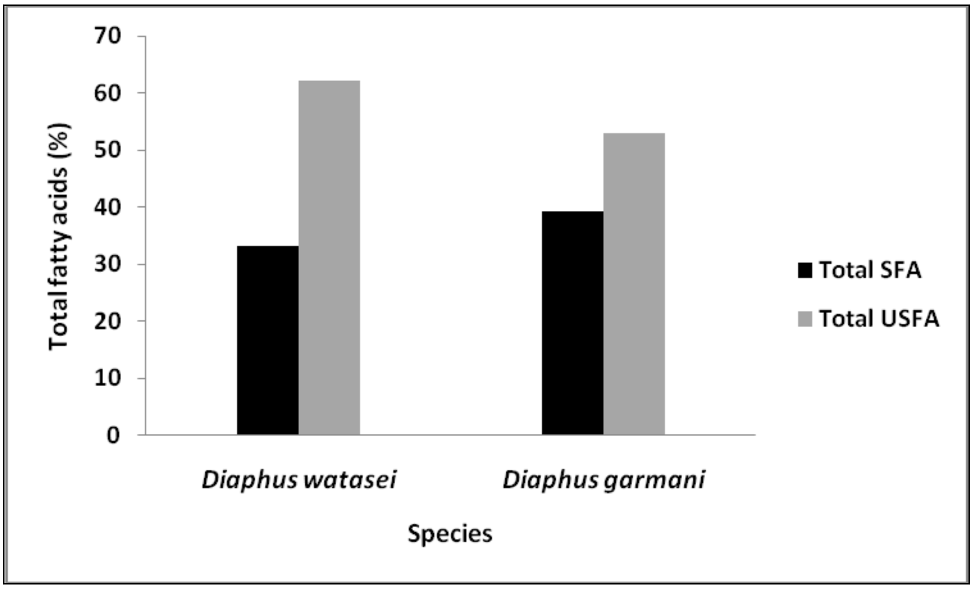



**Fig. 9.2.** Percentage variation of saturated and unsaturated fattyacids in *D. watasei* and *D. garmani*

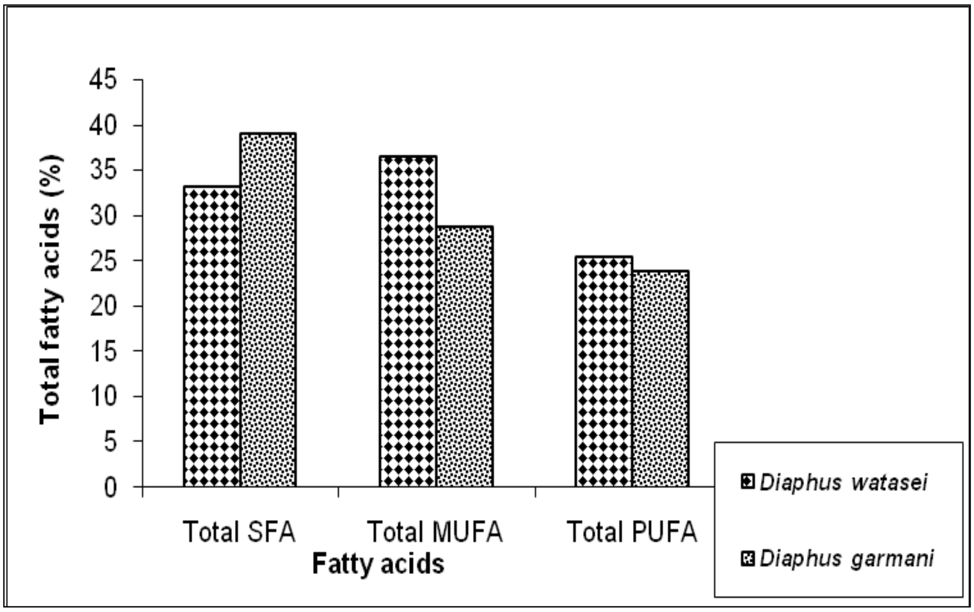



**Fig. 9.3.** Percentage variation of fatty acids of *D. watasie* and *D. garmani*

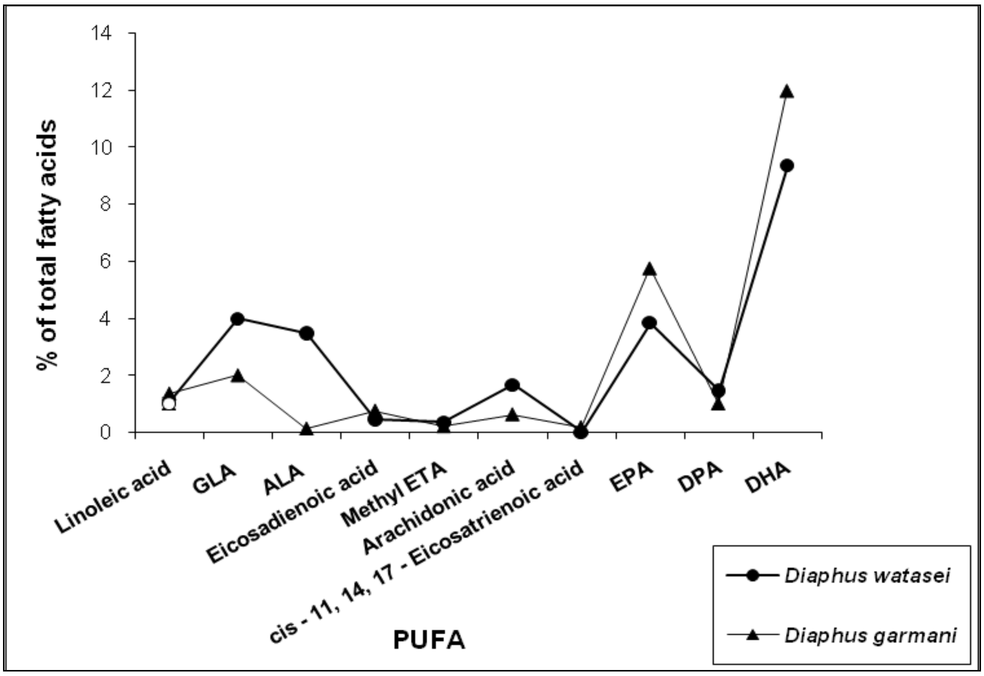



**Fig. 9.4.** Percentage of PUFA with respect to total fatty acids of *D. watasei* and *D. garmani*

# CHAPTER 10

# SUMMARY AND CONCLUSION

# CHAPTER 10

# SUMMARY AND CONCLUSION

## SUMMARY

*Diaphus* species belonging to the family Myctophidae commonly called myctophids/lantern fishes/headlightfishes are widely distributed in Indian waters. They constituted as by-catch in deep sea shrimp fishery and have no demand for consumption in Kerala. They are mainly discarded into the sea at the time of harvest itself. There was no concentrated effort to study the stocks and population characteristics of myctophids from the Indian waters. The present investigation was undertaken mainly on taxonomy, fishery biology, stock and population characteristics of *D. watasei* and *D. garmani*. The findings would help in the proper understanding of the ecological importance of these resources in the oceanic habitat and may help in future planning.

Database for the present study were collected from two major fish landing centres of Kerala *viz.*, Cochin and Kollam during 2009 – 2011. Besides reviewing the key morphometric characters of the family myctophidae and the genus *Diaphus,* the species has been described in detail for easy identification.

Fishing operation by multi-day trawlers of Kerala spread widely between off Kollam in Kerala in the south to off Ezhimala in the north ($8^0$ 81' – $12^0$ 79' N; $75^0$ 58' – $74^0$ 11' E). Generally deep-sea shrimp trawlers commence operation soon after the monsoon (August) and peak activities are observed during November – February. Fishing continued till the end of May. Fishing was carried out during day time at depths of 250-500 m. The trawlers specifically targeted for deep sea shrimps like *Aristeus alcocki, Heterocarpus gibbosus, Heterocarpus woodmasoni, Metapenaeopsis andamanensis, Plesionika quasigrandis, Plesionika martia* and *Solenocera hextii*. Usually in each operation, by-catch contributes about 20 to 40% along with targeted species. Sometimes the by-catch exceeded more than 80% and was discarded without being taken onboard vessel.

The average annual catch of myctophids during 2009-11 was 2587 t/yr. The year wise catch of myctophids during 2009, 2010 and 2011 were 2421 t, 2610 t and 2729 t respectively with an increasing trend in the catch. Catch per Hour (CPH) ranged from 6.3 to 9.5 kg with an average of 7.9 kg. Myctophids formed 10 – 20% of the total catch. During 2009, myctophids formed 15% of the total deep-sea trawl catch, it was 18% in 2010 and 20% in 2011. The month-wise catch indicates that myctophids are more abundant in the trawling grounds during November – February. Accordingly peak catch was in February and minimum in August.

Myctophid catch in deep-sea shrimp trawl was supported by five species *viz*., *Diaphus watasei* (74.23%), *Neoscopilus microchir* (20.56%), *Benthosema fibulatum* (1.94%), *Diaphus garmani* (1.69%) and *Myctophum obtusirostre* (1.58%). In all three years, *Diaphus watasei* was dominant in the fishery and contributed by 1767 t, 1949 t and 2048 t in the years 2009, 2010 and 2011 respectively.

Estimates of growth parameters, $L_\infty$, and K by FiSAT was 15.06 cm SL and 0.80/year respectively and for *D. garmani*, $L_\infty$ = 7.61 cm SL and K = 1.3/year. For *D. watasei*, age of the species at zero length ($t_o$) was estimated as -0.0284 years. They are estimated to attain 8.1, 12, 13.7 and 14.4 cm SL respectively by the end of 1$^{st}$, 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ years. It will take more than 4 years to reach the $L_{max}$ (14.5 cm SL). In *D. garmani*, age of the species at zero length ($t_o$) was estimated as -0.0104 years. They are estimated to attain 5.4 and 7 cm SL respectively by the end of 1$^{st}$ and 2$^{nd}$ years. It will take more than 2 years to reach the $L_{max}$ (7.14 cm SL).

The length-weight relationship in the males and females of *D. watasei* and *D. garmani* were estimated. Both sexes of *D. garmani* and males of *D. watasei* showed a slight negative allometric growth whereas females of *D. watasei* showed isometric growth with an ideal value of 3.

Size at first capture ($L_c$) of *D. watasei* in trawl was 11 cm SL. Age corresponding to size at first capture was sixteen months. $L_c$ during 2009, 2010 and 2011 was 8.5 cm SL, 10.9 cm SL and 10.5 cm SL and their corresponding age was 1, 1.6 and 1.5 years. Optimum size of exploitation ($L_{opt}$) was 8.4 cm SL at one year. Length at maturity ($L_m$) was estimated at 9.8 cm SL and their age ($t_m$) was 1.3 years. The values of length estimated by the probability of capture were $L_{25}$ = 10 cm, $L_{50}$ = 11 cm and $L_{75}$ = 12 cm of SL for the period.

Average size at first capture ($L_c$) of *D. garmani* in trawl was 5.2 cm SL and their corresponding age was nine months. $L_c$ during 2009 and 2010 was 5.2 cm SL and age was nine months, $L_c$ in 2011 was 5.5 cm SL, at an age of 1 year. Optimum size of exploitation ($L_{opt}$) as 5.4 cm SL at an age of one year. Length at maturity ($L_m$) was 5.3 cm SL at an age ($t_m$) of 9 months. The values of length estimated by the probability of capture were $L_{25}$ = 5.1 cm, $L_{50}$ = 5.2 cm and $L_{75}$= 5.3 cm of SL for the period.

Total mortality (Z) of *D. watasei* population during 2009 - 2011 was 2.53, natural mortality (M) 1.89 and fishing mortality (F) 0.64. Total mortality rates for the years 2009, 2010 and 2011 were 2.7, 2.1 and 2.2 respectively. Natural mortality was 1.9. Average exploitation rate for the period was 0.2. Exploitation ratio was very low being 0.3. Total loss from the population due to fishing is only 25% and that by natural causes is 75%. Total stock assessed for the period was estimated as 8348 t.

In *D. garmani* the average total mortality (Z) during the period 2009 - 2011 was 2.85, natural mortality (M) being 1.65 and fishing mortality (F) 1.2. Total mortality rate estimates during the years 2009, 2010 and 2011 were 2.9, 2.8 and 2.5 respectively. Natural mortality was 1.7. Exploitation rate for the resource was 0.4. Exploitation ratio was very low being 0.4. Total loss from the population due to fishing is only 42% and that by natural causes is 58%. Total stock assessed for the period was estimated as 107 t.

The food and feeding habits of *Diaphus* spp. were studied following index of pre-ponderance. The diet of the fish in relation to months, was analysed. Annually the shrimps formed the major component in the food of *D. watasei* with the Index of

Preponderance (IP) being 49.07 followed by the digested matter (38.09), squids (6.99), euphausids (3.45), detritus (1.96), fishes (0.41), and crabs (0.03). In the stomachs of *D. watasei*, crustaceans were most dominant round the year. Among the crustaceans, shrimps were the major group. Other crustaceans mainly comprised of euphausids, small crabs and negligible amount of zoea. Squids represented the molluscs content in the stomach. Stomach with fully digested food matter was very common. Unidentified digested matters were also observed.

In *D. garmani* crustaceans followed by digested matter, molluscs, detritus and fishes were the dominant component in the food. The respective index being 85.61, 11.54, 2.37, 0.32 and 0.16. The crustaceans component in the stomach were represented by euphausids (67.32) and shrimp (18.29). Squids represented the molluscan food. Only traces of fish were observed in the diet.

In *D. watasei* the highest index of crustaceans was observed in January (83.86) and the least during March (78.59). The principle food item among the crustaceans was shrimps. During all months the index of shrimps was high. The index ranged between 78.09 in March and 83.13 in January. Digested matter was the second dominant item in the stomach contents, with an highest index (15.53) observed in August and the lowest (12.6) in February. Squid was the third important component which recorded the highest index of 4.55 in September and the lowest of 1.67 in November. Crabs and zoea were observed in the stomach occasionally in small quantities.

*Diaphus garmani*, also had a similar trend with the crustacean component forming the main diet during all the months. The highest index was observed in September (97.4) and the lowest in May (92.67). Among the crustaceans, euphausids formed the main diet during January, August, September, October, November and December; and shrimps formed the main diet during rest of the months. The index of euphausids ranged from 38.54 (May) to 72.73 (September) and that of shrimp from 24.46 (December) to 54.13 (May). Fish remains were observed in the stomach occasionally in small quantities.

In *D. watasei* the empty, poor, moderate and active feeding conditions comprised of 57 %, 19 %, 14 % and 10 % respectively. Active feeding condition was maximum during May (18%) and minimum during September (5.72%). Empty stomachs were minimum during May (50%) and maximum during October (71%).

In *D. garmani*, the empty, poor, moderate and active feeding conditions comprised 55 %, 20 %, 14 % and 11 % respectively. Active feeding was observed maximum in August and November (16 %) and minimum in January (6.46). Empty stomachs were minimum during May (46%) and maximum during November (63 %).

The description of gonads and maturity stages of *D. watasei* and *D. garmani* based on their morphometry and ova diameter studies has been provided. Seven stages of maturity were recognized in females and males. Size at first maturity, sex ratio, spawning season and fecundity also were studied in detail. In *D. watasei*, 50 % of fish attained maturity at 9.8 cm standard length when the fish is 1.3 years old. The size of first maturity of *D. garmani* was 5.3 cm SL at an age of 9 months. From the curves, it shows that *D. watasei* mature and spawns after one year old, whereas *D. garmani* mature and spawn much early before they reach one year old.

*Diaphus watasei* has a prolonged and almost continuous spawning season with all stages of maturity occurring round the year. Peak spawning was observed during May – August and November – December. Intermediate and immature fishes were abundant during September – October and February – April. It is observed that spawning commences early August and peaks during September.

The spawning season in *D. garmani* is also prolonged with active spawning during October – December. Though *D. garmani* were not available in the catch during monsoon months, the presence of young fishes during pre-monsoon months indicated that they also spawn during post-monsoon months.

In *D. watasei* the matured ova diameter ranged between 30 µm and 483 µm with peak around 330 µm. The ova diameter in *D. garmani* ranged between 13 µm and 212 µm with a peak around 130 µm. The ova were spherical, translucent with a prominent oil globule. There were different batches of eggs having different size present in each ovary indicating that they are batch spawners.

Sex ratio of *D. watasei* indicated the dominance of female with a sex ratio of 1 : 1.5 (male : female) where dominance of males were observed only in October and December. In *D. garmani* dominance of female was observed with a sex ratio of 1: 1.3 (male : female) where dominance of males were observed only in April, September and December.

Fecundity of *D. watasei* ranged from 9826 to 49659 no. in fishes of length range of 11.5 – 13.1 cm SL. Relative fecundity of *D. watasei* ranged from 434 no/gm body weight to 1443 no/gm body weight. The wet weight of the fish ranged from 18.8 g to 34.4 g and the gonad weight ranged between 0.66 g – 1.62 g. In case of *D. garmani* the fecundity ranged from 5864 to 9358 no. in fishes having a length range of 6.1 – 6.8 cm SL. Relative fecundity of *D. garmani* ranged from 1668 no/gm body weight to 2491 no/gm body weight. The wet weight of the fish ranged from 3.2 g to 4.2 g and the gonad weight ranged between 0.17 g – 0.33 g. The present study indicates that *D. watasei* has a wide range in fecundity where as *D. garmani* has a nominal range of fecundity, this may be due to the size difference between the species as *D. watasei* attain much larger size than *D. garmani*. The fecundity is directly proportional to the fish length, wet weight and gonad weight.

Studied the proximate composition and fatty acid profile of *D. watasei* and *D. garmani* following the established methods. *D. watasei* is having high meat yield (47.25% wet weight) compared to *D. garmani* (44.48% ww). The proximate composition of the flesh of *D. watasei*, *viz.*, moisture, fat, protein and ash content are 72%, 12%, 16% and 0.47% ww and for *D. garmani* are 81, 4, 14 and 0.38% ww respectively. When comparing two species *D. watasei* showed a high quantity of fat, protein and minerals.

The fatty acid profile shows that the flesh of *Diaphus* spp. contain more unsaturated fatty acids than saturated fatty acids In *D. watasei* monounsaturated fatty acids (MUFA) form the major fatty acids followed by saturated fatty acid (SFA) and polyunsaturated fatty acid (PUFA) *viz*., 37%, 33% and 26% respectively, whereas in *D. garmani*, SFA form the major fatty acid followed by MUFA and PUFA *viz*., 39%, 29%, 24% respectively. In *D. garmani* the weight percentage of monoenes was much high followed by hexaenes and pentaenes of total fatty acids whereas in *D. watasei* monoenes followed by hexaenes and trienes were more abundant The most abundant fatty acids were oleic acid, palmitic acid, docosahexaenoic acid, eicosapentaenoic acid, stearic acid, palmitoleic acid; of the total fatty acids. Palmitic acid (C16:0) was found to be the most prominent in *D. garmani*. SFA has the principal component as palmitic acid. Oleic acid (C18: 1n9) is the major component of MUFA. Docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA) and γ linolenic acid (GLA) constitute the principal components of PUFA. *Diaphus* spp. contain a range of 18.9 – 19.5% of ω-3 fatty acids and 4.96 – 7.45% of ω-6 fatty acids. ω-3 PUFA contributed nearly 70.83 – 79.34 % of the total PUFAs and 18.94 – 20.67 % of total fatty acids. The most important ω-3 PUFAs, namely EPA and DHA contributed to 72.74 – 93.07 % of the total ω-3 poly unsaturated fatty acids. Fishes had a higher ω-3/ω-6 ratio ranged from 2.42 to 3.84.

## CONCLUSION

Globally most of the conventional fish stocks have reached a state of optimum exploitation or even over-exploitation; efficient utilization of non-conventional resources is necessary to meet the supply-demand gap for protein supply. Mesopelagic fishes can be considered as one such promising resource for the future, if appropriate harvest and post-harvest technologies are developed. Increasing human population and increasing demand for cheaper food fishes has made myctophids a possible potential resource for future exploitation and utilization. Earlier studies indicated the abundance of *Diaphus* spp. in the eastern and northeastern Arabian Sea. The present study also indicates the dominance of *Diaphus* spp. in the deep sea trawling grounds of south west coast of India.

There is no targeted fishing for myctophids. They form only an incidental catch in deep sea shrimp trawls. Present study shows that *D. watasei* is a good source of protein, fat and PUFA and hence it could well be a potential source of alternative low cost protein and fat for future. At present there is no demand for the resource and so used in the fish meal industry. More studies are required for the development of value added products. Research is required on post harvest technologies, like processing, marketing and utilization for better profit from this sector. Their enormous biomass may make them suitable for much greater commercial exploitation in future. An understanding of the fishery biology and population parameters of the component species is essential for development of fishery sustainable exploitation strategy for the future.

Commercial viability of the myctophid fishing in the Indian waters has to be workedout. The present catch estimation is based on the Stratifed Random Sampling Method from the landing data. As the coverage of sampling area was limited and the gear efficiency was not standardized, the data generated are not precise. A counter check for the estimates is also not possible due to the absence of comparable works in the study area. Therefore much more research is needed in areas like exploratory resource surveys and standardized models have to be developed. Fish biomass estimation by acoustics survey coupled with direct fishing would only confirm the accuracy of estimates. Exploratory surveys for new fishing areas to be continued, for gathering the distribution, abundance, biological and ecological data and map the potential fishing ground on a GIS platform and the data should be provided to the commercial entrepreneurs.

Generally non-conventional and non-targeted resources are under low fishing pressure and exploitation rates. Low values of fishing mortality and exploitation rates indicate that removal from the stock by fishing was only nominal from the present fishing grounds. The results indicate that the stock is almost at virgin state and remains grossly underexploited. Since the extent of distribution and abundance of the stock in the ecosystem remains to be ascertained, sustainable yield could not be estimated. Also the impact of myctophids harvest, on other commercially important fishes, has to be studied.

The database developed from the present study will form primary information on the population characteristic of the species. Hence, detailed studies are required to arrive at conclusive estimates for stock as well as potential yield of the resource, which are essential for management of the resource.

……………………………

# REFERENCES

# REFERENCES


Ackman, R. G., 1989. Fatty acids. *In*: R. G. Ackman (Ed.) *Marine Biogenic Lipids, Fats and Oils*. CRC press, p. 103 - 138.

Ackman, R. G. 1990. Seafood lipids and fatty acids. *Food Rev. Int.*, 6(4): 617.

Ahlstrom, E. H. 1968. Appraisal of the IIOE larval fish collection at IOBC, Cochin, India, *UNESCO Inf. Pap.*, 137: 1-10.

Alagaraja, K. 1984. Simple methods of estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.*, 31(2): 177 – 208.

Alcoock, A. 1994. *A Descriptive Catalogue of the Indian Deep –Sea Fishes in the Indian Museum*. Oxford and IBH Publishing Co. Pvt. Ltd. P. 152-165.

Alekseeva, E. J. and F. E. Alekseeva. 1983. Some aspects of the reproductive biology of lantern fishes *Myctophum punctatum* and *Notoscopelus resplendens* (myctophidae, Myctophiformes) from the eastern tropical Atlantic. *Vopr. Ikhtiol.*, 23(4): 779 – 785.

Allen, K.R. 1938. Some observations on the biology of the trout (*Salmo trutta*) in Windermere. 1. *Anim. Ecol.*, 7: 333 - 349.

*Anderson, R. 1967. Feeding chronology in two deep-sea fishes off California, *M. S. Thesis*, University of Southern California.

Andrianov, D. P. and V. E. Bekker, 1989. Reproductive biology of mesopelagic fishes of the eastern Pacific. *J. Ichthyol.*, 29(6): 43 – 48.

AOAC. 2006. *Official Methods of Analysis*. 18$^{th}$ edition, Association of Official Analytical Chemists, AOAC, USA, 2000 pp.

Aravindakshan, M., K. B. Waghmare, J. P. Karbhari, C. J. Jokutty and M. Shriram. 1987. Observations of the landing of lantern fish *Myctophum pterotum* Alcock along Maharashtra coast. *Mar. Fish. Infor. Serv. T & E Ser.*, 72: 20.

Aron, W. and R. H. Goodyear. 1969. Fishes collected during a midwater trawling survey of the Gulf of Elat and the Red Sea. *Israel J. Zool*., 18: 237 – 244.

Ayyappan, M. P. K., A. V. Shenoy and K. Gopakumar. 1976. Proximate composition of 17 species of Indian fish. *Fish. Technol*., 13(2): 153 - 155.

Badcock, J. and N. R. Merrett. 1976. Mid water fishes in the Eastern North Atlantic. i. Vertical distribution and associated biology in $30^0$ N, $23^0$ W, with developmental notes on certain myctophids. *Prog. Oceanogr*., 7(1) : 3 – 58.

Badcock, J. And T. M. H. Araujo. 1988. On the significance of variation in a warm water cosmopolitan species, normally *Ceratoscopelus warming* (Pisces, Myctophidae). *Bull Mar Sci*., 42: 16 – 43.

Bagenal, T. B. 1955. The growth of the long rough dab *Hyppoglossoides platessoides* (Fabr.). The growth of the long rough dab *Hyppoglossoides platessoides* (Fabr.) a correction. *J. Mar. Biol. Ass. UK*., 34: 297 – 311; 643 – 647.

Bagenal, T. B. 1957. The breeding and fecundity of the long rough dab, *Hippoglossoides platessoides* (Fabr.) and the associated cycle in condition. *J. Mar. Biol. Ass. U.K*., 36: 339 - 375.

Bagenal, T. B. 1974. Ageing of fish. Proceedings of an international symposium on the ageing of fish held at the University of Reading, England 19 – 20 July 1973. Old working Surrey, England, Unwin Bros. Ltd., 234 pp.

Baglin, R. E. Jr. 1982. Reproductive biology of Western Atlantic bluefin tuna. *U. S. National Mar. Fisheries Serv. Fishery Bull*., 80: 121 - 134.

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

Bal, D. V. and M. S. Joshi. 1956. Studies on the biology of *Coilia dussumieri* (Cuv. & Val). *Indian J. Fish*., 3(1): 91 – 100.

*Balasubramanian, N. K. 1997. Tudies on *Decapterus russelli* (Rupell) and *Decapterus macrosoma* Bleeker (Pisces Family: Carangidae) with special reference to population analysis. *Ph. D. thesis*, Kerala University, Trivandrum, India.

Balu, S. and N. G. Menon. 2006. Lantern fish - a potential deep sea resource. *Marine Ecosystem, ENVIS*, 5(1): p. 3 - 5.

Banerji, S. K. 1973. An assessment of the exploited pelagic fisheries of the Indian Seas. *Proc. Symp. Liv. Res. Seas. Around India*. CMFRI, Cochin, p. 114 – 135.

Bapat, S. V., V. M. Deshmukh, B. Krishnamoorthi, C. Muthiah, P. V. Kagwade, C. P. Ramamritham, K. J. Mathew, S. K. Pillai and C. Mukundan. 1982. Fishery resources of the Exclusive Economic Zone of the northwest coast of India, *Bull. Cent. Mar. Fish. Res. Inst.,* 33: 1 - 86.

*Barnov, F. I. 1918. On the question of the biological basis of fisheries. *Nauchn. Issled. Ikhtiol. Inst. Izv*., 1: 81 – 128. (In Russian).

Bekker, V. E. 1967. The lantern fishes (Myctophidae) from the “Petr Lebedev” Atlantic Expeditions 1961-1964. *Acad. Sci USSR, Trudy Inst. Okeanol., Moscow*, 84: 84 - 124.

*Bekker, V. E. 1967a. Luminescent anchovies: family Myctophidae. *In*: T. S. Rass (Ed.) *Biology of the Pacific Ocean*, Vol. 7, Book III. Ratisu, Tokyo, p. 145 – 181. (in Japanese, translated from Russian).

Bekker, V. E. 1976. Lantern fishes: family myctophidae. *Biology of the Pacific Ocean*, 7(III): 145 – 181.

Bengtson, D. A., R. C. Barkman and W. J. Berry. 1987. Relationships between maternal size, egg diameter, time of spawning season, temperature and length of hatch of Atlantic silverside, *Menidia menidia*. *J. Fish Biol.,* 31: 697 – 704.

*Ber, K. M. 1954. History of fishing in Russia and adjacent seas. *Uch. Zap. Akad. Nauk*, 2(4).

Bernardes, R. A. and C. L. D. B. Rossi-Wongtschowski. 2000. Length-weight relationship of small pelagic fish species of the southeast and south Brazilian exclusive economic zone. *NAGA*, 23(4): 30 – 32.

*Bertalanffy, L. Von. 1934. Untersuchungen Uber die Gesetzlichkeiten des Wachstums. 1. Allgemeine Grundiagen der Theorie. *Roux' Arc. Entwicklungsmech. Org.*, 131: 613 – 653.

Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of the exploited fish populations. *Fish Invest. Minis. Agri. Fish. Food. G. B.* (2 sea fish), 19: 533 pp.

Beverton, R. J. H. and S. J. Holt. 1959. A review of the lifespan and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. *In*: G. E. W. Wolstenholme and M. O. Connor (Eds.) *CIBA Foundation Colloquia on Ageing The Lifespan of Animals*. London, Churchill, Vol. 5: 80 – 142.

Bhattacharya, C. G. 1967. A simple method of resolution of a distribution into Gausian component. *Biometrics*, 23: 115 – 135.

Bhimachar, B. S. and P. C. George. 1952. Observations on the food and feeding of the Indian mackerel *Rastrelliger kanagurta* (Cuvier). *Proc. Indian Acad. Sci.*, 36 B (3): 105 – 118.

Bineesh, K. K., S. Manju, K. V. Akhilesh., C. P. Rajool Shanis, M. Hashim, N. G. K. Pillai and U. Ganga. 2009. Diversity of mesopelagic fishes in the deep-sea prawn trawlers from south west coast of India with notes on myctophids. *Book of Abstracts 20th All India Congress of Zoology*, CIFE, Mumbai, p. 167.

Bineesh, K. K., Manju, S., Akhilesh, K. V. and Pillai, N. G. K. 2010. First record of the Garman's lantern fish *Diaphus garmani* (Family: Myctophidae) from Indian waters. *J. Mar. Biol. Ass. India*, 52 (1): 109 – 112.

Bligh, E.G. and W. J. Dyer. 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.*, 3: 911-917.

Blindheim, J., D. Chakraborthy, and M. D. Menon. 1975. The pelagic fishery resources off the south-west coast of India. *In*: J. V. Shankar, D. P. Sen, P.B. R. Rao, V. H. Potty, K. A. Ranganath, B. S. N. Rao and M.V. Sastry (Eds.) *Fish Processing Industry in India*. Symposium held at CIFTRI, Mysore, p. 3 - 11.

Bolin, R. L. 1946. Lantern fishes from '*Investigator*' station 670, Indian Ocean. Stanford University, *Bull. Nat. Histotic Mus*., 3(2): 137 – 152.

Bolin, R. L. 1959. Iniomi: Myctophidae. *Rep. 'Michael Sars' North Atantic Deep Sea Expedition*, 1910, Part 4, 2(7): 1 - 45.

*Borutsky, E. V., O. A. Kliuchavera and G. V. Nikolsky. 1952. Bottom invertebrates and their role in the nourishment of fishes in the Amur. *Trans. Ichthyol. Exped. To the Amur*, 3.

Brauer, A. 1904. Die Gattung *Myctophum*. *Zool. Anz*., 28(10): 377 – 404.

Brothers, E. B. 1980. Age and Growth studies in tropical fishes. *In*: S. Ksaila and P. Roedel (Eds.) *Stock Assessment for Tropical Small-scale Fisheries*. Intern. Cent. Mar. Res. Management. Univ. Rhodes, 119 – 136.

Bunag, D. M. 1956. Spawning habits of some Phillippine tuna based on diameter measurements of the ovarian ova. *Phillippine Journal of Fisheries*, 4: 145 - 175.

Caddy, J. F. 1980. Surplus production models. *In*: Selected lectures from the CIDA/FAO/CECAF seminar on fishery resource evaluation. Casablanca, Morocco, 6 6 – 24 March 1978, Rome, FAO Canada Funds in Trust, FAO/TF/INT © 180 Suppl., 29 – 55.

Caddy, J. F. 1982. Some conditions relevant to the definition of shared stocks and their allocation between adjacent economic zones. *FAO Fish. Circ*., 749: 44 pp.

Casselman, J. M. 1983. Age and growth assessment of fish from their calcified structures – techniques and tools. *U.S. Dep. Commer. NOAA Tech. Rep. NMFS*, 8: 1 – 7.

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

Cassie, R. M. 1954. Some uses of probability paper in the analysis of size, frequency distributions. *Australian J. Mar. Freshwater Res*., 5: 513 – 522.

Chacko, P. I. 1949. The food and feeding habits of the fishes of the Gulf of Mannar. *Proc. Ind. Acad. Sci*., 29 B: 83 – 97.

Chakraborty, K., P. Vijayagopal, R. D. Chakraborty and K. K. Vijayan. 2010. Enrichment of eicosapentaenoic acid concentrates from sardine oil by bacterial (*Bacillus circulans*) lipase isolated from seaweed *Turbinaria conoides. Food Chem.,* 120: 433-442.

Chakraborty, R. D., K. Chakraborty and E.V. Radhakrishnan. 2007. Variation in fatty acid composition of *Artemia salina* nauplii enriched with microalgae and baker's yeast for use in larviculture *J. Agric. Food Chem.*, 55: 4043-4051.

*Chigiriskiy, A. I. 1970. The nature of oogenesis and fecundity in the Japanese horse mackerel *Trachurus japonicus* (Temminek et Schegel). *J. Icth.*, 10: 755 – 760.

Childress, J. J., S. M. Taylor, G. M. Cailliet and M. H. Price. 1980. Patterns of growth, energy utilization and reproduction in some meso and bathy pelagic fishes off Southern California. *Mar. Biol*., 61: 27 – 40.

*Chilton, D. E. and R. J. Beamish.1982. Age determination methods for fishes studied by the groundfish programme at the Pacific Biological Station. *Can. Spec. Publ. Fish. Aquat. Sci*., 60.

*Chugunova, N. L. 1935. Biostatic determination of fish stocks in the North Caspian. *Rybn. Khoz. SSSR*, No. 6.

*Chugunova, N. L. 1959. *Handbook for the Study of Age and Growth of Fish*. Acadamy of Science Press, Moscow. 164 pp.

*Clark, F. N. 1934. Maturity of the California sardine (*Sardina Caerulea*) determined by ova diameter measurements. *California Department of Fish and Game Fish. Bulletin*, No. 42.

Clarke, T. A. 1973. Some aspects of the ecology of lantern fishes (Myctophidae in the Pacific Ocean near Hawaii. *Fish* . *Bull*. NOAA / NMFS, 71(2): 401 – 434.

Clarke, T. A. 1983. Sex ratio and sexual differences in size among mesopelagic fishes from the central Pacific Ocean. *Marine Biology*, 73: 203 – 209.

Craddock, J. E. and G. E. Mead. 1970. Midwater fishes from the eastern Pacific Ocean. *Sci. Res. Exped. 'Anton Bruun' Rep*. No. 3: 3.1 – 3.16.

Crossland, J. 1977. Seasonal reproductive cycle of snapper, *Chrysophrys auratus* (Foster) in the Hauraki Gulf. *New Zealand J. Marine and Freshwater Research*, 11: 37 - 60.

Cushing, D. H. 1968. *Fisheries Biology: A Sudy in Population Dynamics*. Madison, University of Winconsin Press, 200 pp.

Cushing, D. H. 1988. *Fisheries Biology: A Study in Population Dynamics*. Madison University of Winconsin Press, 200 pp.

Cushing, D. H. 1988a. The study of stock and recruitment. *In*: J. A. Gulland (Ed.) *Fish Population Dynamics: The Implicatons for Management*. John Wiley and Sons Ltd., p. 105 – 128.

*Dalpadado, P. 1985. Biology of the lantern fish *Benthosema pterotum* from the Indian Ocean. *Ph.D. Thesis*, Dept. of Fish. Biol., Uty. of Bergen, Norway.

Dalpadado, P. 1988. Reproductive biology of the lantern fish *Benthosema pterotum* from the Indian Ocean. *Mar. Biol.*, 98: 307 – 316.

Dalpadado P. and J. Gjøsæter. 1988. Feeding ecology of the lantern fish *Benthosema pterotum* from the Indian Ocean. *Mar. Biol.*, 99(9): 555 – 567.

Dalpadado, P. and J. Gjosaeter. 1993. Lantern fishes (Myctophidae) in Sri Lankan Waters. *Asian Fisheries Society,* 9: 161 - 168.

*Danilevskii, N. Ya. 1862. Fisheries of the White Sea and Artic Ocean. *In*: *Research on the Fisheries of Russia* (in Russian), 7. St. Petersburg.

*Danilevskii, N. Ya. 1871. Fisheries of the Black and Azov Seas. *In*: *Research on the Fisheries of Russia* (in Russian), 4. St. Petersburg.

*Danilevskii, N. Ya. 1875. Fisheries in NW Lakes. *In*: *Research on the Fisheries of Russia* (in Russian), St. Petersburg, 9.

Datar, G. G. 1954. Food and feeding of *Caranx rottleri* (Cuv. And Val.). *Proc. 41st Ind. Sci. Cong. Assoc*., 3, Abstract, p. 181.

David, A. 1963. Fishery and biology of the schiboid catfish *Pangasius* (Hamilton), its utility and propagation in culture ponds. *Indian J. Fish*., 10(2) (Section A): 521 – 600.

Davis, T. L. O. 1985. Seasonal changes in gonadal maturity and abundance of larvae and early juveniles of barramundi, *Lates calcarifer* (Bloch) in Van Diemen Gulf and Gulf of Carpentaria. *Australian Journal of Marine and Freshwater Research,* 36: 177 – 190.

Day, F. 1882. The food of herring. *Zoologist 3rd Ser*., 6: 268.

*De Bont, A. F. 1967. Some aspects of age and growth of fish in temperate and tropical waters. *In*: S. D. Gerking (Ed.) *The Biological Basis of Freshwater Fish Production*. Blackwell, Oxford.

De Jong, J. K. 1940. A preliminary investigation on the spawning habits of the fishes of the Java Sea. *Treubia*, 17: 307 – 330.

De Vlaming, V. 1983. Oocyte development patterns and hormonal involvements among teleosts. *In*: J. C. Ramkin, T. J. Pitcher and R. T. Duggan (Eds.) *Control Processes in Fish Physiology*. p. 176 - 199.

Devanesan, D. W. 1932. A note on the food and feeding habits of *Sardinella gibbosa*. *J. Madras Univ*., 4: 159 - 164.

Devaraj, M. 1977. The biology and the fishery for the seerfishes of India. *Ph. D. Thesis*. Kamaraj University, 337 pp.

Devaraj, M. 1982. Age and growth of three species of seerfishes *Scomberomorus commerson*, *S. guttatus* and *S. lineatus*. *Indian J. Fish*., 28(1&2): 104 – 127.

Devaraj, M. 1983. Fish population dynamics course manual. *CIFE Bulletin*, 3(10) 83: 98 pp.

Eigenmann, C. H. and R. S. Eigenmann. 1890. Additions to the fauna of San Diego. *Proc. Calif. Acad. Sci. Ser*. 2, 3: 1 – 24.

Fairbridge, W. S. 1951. The New South Wales tiger flathead, *Neoplatycephalus macrodon* (Ogilby) 1. Biology and age determination. *Australian Journal of Marine and Freshwater Research*, 2: 117 - 178.

FAO. 1997. Review of the state of world fishery resources: marine fisheries. FAO Fisheries Circular No. 920, FAO, Marine Resource Service, Fisheries Resources Division, Fisheries Department. *FAO Fisheries Circular*. No. 920. Rome, FAO, 173 pp.

FAO. 1998. Trial fishing for lantern fishes (myctophids) in the gulf of Oman (1989-1990). *FAO Fisheries Circular No. 935 FIRM/C935*, pp.66.

Fast, T. N. 1960. Some aspects of natural history of *Stenobranchius leucopsaurus*. *Ph.D. Thesis*, Stanford University, 107 pp.

Fernandez, T. J., K. Pradeep, P. M. Vipin, R. R. Renju, M. P. Zynudheen, N. A. A. George and M. R. Boopendranath. 2011. Bycatch and discards of deep-sea shrimp trawlers and approaches for their utilization. *Proceeds of 21st Swadeshi Science Congress*. p. 398 – 404.

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

Fischer, W. and G. Bianchi. 1984. FAO *Species Identification Sheets for Fishery Purposes. Western Indian Ocean* (Fishing Area 51). Vol. III. FAO, UN, Rome.

Forberg, K. G. 1982. A histological study of development in capelin, *Mallotus villosus villousus* (Muller). *J. Fish Biol.*, 20: 143 – 154.

Fowler, H. W. 1934. Descriptions of new fishes obtained 1907 to 1910, chiefly in the Philippine Islands and adjacent Seas. *Proc. Acad. Nat. Sci. Philadelphia*, 85: 233 – 367.

Frasaer-Brunner, A. 1949. A classification of the fishes of the family Myctophidae. *Proc. Zool. Soc. London*, 118: 1019 – 1106.

Froese, R. and C. Binohlan. 2000. Empirical relationships to estimate asymptotic length, length at first maturity, and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. *J. Fish. BioI.*, 56: 758 - 772.

Froese, R. and D. Pauly. (Eds.). 2009. Fish Base. World Wide Web electronic publication. www.fishbase.org., version (09/2009).

Frost, W. E. 1946. On the food relationships of the fish in Windermere. *Biol. Jaarb*., 13: 216 – 231.

Fulton, T. W. 1898. On the growth and maturity of the ovarian eggs of teleostan fishes. *Fisheries Board of Scotland 16th Annual Report*, Part 3: 88 - 124.

Garcia, S. 1985. Reproduction, stock assessment models and population parameters in exploited penaeid shrimp populations. *In*: P. C. Rothlisberg, B. J. Hill and D.

Staples (Eds.) *Second Australian National Prawn Seminar*. Cleveland, Queensland, Australia, NPS2: p. 139 – 158.

Garcia, S. and L. Le Reste. 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fish. Tech. Paper*, 203: 215 pp.

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

Gartner, J. V. 1993. Patterns of reproduction in the dominant lantern fish species (pisces: Myctophidae) of the eastern gulf of Mexico, with a review of reproduction among tropical – sub tropical myctophidae. *Bull. Mar. Sci*., 52(2): 721 – 750.

George, K. C. and S. K. Bannerji. 1964. Age and growth studies of the Indian mackerel *Rastrelliger kanagurta* (Cuvier) with special reference to length frequency data collected at Cochin. *Indian J. Fish*., 11(2): 621 – 638.

Gibbs, R. H. and W. H. Krueger. 1987. Biology of the mid water fishes of the Bermuda Ocean acre. *Smithsonian Contributions to Zoology*, 452: 51 – 168.

Gilbert, C. H. 1906. Certain scopelids in the collections of the Museum of Comparative Zoology. *Bull. Mus. Comp. Zool., Harvard Univ*., 46(14): 253 – 263.

Gilbert, C. H. 1908. Reports on the scientific results of the expedition to the tropical Pacific, etc X. The lantern fishes. *Mem. Mus. Com. Zool. Harvard Univ*., 26(6): 217 – 238.

Gilbert, C. H. 1913. The lantern-fishes of Japan. Mem. *Carrnegie Mus*., 26(2): 67 – 107.

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

Gjosaeter, J. 1973. Age, growth and mortality of the myctophids fish, *Benthosema glaciale* (Reinhardt), from Western Norway. *Sarsia*, 52: 1 – 13.

*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. Instiute of Marine Research, Bergen. 36 pp.

Gjosaeter, J. 1978. Aspectsof the distribution and ecology of the myctophidae from the western and northern Arabian Sea. *In*: *Report of the FAO, Norway Workshop on the Fshery Resources in the North Arabian Sea*, Vol. 2. IOFC/DEV/78/432: 62 – 108.

Gjosaeter, J. 1981. Abundance and production of lantern fish (Myctophidae) in the Western and Northern Arabian Sea. *Fisk Dir. Skr. Ser. Hav Unders*., 17: 215 – 251.

Gjosaeter, J. 1981a. Life history and ecology of the myctophids fish *Notoscopelus kroeyeri* from the north-east Atlantic. *Fisk Dir. Skr. Ser. Hav Unders*., 17: 133 – 152.

Gjosaeter, J. 1984. Mesopelagic fish, a large potential resource in the Arabian Sea. *Deep Sea Research, Part A Ocanographic Research Papers*, 31(6-8): 1019 – 1035.

Gjosaeter ,H. 1987. Primary growth increments in otoliths of six tropical myctophids species. *Biol Oceanogr*., 4: 359 – 382.

Gjosaeter, J. and K. Kawaguchi. 1980. A review of the world resources of mesopelagic fish. *FAO Fish. Tech. Pap*., 193: 1 - 151.

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

GLOBEC (Global Ocean Ecosystem Dynamics). 1993. *Implementation Plan and Workshop Report for U.S. GLOBEC Studies in the Arabian Sea*. Report No. 3, Scientific steering Committee coordinating Office, USA. pp 89.

Go. Y. W., K. Kawaguchi and T. Kusaka. 1977. Ecologic study on *Diaphus suborbitalis* Weber (Pisces Myctophidae) in Saruga Bay, Japan. 1. Method of ageing and its life span. *Bull. Jap. Soc. Scient. Fish*., 43(8): 913 – 919.

Goode, G. B. and T. H. Bean. 1896. Oceanic Icthyology. *Special Bull. U. S. Natn. Mus*., 2: 1 – 553.

Goodyear, R. H., B. J. Zahuranec, W. L. Pugh and R. H. Gibbs Jr. 1972. Ecology and vertical distribution of Mediterranean mid water fishes. *In*: *Mediterranean Biological Studies*. Final Report. Vol. 1. Smithsonian Institution, Washington D. C. p. 91 – 230.

Gopakumar, K., A. V. Shenoy, M. P. K. Ayyappan, M. R. James and K. M. Iyer. 1976. Speciality products from miscellaneous trash fish. *In*: J. V. Shanker, D. P. Sen, B. P. R. Rao, V. H. Potty, K. A. Ranganath, S. B. N. Rao and V. M. Sastry (Eds.) *Fish Processing Industry in India*. Association of food scientists and technologists, India, p. 68 - 70.

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

*Gompertz, B. 1825. *On the Nature of the Function Expressive of the Law of Human Mortality and on a New Model of Determining the Value of Life Contingencies*. London, 115(1): 513 – 585.

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

Gorelova, T. A. 1978. Nutrition of the luminescent anchovies, *Ceratoscopelus warmingi* (Lutken) and *Bolinichthys longipes* (Brauer) fam. Myctophidae in the western equatorial part of the Pacific Ocean. *J. Ichthyol*., 18: 673 – 683.

Gorelova, T. A. and V. G. Prut'ko. 1985. Nutrition of *Diaphus suborbitalis* (Myctophidae) in the equatorial part of the Indian Ocean. *Okeanologiya*, 25(4): 677 – 684.

*Graham, M. 1935. Modern theory of exploiting a fishery and application to North Sea trawling. *J. Cons. CIEM*., 10(3): 264 – 274.

*Graham, M. 1939. The sigmoid curve and the overfishing problem. *Rapp. It. Proc. Verb. Cons. Expl. Mar*., 110: 15 – 20.

*Graham, M. 1943. *The Fishgate*. 2nd edition, Faber and Faber Ltd., London.

*Graham, M. 1948. Rational fishing of the cod of the North Sea. The Buckland Lectures for 1939. Edward Arnold and Co. London.

Greeley, M. S. Jr., D. R. Calder and R. A. Wallace. 1987. Oocyte growth and development in striped mullet, *Mugil cephalus* during seasonal ovarian recrudescence relationship to fecundity and size at maturity. *U. S. National Mar. Fisheries Serv. Fishery Bull.*, 85: 187 - 200.

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

*Gulland, J. A. 1965. Estimation of mortality rates. Annexure to Arctic fisheries working group report,Int. Counc, Exploration, Sea, Ann, Meeting.

Gulland, J. A. 1969. Manual of methods for fish stock assessment. Pt.1. Fish population analysis. *FAO Manuals in Fisheries Science*, 4: FRS/M4, 154 pp.

Gulland, J. A. 1971. The fish resources of the Ocean, West Byfleet, Surrey, Fishing News (Books), Ltd., for FAO 255 pp, Revised edition of *FAO Fish. Tech. Pap*., 97: 425 pp.

Gulland, J. A. 1977. The analysis of data and development of models. *In*: J. A. (Ed.) *Fish Population Dynamics*. John Wiley and Sons, London, 372 pp.

Gulland, J. A. 1983. Fish stock assessment: a manual of basic methods. Chichester, UK, Wiley Interscience, FAO Wiley Series on food and agriculture, Vol. 1: 223 pp.

Gulland, J. A. 1988. *Fish Population Dynamics: The Implications for Management*. 2nd Edn., Chichester, John Wiley and Sons Ltd. 422 pp.

Gunderson, D. R. and P. H. Dygert. 1988. Reproduction effort as a predictor of natural mortality rate. *J. Cons. CIEM*., 44: 200 – 209.

Halliday, R. G. 1970. Growth and vertical distribution of the glacier lantern fish *Benthosema glaciale* in the North Western Atlantic. *J. Fish. Res. Bd. Can*., 27: 105 – 116.

Haque, A., J. Pettersen, T. Larsen and J. Opstvedt. 1981. Fishmeal and oil from lantern fish (Myctophidae) with special emphasis on protein quality. *J. Sci. Food Agric*., (1): 61-70.

Harding, J. 1964. The use of probability paper for the graphical analysis of polymodal frequency distributins. *J. Mar. Biol. Assoc*. UK., 28: 141 – 153.

Hardy, A. C. 1924. The food and feeding habits of the herring with special reference to the east coast of England. *Fish. Invest*., 2(7): 3.

Hartmann, A. R. and T. A. Clarke. 1975. The distribution of myctophid fishes across the central equatorial Pacific. *Fish. Bull*., 73(3): 633 – 641.

Hasselblad, V. 1966. Estimation of the parameters for a mixture of normal distributions. *Technometrics*, 8: 431 – 444.

Hasselblad, V. and P. K. Tomlison. 1971. NORMSEP. Normal distribution separator. *In*: N. J. Abramson (Ed.) *Computer Programs for Fish Stock Assessment*. *FAO Fish. Tech. Pap*., 101(11).

*Hederman, W. A. and P. B. I. Corbin. 1892. The food of young fishes. *Rep. Laces. Sea. Fish. Labs*., 110 pp.

*Hederstrom, H. 1959. Observations on the age of fishes. *Rep. Inst. Freshwater Res. Drottingholm*., 40: 161 – 164.

*Heincke, F. 1898. Natugeschichte DES Herings. Abt Dtsch. Seefischereivereins, 2(1).

*Hensen, V. and C. Apstein. 1897. Die Nordsee – expedition 1895 des Deutschen seefischerei – Verseins. Uber die Eimenge der in Winter laichenden Fische. *Wiss. Meeresuntersuch*. 2(2).

Hickling, C. F. and R. Reutenberg. 1936. The ovary as an indicator of the spawning period of fishes. *J. Mar. Biol. Ass. U. K.*, 21: 311 – 317.

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

*Hjort, J., G. John and P. Ottestad. 1933. The optimum catch. Essays on population. *Hvalrad. Skr. Nr*., 7: 92 – 127.

Holden, M. J. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. *In*: F. R. Harden – Jones (Ed.) *Sea Fisheries Research*. Lagos Press, London. p. 117 - 138.

Holden, M. J. and D. F. S. Raitt. 1974. Manual of fishing science, part 2 – Methods of resource investigation and their application. *FAO Fish. Tech. Pap*., 115(1): 214 pp.

Holt, S. J. 1965. A note on the relationship between mortality rate and the duration of life in an exploited fish population. *ICNAF Res. Bull*., 2: 73 – 75.

Holton, A. A. 1969. Feeding behaviour of a vertically migrating lanternfish. *Pacif. Sci*., 23: 325 – 331.

Hornell, J. and M. R. Nayadu. 1924. A contribution to the life history of the Indian sardine with notes on the plankton of the Malabar coast. *Madras Fish. Bull*., 17: 129 – 197.

Hubbs, C. L. and K. F. Lagler. 1958. Fishes of the great lakes region. *Bulletin of Cranbrook Institute of Science*, 26(9): 1 – 23.

Hulley, P. A. 1972. A report on the mesopelagic fishes collected during the deep-sea cruises of R. S. 'Africana II', 1961 – 1966. *Ann. So. Afr. Mus.*, 60(6): 197 – 236.

Hulley, P. A. 1981. Results of the research cruises of FRV '*Walther Herring*' to South America. LVIII. Myctophidae. *Archiv fur Fischereiwissenschaft*, 31(1): 1 – 300.

Hulley, P. A. 1984. Myctophidae. *In*: P. J. P. Whitehead, M. Hureau, J. Nielsen and J. Tortonese (Eds.) *Fishes of the Northwest Atlantic and the Mediterranean*, Vol. 1, Paris, p. 429 - 483.

Hulley, P. A. 1985. Lantern fishes – myctophidae. *In*: W. Fisher and J. C. Hureau (Eds.) *FAO Species Identification Sheets for Fishery Purpose*. FAO, Southern Ocean, p. 316 – 322.

Hulley, P. A. 1986. Family myctophidae. *In*: M. M. Smith and P. C. Heemstra (Eds.) *Smiths' Sea Fishes*. Johannesburg, Macmillan, South Africa, p. 282 – 322.

Hulley, P. A. 1994. Lantern fishes. *In*: J. R. Paxton and W. N. Eschmeyer (Eds.) *Encyclopedia of Fshes*. Academic Press, San Diego, p. 127-128.

Hunter, J. R. and B. J. Macewiez. 1985. Measurement of spawning frequency in multiple spawning fishes. *In*: R. Lasker (Ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. *NOAA Technical Report No. NMFS*, 36: 79 – 94.

Hussain, S. M. and J. Ali Khan. 1987. Fecundity of *Benthosema fibulatum* and *Benthosema pterotum* from the Northern Arabian Sea. *Deep Sea Res*., 34(7): 1293 – 1299.

Hussain, S. M. and J. Ali Khan. 1988. On the ovarian eggs of *Benthosema fibulatum* and *B. pterotum* (Myctophidae) from northern Arabian Sea. *Indian J. Fish*., 35(1): 66 – 67.

Hynes, H. B. N. 1950. The food of freshwater sticklebacks (*Gasterosteus acullatus* and *Pygosteus pungtius*) with areview of the methods used in the studies of food of fishes. *J. Anim. Ecol.*, 19: 36 – 58.

Hyslop, E. J. 1980. Stomach content analysis – a review of methods and their application. *J. Fish. Biol*., 17: 411 – 429.

Ivanov, O.A. and V.V. Lapko. 1994. Size and age characteristics of the mesopelagics fish *Diaphus theta* (Myctophidae) in the south Kurile region. *Russ. J. Mar. Biol*., 20 : 148 – 152.

James, P. S. B. R. 1967. Memoir I: The ribbonfishes of the Family Trichuridae of India. *Mar. Biol. Ass. India, Mandapam*, 26 pp.

James, P. S. B. R. 1967a. Some observations on the fishery of *Chorinemus lysen* on the Rameshwaram Island with notes on its biology. *Indian J. Fish*., 11(1): 268 – 276.

James, P. S. B. R. and V. M. Baragi. 1980. Ovary as an indicator of the spawning in fishes. *Proc. Indian. Natu. Sci. Academy*. B46(4): 479 - 489.

*Jerald, A. 1983. Age determination. *In*: L. A. Nielson and D. L. Jonson (Eds.) *Fisheries Techniques*. *Am. Fish. Soc*., Bethesda, Maryland.

*Johnstone, J. 1906. The food fishes. *Rep Lances. Sea. Fish. Labs*., 216 pp.

Jones, C. M. 2002. Age and growth. *In*: L. A. Fuiman and R. G. Werner (Eds.) *Fisheries Science: the Unique Contributions of Early Life Stages*. Blackwell, Oxford, p. 33 – 63.

Jones, R. 1976. Growth of fishes. *In*: D. H. Cushing and J. J. Walsh (Eds.) *The Ecology of the Seas*. Blackwell Scientific Publications, Oxford, p. 251- 279.

Jones, R. 1984. Assessing the effects of changes in exploitation pattern using length composition data (with note on VPA and Cohort analysis) *FAO Fish. Tech. Paper*, 256: 118 pp

Jones, R. and N. P. van Zalinge. 1981. Estimates of mortality rates and population size for shrimp in Kuwait waters. *Kuwait Bull. Mar. Sci*., 2: 273 – 288.

Jons, G. D. and L. E. Miranda. 1997. Ovarian weight as index of fecundity, maturity and spawning periodicity, *J. Fish Biol*., 50: 150 - 156.

Jordan, D. S. 1963. *The Genera of Fishes and a Classification of Fishes*. Stanford Univ. Press, Stanford, California, 800 pp.

Jordan, D. S. and E. C. Starks. 1904. List of fishes dredged by the steamer '*Albatross*' off the coast of Japan in the summer of 1900, with descriptions of new species and a review of the Japanese Mactouridae. *Bull. U. S. Fish Comm*., 22: 577 – 628.

Josse, E., J. C. Le Guen, R. Kearney, A. Lewis, B. Smith, L. Marec and P. K. Tomilinson. 1979. Growth of skipjack. South Pacific Commission, *Occasional paper* 11 Numea, New Caledonia, 83 pp.

June, F. C. 1953. Spawning of yellow fin tuna in Hawaian waters. *U. S. National Marine Fisheries Serv. Fish. Bull*., 54: 47 – 64.

Karnella, C. 1987. Family Myctophidae, lantern fishes. *In*: R. H. Gibbs Jr. And W. H. Krueger (Eds.) *Biology of Midwater Fishes of Bermuda Ocean Acre No. 452*. Smithsonian Contributions to Zoology, Smithsonian Institution Press, Washington DC, p. 51 – 168.

Karnella, C. and R. H. Gibbs. 1977. The lantern fish *Lobianchia dofleini* : an example of the importance of life history information in prediction of Oceanic sound scattering. *In*: N. R. Anderson and B. J. Zahuranec (Ed.). *Oceanic Sound – Scattering Prediction*. New York, Plenum press, p. 361 – 379.

Karuppasamy, P. K., K. Balachandran, G. Simmy, S. Balu, P. Vimala and N. G. Menon, 2006. A checklist of fishes collected by IKMT from the DSL survey in the Indian EEZ of Arabian Sea. *Indian Hydrobiology*, 9(2): 311 – 316.

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

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

Kawaguchi, K and H. Shimizu. 1978. Taxonomy and distribution of lantern fishes genus *Diaphus* (pisces myctophidae) in the western Pacific, eastern Indian Oceans and the southeast Asian seas. *Bull. Ocean Research Institute University of Tokyo,* 10: 145 pp.

Kawaguchi, K. and J. Mauchline. 1982. Biology of myctophid fishes (Family Myctophidae) in the Rockall Trough, northeastern Atlantic Ocean. *Biological Oceanography*, 1(4): 337-373.

Kinzer, J., R. Bottger-Schnack and K. Sculz. 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*., 40(3): 783 – 800.

Klingbeil, R. A. 1978. Sex ratios of the northern anchovy *Engraulis mordax*, off southern California. *Calif. Fish Game*, 64: 200 – 209.

*Klunzinger, C. B. 1871. Synopsis der Fische des Rothen Meeres. II. *Verhandlungen Zool. Bot. Gesellscaft Wien*., 21: 441 – 688.

Kosaka, M., T. Kubota, M. Ogura, T. Oda and Z. Nakai. 1969. Studies of the predatory species on the shrimps, *Sergestes lucens* in Suruga Bay. *J. Coll. Mar. Sci. Tecinol. Tokai Univ*., 3: 87 – 101.

Kosenok, N. S., V. I. Chuchukalo and V. F. Savinykh. 2006. The characteristics of feeding of *Diaphus theta* (myctophidae) in the northwestern part of the Pacific Ocean in the summer autumn period. *Journal of Ichthyology*, 46: 606 – 612.

*Kotthaus, A. 1972. Die meso- und bathypelagischen Fische der Meteor – Rossbreiten Expedition 1970. *Meteor Forschung Ergebnisse, Reihe D*, 11: 1 – 23.

*Krefft, G. and V. E. Bekker. 1973. Myctophidae. *In*: J. C. Hureau and T. H. Monod (Eds.) *Checklist of the Fishes of the North-eastern Atlantic and of the Mediterranean (CLOFNAM)*. I. Unesco, Paris.

Kubota, T. 1982. Food of lantern fishes in Suruga Bay, Central Japan. *In*: B. R. Melteff and R. A . Neve (Eds.) *Proc. North Pacific Aquaculture Symposium.*University of Alaska, p. 275 - 283.

Kulikova, E. B. 1961. On the lantern fishes of the genus *Diaphus* (Scopelidae) from the western Pacific Ocean. *Acad. Sci. USSR, Trudy Inst. Okeanol., Moscow,* 43: 5 – 39.

Kuthalingam, M. D. K. 1961. Observations on the life history and feeding habits of a plankton feeder, the rainbow sardine (*Dussumeria acuta*) with a note on the method of securing stomach contents of the live fish. *J. Zool. Soc. India*, 13: 24 – 33.

Lagler, K. F. 1956. *Fresh Water Fishery Biology*. W. M. C. Brown Company Publishers, 2$^{nd}$ edition, Debereque, IOWA, 4221 pp.

Lam, W. V. Y. and D. Pauly. 2005. Mapping the global biomass of mesopelagic fishes. *Sea Around Us Project Newsletter*, 30: p. 4.

*Lapin, Yu. E. 1961. Types of spawning population and some aspects of research methods for the dynamics of commercial fish. *Vopr. Ikhtilo*., 1(4).

Le Bour, M. V. 1919. Feeding habits of some young fishes. *J. Mar. Biol. Ass. U. K.* 12: 1 – 18.

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

Lekshmy, N. A., J. M. Arul, P. T. Mathew and K. Gopakumar. 1983. Studies on lantern fish (*Benthosema pterotum*) II. Nutritional evaluation. *Fish. Technol.*, 20(1): 17-19.

Linkowski, T. B. 1985. Population biology of the myctophid fish *Gymnoscopelus nicholsi* (Gillbert, 1911) from the western South Atlantic. *J. Fish Biol.*, 27(6): 683 – 698.

Linkowski, T. B. 1987. Age and growth of four species of *Electrona* (Myctophidae). *In*: S. O. Kullander, and B. Fernhom (Eds.) *Proceedings of the Fifth Congress of European Ichthyologists*. Swedish Mus. Nat. Hist. Stockholm, p. 435 – 442.

Linkowski, T. B., R. L. Radke and P. H. Lenz. 1993. Otolith micro structure, age and growth of two species of *Ceratoscopelus* (Osteichthyes : Myctophidae) from the Eastern North Atlantic. *J. Exp. Mar. Biol. Ecol.*, 167: 237 – 260.

Lipskaya, N. Ya. 1967. Assessment of energy losses on making of sex products in fishes. *Vopr. Ikhthiologii*, 7(6): 1123 – 1126.

Lisovenko, L. A. and V. G. Prut'ko. 1987. Reproductive biology of *Diaphus suborbitalis* (Myctophidae) in the equatorial part of the Indian Ocean. 1. Nature of oogenesis and type of spawning. *J. Ichthyol.*, 26: 47 – 58.

Lisovenko, L. A. and V. G. Prut'ko. 1987a. Reproductive biology of *Diaphus suborbitalis* (Myctophidae) in the equatorial part of the Indian Ocean. 2. Fecundity and reproductive potential. *J. Ichthyol.*, 27(3): 1 – 11.

Lourenço S., R. P. Vieira, M. Collins, C. A. Assis, J. Watkins and J. C. Xavier. 2011. Myctophid Life Strategies and Population Dynamics In The Scotia Sea: Ageing Myctophidae Fishes. Poster presented on III Conference Portuguesa Das Ciencias Polares. Portuguese.

Lovern, J. A. and H. Wood. 1937. Variation in biochemical composition of herring. *J. Mar. Biol. Ass. U. K.*, 22: 281 - 293.

Macer, C. T. 1974. The reproductive biology of horse mackerel, *Trachurus trachurus* (L) in the North Sea and English Channel. *J. Fish Biol.*, 6: 415 - 438.

Mac Gregor, J. S. 1957. Fecundity of the Pacific sardine (*Sardinops caerulea*). *U. S. National Mar. Fish. Serv. Fishery Bull.*., 57: 427 - 449.

Macdonald, P. D. M. and T. J. Pitcher. 1979. Age groups from size frequency data: a versatile and efficient method of analysing distribution mixtures. *J. Fish. Res. Board Can.*, 36: 987 – 1001.

Magnusson, J. J. and J. G. Heltz. 1971. Gill apparatus and food selectivity among mackerels, tunas and dolphins. *Fish. Bull*., 68(2): 361 – 370.

*Maier, H. N. 1906. Beitroge zur Altersbestimmung der Fishe I. Allgemeines. Die Altersbestimmung nach den Otoliten bei Schoole und Kadeljan. Wissenchaftliche Meeresuntersuchungen (Helgoland), 8(5): 60 – 115.

*Maitland, P. S. 1965. The feeding relationships of salmon, trout, minnows, stone loach and three – spined sticklebacks in the river Endrick, Scotland. *J. Anim. Ecol*., 34: 109 – 133.

Manju, S., Chakraborty, K., Bineesh, K. K., Pillai, N. G. K., Abdussamad, E. M. and Vijayan, K. K. 2011. Proximate composition and fatty acid profile of myctophid (*Diaphus watasei* Jordan & Starks, 1904) from the Arabian Sea. *Indian J. Fish*., 58(1): 103-107.

Manju, S., K. K. Bineesh, E. M. Abdussamad and N. G. K. Pillai. 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, W. R. 1949. The mechanics of environmental control of body form in fishes. *Univ. Toronto. Stud. Biol., 58 Publ. Ont. Fish. Res. Lab*., 70: 1 – 91.

*Marza, V. D. 1938. *Histophysiologie de I'ovogenese*. Herman and Cie Editors. 81 pp.

Menon, M. D. 1976. Handling and processing of pelagic fish in India. *In*: J. V. Shankar, D. P. Sen, P.B. R. Rao, V. H. Potty, K. A. Ranganath, B. S. N. Rao and M.V. Sastry (Eds.) *Fish Processing Industry in India*. Symposium held at CIFTRI, Mysore, p. 12 – 15.

Menon, N. G. 2002. Completion report on the project, studies on the deep scattering layer. DOD, New Delhi, 634 pp.

Menon, N. G. and N. Venugopal. 2004. Potential exploitable micronektons from the deep scattering layers (DSL) of the Indian EEZ. *Mar. Fish. Infor. Serv. T & E Ser.*, 182: 1 – 9.

Mini, R. And P. S. B. R. James. 1990. Distribution and abundance of lantern fishes of the family myctophidae in the EEZ of India. Proc. *First Workshop Scient. Resul. FORV Sagar Sampada*, 285 – 290.

Moku, M., A. Tsuda and K. Kawaguchi. 2002. Spawning season and migration of the myctophids fish *Diaphus theta* in the western north Pacific. *Ichth. Res.*, 50: 52 – 58.

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

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

Munro, J. L. and D. Pauly. 1983. A simple method for comparing growth of fishes and invertebrates. *ICLARM Fishbyte*, 1(1): 5 – 6.

Murty, V. S. R. 1991. Observations on some aspects of biology and population dynamics of the scad *Decapterus russelli* (Rupell) (Carangidae) in the trawling grounds off Kakinada. *J. Mar. Biol. Ass. India*, 33(1&2): 396 – 408.

Muthiah, C. 1986. Maturation and spawning of *Euthynnus affinis*, *Auxix thazard* and *A. rochei* in the Mangalore inshore areas during 1972-82. *In*; E. G. Silas (Ed.) *Tuna Fisheries of Exclusive Economic Zone of India*. *Bull. Cent. Mar. Fish. Res. Inst*., 36: 71 – 85.

*Muthiah, C. 1994. Studies on the fishery and biology of the lizardfish, *Saurida* spp. from the Karnataka coast. *Ph. D. Thesis,* Dept. of Marine Biology, Karnataka University, Karwar.

Nafpaktitis, B. 1968. Taxonomy and distribution of lantern fishes, genera *Lobianchia* and *Diaphus,* in the North Atlantic. *Dana Rep*. No. 73: 1 – 131.

Nafpaktitis, B. 1973. A review of the lantern fishes (Family Myctophidae) described by A. V. Taning. *Dana Report*, 83: 1 – 46.

Nafpaktitis, B. 1974. A new record and a new species of lantern fish, genus *Diaphus* (Family: Myctophidae) from the northern Atlantic Ocean. *Los Angels Co. Mus. Nat. His. Contribution in Science*, 254: 1 – 6.

Nafpaktitis, B. G. 1978. Systematics and distribution of lantern fishes of the genera *Lobianchia* and *Diaphus* (Myctophidae) in the Indian Ocean. *Natural History Museum of Los Angeles County Science Bulletin*, 30: 92 pp.

Nafpaktitis, B. G., R. H. Backus, J. E. Craddock, R. L. Haedrich, B. H. Robinson and C. Karnella. 1977. Family myctophidae. *In*: R. H. Gibbs Jr. (Ed.) *Fishes of the Western North Atlantic*. *Mem. Sears Found. Mar. Res*., 1. Pt. 7.

Nafpaktitis, B. G. 1984. Myctophidae. *In*: W. Fisher and G. Bianchi (Eds.) *FAO Species Identification Sheets for Fishery Purposes Western Indian Ocean*, Vol. III. FAO publication, Rome, p. 1 - 8.

Nafpaktitis, B. G., D. A. Robertson and J. R. Paxton. 1995. Four new species of the lantern fish genus *Diaphus* (Myctophidae) from the Indo-Pacific. *New Zeal. J. Mar. Fresh.,* 29: 335 - 344.

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

Nakamura, E. L. 1970. Observations on the biology of the myctophid, *Diaphus garmani*. *Copeia*, 2: 374 – 377.

Natarajan, A. V. and V. G. Jhingran. 1962. Index of preponderance – a method of grading the food elements in the stomach analysis of fishes. *Indian J. Fish*., 8(1): 54 – 59.

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

Neill, R. M. 1938. The food and feeding of the brown trout (*Salmo trutta* L.) in relation to the Oceanic environment. *Trans. R. Soc. Edinb*., 59: 481 – 520.

Nelson, J. S. 2006. *Fishes of the World*. 4th Edn. John Wiley and Sons, New York, 601 pp.

Nicholas, P. D., D. S. Nicholas and M. J. Bakes 1994. Marine oil products in Australia. *Inform*., 5: 254 - 261.

*Nikolskii, G. V. 1950. Biological basis of contingent catches and ways of controlling the numbers of fish populations. *Zool. Zhurn*., 29: 1.

*Nikolskii, G. V. 1953. Theoretical principles of studies on the dynamics of fish numbers. Transanctions of the All-union conference on Fisheries (in Russian). *Izd. Akad. Nauk. SSSR*.

*Nikolskii, G. V. 1956. Biological basis of fisheries in inland waters. *Trudy Biol. Stants* U Borok, 2.

*Nikolskii, G. V. 1965. Theory of population dynamics of fish. Moscow, Izd. Nauka. English Edn. (1969) Theory of fish population dynamics as the biological background for rational exploitation and management of fishery resources. Oliver and Boyd, Edinburg.

Norman, J. R. 1929. Notes on the myctophid fishes of the genera *Diaphus* and *Myctophum* in the British Museum (Natural History). *Ann. Mag. Nat. Hist*., 4(10): 510 – 515.

Noguchi, S. F. 2004. Utilization of the resources of lantern fish as fisheries products. *In*: M. Sakaguchi (Ed.) *More Efficient Utilization of Fish and Fisheries Products*. Elsevier Ltd., U. K., p. 63-74.

Odate, S. and T. Ogawa. 1961. Study on the fishes of the family myctophidae in the north eastern sea area along the Pacific coast off Japan. *Bull. Tohuku reg. Fish. Res. Lab.*, 19: 90 – 97.

O'Day, T. William and B. G. Nafpaktitis. 1967. A study of the effects of expatriation on the gonads of two myctophid fishes in the North Atlantic Ocean. *Harvard Univ. Mus. Comp. Zool. Bull.*, 136: 77 – 90.

Olivar, M. P. 1987. Larval development and spawning of *Diaphus hudsoni* in the Bermuda current region. *Mar. Biol.*, 94(4): 605 – 611.

Olivar, M. P. and L. E. Beckley. 1995. Early development of *Diaphus* spp. (pisces: Myctophidae) of the Agulhas current. *South Afr. J. Mar. Sci.*, 16: 129 – 139.

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

Otsu, T. and R. N. Uchida. 1959. Seasonal maturity and spawning of albacore in the Pacific Ocean. *U. S. National Mar. Fish. Serv. Fishery Bull.*., 59: 287 - 305.

Oven, L. S. 1983. Sex cycles and spawning of lantern fishes of genus *Myctophum* of the tropical Atlantic. *In*: Abstract. *Problems of Early Ontogenesis of Fishes* (Russian). Kalingrad, p. 118 – 120.

Oven, L. S. 1986. Comparative analysis of reproductive biology of some lantern fishes (Myctophidae) from the tropical zone of the Atlantic Ocean. *J. Ichthyol*., 25: 50 – 60.

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

Paloheimo, J. E. 1961. Studies on the estimation of mortalities 1. Comparision of a method described by Beverton and Holt and a new linear formula. *J. Fish Res. Bd. Canada*, 18: 645 – 662.

Pannikar, N. K. and R. G. Aiyar. 1939. Observations on breeding in brackishwater animals of Madras. *Proc. Nat. Indian. Acad. Sci*., 9B: 343 - 364.

Parr, A. E. 1928. Deep-seafises of the order Iniomi from the waters around the Bahama and Bermuda Island. *Bull. Bingham Oceanogr. Coll*., 3(3): 1 – 193.

Parr, A. E. 1929. Notes on the species of myctophine fishes represented by type specimens in the United States National Museum. *Proc. U. S. Nat. Mus*., 76: 1 - 47.

Parrish, R. H., D. L. Mallieoate and R. A. Klingbeil. 1986. Age dependent fecundity, number of spawnings per year, sex ratio and maturation stages in northern anchovy, *Engraulis mordax. U.S. National Mar. Fisheries Serv. Fishery Bull*.., 84: 503 - 517.

*Parulekar and D. V. Bal. 1971. Maturation and spawning of *Bregmaceros mcclellandi* (Thomson). *J. Bombay Nat. Hist. Soc*., 68: 20 – 28.

Pauly, D. 1978. A discussion of the potential uses in population dynamics of the interrelationship between natural mortality, growth parameters and environmental temperature in 122 stocks. *ICES, C. M.*, 21: 35 pp.

Pauly, D. 1979. Theory and management of tropical multispecies stocks. A review with emphasis on the Southeast Asian demersal fisheries. *ICLARM Stud. Rev*., 1: 35 pp.

Pauly, D. 1980. A selection of simple methods for the assessment of tropical fish stocks. *FAO Fish, Circ*., 729: 54 pp.

Pauly, D. 1980a. A new methodology for rapidly acquiring basic information on tropical fish stocks: growth, mortality and stock recruitment relationships. *In*: S. B. Saila and P. Roedel Kingston (Eds.) *Stock Assessment for Tropical Smell Scale fisheries*. Proceedings of an International Workshop held on 19 – 21 September 1979. University of Rhode Island, international Centre for Marine Resources Development. p. 154 – 172.

Pauly, D. 1980b. on the interrelationship between natural mortality, growth parameters and linear temperatures in 175 fish stocks. *J. Cons. Int. Explor. Mar*., 39(3): 175 – 192.

Pauly, D. 1981. Tropical fish stock assessment package for programmable calculators and microcomputers. ICLARM Newsletter, 4(3): 10 – 3.

Pauly, D. 1982. Studying single species dynamics in a tropical multispecies context. In: D. Pauly and G. I. Murphy (Eds.) *Theory and Management of Tropical Fisheries*. p. 33 – 70.

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

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

Pauly, D. 1984. Fish population dynamics in tropical water. A manual for use with Programmable calculators. *ICLARM Stud. Rev*., 8: 325 pp.

Pauly, D. 1984a. Length converted catch curves. A powerful tool for fisheries research in the tropics (Part II). ICLARM *Fiishbyte*, 2(2): 17 – 19.

Pauly, D. 1984b. Length converted catch curves. A powerful tool for fisheries research in the tropics (Part III: Conclusion). ICLARM *Fiishbyte*, 2(3): 9 – 10.

Pauly, D. 1986. On improving operation and use of the ELEFAN programme Part II: improving the estimation of $L_\infty$. *ICLARM*, *Fishbyte*, 4(1): 18 – 20.

Pauly, D. 1987. A review of the ELEFAN systems for analysis of length frequency data in fish and aquatic invertebrates. *ICLARM Conf. Proc*., 13: 7 – 34.

Pauly, D. and G. R. Morgan. 1987. Length based methods in fisheries research. *ICLARM Conf. Proc*., 13: 468 pp.

Pauly, D. and J. F. Caddy. 1985. A modification of Bhattacharya's method for the analysis of mixtures of normal distributions. *FAO Fish. Circ*., 781: 16.

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

Pauly, D. and N. David. 1981. ELEFAN I, a BASIC programme for the objective extraction of growth parameters from length-frequency data. *Meereforschung*, 28(4): 205 – 211.

Paxtron, J. R. 1967. Biological notes on southern California lantern fishes (family Myctophidae). *Calif. Fish Game*, 53: 214 – 217.

Paxtron, J. R. 1972. Osteology and relationships of the lantern fishes (family Myctophidae). *Bull. Los Angeles Co. Mus. Nat. Hist. Sci*., 13: 1 – 81.

Paxtron, J. R. 1979. Nominal genera and species of lantern fishes (Family Myctophidae) contribution of science. *Natural Historic Museum Los Angeles*, *County*, 322: 1 – 28.

*Pearl, R. and L. J. Reed. 1923. On the mathematical theory of population growth. *Metron*., 3(1): 6 – 19.

Pertseva – Ostroumova, T. A. 1972. Larvae of lantern fishes (pisces : myctophidae) from the collections of the Australian expeditions of ships Gaskoin and Diamantina. *Vopr. Ikhtiol*., 12(4): 693 – 703.

Pertseva – Ostroumova, T. A. 1973. The reproduction of lantern fishes (pisces: myctophidae) and the structure of their eggs. *J. Ichthy*., 13: 937 – 939.

*Petersen, C. G. J. 1892. Fiskenes biologiske forhold i Holdback Fjord. *Beret. Damm. Biol. St*., 1890 – 91(1): 121 – 183.

*Petersen, C. G. J. 1895. Eine Methode zur Bestimmung des alters and Wochses des Fische. *Mitt Dtsch Seefischerei – Vereins*, 11: 8.

*Petersen, C. G. J. 1900. What is overfishing? *J. Mar. Biol. Assoc*. U.K., N.S., 6: 587 – 594.

*Petersen, C. G. J. 1903. Where and under what conditions can eggs of plaice be developed into young fish within the skrei. *Rep. Danish Biol. Station*, 12.

Phleger, C. F., M. W. Nealson, B. D. Mooney and P. D. Nicholes. 1999. Wax esters versus triacylglycerols in myctophid fishes from the Southern Ocean. *Antartct. Sci.*, 11(4): 436 – 444.

Piggott, G. M., and B. W. Tucker. 1990. *The Effect of Technology on Nutrition*. Marcel Dekker Inc., New York, USA, 362 pp.

Pillai, N. G. K., K. K. Bineesh, Manju Sebastine and K. V. Akhilesh. 2009. Lantern fishes (Myctophids): by-catch of deepsea shrimp trawlers operated off Kollam, south-west coast of India. *Mar. Fish. Infor. Serv. T & E Ser*., 202: 1 – 4.

Pillai, T. V. R. 1952. A critique of the methods of study of food of fishes. *J. Zool. Soc. India*, 4: 185 – 200. 0144

Pon Siraimeetan. 1990. Bioproductivity studies in the southwest coast of India and equatorial region. *In*: K. J. Mathew (Ed.) *Proc. First Workshop Sci. Result FORV Sagar Sampada*. CMFRI, Cochin, 297 – 303.

*Pope, J. G. 1980. Assessment of multispecies resources. *In*: Selected lectures from the CIOA/FAO/CEAF seminar on fishery resources evaluation. Casablanca, Morroco, 6 – 24 March 1978. Rome FAO, Canada Funds-in-Trust, *FAO/TF/INT* 180 (c) suppl., p. 93 – 137.

Powell, D. G. 1979. Estimation of mortality and growth parameters from the length frequency of a catch. *Rapp. P. V. Cann CIEM*, 175: 167 – 169.

Prabhu, M. S. 1956. Maturation of intra ovarian eggs and spawning periodicities in some fishes. *Indian J. Fish*., 3: 59 - 90.

Pradhan, L. B. 1956. Mackerel fishery of Karwar. *Indian. J. Fish*., 3(1): 141 – 185.

Pradhan, L. B. and V. C. Palekar. 1956. Key to the stages of sexual maturity of *Rastrelliger Kanagurta* (C). *Indian J. Fish*., 3: 183 - 185.

Prosch, R. M. 1991. Reproductive biology and spawning of the myctophid *Lampanyctus hectoris* and the sternoptychid *Maurolicus muelleri* in the southern Benguela ecosystem. *S. Afr. J. Mar. Sci*., 10: 241 – 252.

Qasim, S. Z. 1972. The dynamics of food and feeding habits of some marine fishes. *Indian J. Fish*., 19(1 & 2): 11 – 28.

Qasim, S. Z. 1973. An appraisal of the studies on maturation and spawning in marine teleosts from the Indian waters. *Indian J. Fish*., 20: 166 - 181.

Qasim, S. Z. and A. Qayyum. 1961. Spawning frequencies and breeding seasons of some freshwater fishes with special reference to those occurring in the plains of Northern India. *Indian J. Fish*., 8: 24 - 43.

QFPCO. 2011. Qeshm fish processing company, Iran. http://www. qfpco.com/static.php?.id=products, 15.10.2011.

Rafail, S. Z. 1973. A simple and precise method for fitting a Von Bertalanffy growth curve. *Mar. Biol.*, 19(14): 354 – 358.

Raja, A. B. T. 1964. Some aspects of spawning biology of Indian oil sardine *Sardinella longiceps* Val. *Indian J. Fish.*, 11A: 45 - 120.

Raja, A. B. T. 1967. Length weight relationship in the oil sardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 14(1&2): 150 – 170.

Rajamoorthy, K., K. Pradeep, R. Anandan, Libin Baby, T. V. Sankar and P. T. Lakshmanan. 2013. Biochemical composition of myctophid species *Diaphus watasei* and *Myctophum obtusirostre* caught from Arabian Sea. *Fish. Technol.*, 50: 41 – 44.

Rajan, K. N., N. G. Kumar and K. Chellappan. 2001. Innovative exploitation of deep-sea crustaceans along the Kerala coast. *Mar. Fish. Inform Serv. T & E Ser.*, 168: 1 - 11.

Rao, G. S. 1988. Biology of *Stolephorus devesi* (Whitley) from Manglore area, Dakshin Kannada. *J. Mar. Biol. Ass. India*, 30(1&2): 28 – 37.

Rao, G. S. 1988a. Some aspects of biology of *Stolepherus bataviensis* Hardenberg, from Manglore area, Dakshin Kannada. *J. Mar. Biol. Ass. India*, 30(1&2): 107 – 113.

Rao, K. S. P. B. 1963. The eggs and early development of *Caranx* sp. from Porto Novo coast. *Zool. Soc. India*, 14(2): 198 - 202.

Ricker, W. E. 1940. Relation of catch per unit effort to abundance and rate of exploitation. *J. Fish. Res. Board. Can.*, 5: 43 – 70.

Ricker, W. E. 1944. Further notes on fishing mortality and effort. Copeia, 1: 23 – 44.

Ricker, W. E. 1945. A method for estimating minimum size limits for obtaining maximum yield. *Copeia*, 2: 84 – 94.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish biology populations. *Bull. Fish Res. Bd. Can*., 191: 382 pp.

Ricker, W. E. 1975. Computations and interpretations of biological statistics of fish populations. *Bull. Fish. Res. Bd. Can*., 191: 382 pp.

Rikhter, V. A. and V. N. Effanov. 1976. On one of the approaches to estimation of natural mortality of fish populations. *ICNAF Res. Doc*., 76/VI/8: 12 pp.

Robertson, D. A. 1977. Planktonic eggs of the lantern fish *Lampanyctodus hectoris* (family Myctophidae). *Deep Sea Res*., 24(9): 829 – 852.

Robison, B. H. 1984. Herbivory by the myctophid fish *Ceratoscopelus warmingii*. *Mar. Biol*., 84(2): 119 – 123.

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

Rohit, P., P. P. Pillai, A. C. Gupta and K. Preetha. 1998. Fishery and population characteristics of mackerel landed by trawlers along the Dakshina Kannada coast. *Indian J. Fish*., 45(1): 21 – 27.

*Russel, E. S. 1931. Some theoretical considerations on the overfishing problem. *J. Cons. CIME*, 6: 1 – 20.

*Russel, E. S. 1939. An elementary treatment of the overfishing problem. *Cons. Int. Explor. Mer. Rapp et Proc. Verb*., 110: 5 – 14.

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

Sajeevan, M. K. and J. R. Nair. 2006. Distribution and abundance of non-conventional deep sea fin fish resources off the southwest coast of India. Indian J. Fish., 53(3): 345 – 352.

Sameoto, D. D. 1988. Feeding of lantern fish *Benthosema glaciale* off the Nova Scotia Shelf. *Mar. Ecol. Prog. Ser*., 44: 113 – 129.

Samuel, C. T. 1932. Papers from the DANA Oceanographical Collections: The Carlsberg Foundation's Oceanographical Expedition round the world 1928 – 30 and previous DANA – Expeditions under the leadership of the late professor Johannes Schmidt. Vol I(XIV): 27 – 32.

Sanders, M. J., S. M. Kedidi and M. R. Hegazy. 1984. Stock assment for the Indian mackerel (*Rastrelliger kanagurta*) caught by purse seine from the Gulf of Suez and more southern Red Sea waters. Cairo, Project for Development of Fisheries in areas of the Red Sea and Gulf of Aden. *FAO/UNDP RAB*/83/023/03: 25 pp.

Sanders, M. J., S. M. Kedidi and M. R. Hegazy. 1984a. Stock assessment for the spotted sardinella (*Sardinella sirm*) caught by purse seine adjacent to the border between Egypt and Sudan. Cairo, Project for Development of Fisheries in areas of the Red Sea and Gulf of Aden. *FAO/UNDP RAB*/83/023/04: 28 pp.

Sanders, M. J., and M. Bouhlel. 1982. Preliminary estimates of some stock assessment parameters for the meso pelagic species *Benthosema pterotum* inhabiting the western and northern Arabian Sea. *FAOIUNDP Rep. Fish.*, RAB77/008, 23 pp.

Sassa, C. and K. Kawaguchi. 2005. Larval feeding habits of *Diaphus theta*, *Protomyctophum thompsoni*, and *Tarletonbeania taylori* (Pisces : Myctophidae) in the transition region of the western North Pacific. *Mar. Ecol. Prog. Ser*., 298: 261 - 276.

Saville, A. 1977. Survey methods of appraising fisheries resources. *FAO Fish. Tech. Pap*., 171: 76 pp.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Bull. Inter. Am. Trop. Tuna Comm.*, 1(2): 27 – 56.

*Scott, T. 1902. Observations of the food fishes. *Ann. Rep. Fish. Bd. Scotland*, Pts. III: 486 – 538.

Sekharan, K. V. 1968. Length weight relationship of *Sardinella albella* (Val) and *S. gibbosa* (Bleek). *Indian J. Fish.*, 15(1&2): 166 – 174.

Sekharan, K. V. 1975. Estimates of the stocks of oil sardine and mackerel in the present fishing grounds off the west coast of India. *Indian J. Fish.*, 21(1): 177 – 182.

Seo, H. S, Y. Endo, K. Fujimoto, H. Watanabe and K. Kawaguchi. 1996. Characterization of lipids in myctophid fish in the subartic and tropical Pacific Ocean. *Fishery Sci.*, 62(3): 447 – 453.

Seo, H. S., Y. Endo, M. Moku, K. Kawaguchi and K. Fujimoto. 2001. Wax ester biosynthesis in the liver of myctophids fishes. *Lipids*, 36(4): 389 - 393.

Seoane E. G., M. Fabeiro, S. Alexandra, M. Isabel. In print. Age-based demography of the glacier lantern fish *Benthosema glaciale* (Reinhardt 1837) in the Flemish Cap. *Marine and Fresh Water Research*.

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

Shoesmith, E. 1990. A comparison of the methods for estimating mean fecundity. *J. Fish Biol.*, 36(1): 73 – 84.

Smith, M. M. and P. C. Heemstra. 1986. *Smiths' Sea Fishes*. J. L. B. Smith Institute of Ichthyology, Grahamstown, p. 282 – 321.

Smoker, W. and W. G. Pearcy. 1970. Growth and reproduction of the lantern fish *Stenobranchius leucopsaurus*. *J. Fish. Res. Bd. Can.*, 27(7): 1265 – 1275.

Snedecor, G. W. and W. G. Cochran. 1967. *Statistical Methods*. Oxford and IBH Publishing Co., New Delhi, 6th edition, 593 pp.

Sousa, M. I. 1988. Sources of bias in growth and mortality estimations of migratory pelagic fish stocks, with special emphasis on *Decapterus russelli* (Carangidae) in Mozabbique. *FAO. Fish. Rep*., 389: 288 - 307.

Sparre, P. 1987. Computer programs for fish stock assessment. Length based fish stock assessment for Apple II computers. *FAO Fish. Tech. Pap*., 101(2): 218 pp.

Sparre, P. 1987a. A method for the estimation of growth, mortality and gear selection/ recruitment parameters from length frequency samples weighed by catch per effort. *ICLARM Conf. Proc*., 13: 75 – 102.

Sparre, P. 1991. Introduction to multispecies virtual population analysis. *ICES Ma. Sci. Symp*., 193: 12 – 21.

Sparre, P., E. Ursin and S. Venema. 1989. Introduction to tropical fish stock assessment. *FAO Fish. Tech. Pap*., 306:H2, 429 pp.

Sparre, P. and S. Venema. 1992. Introduction to tropical fish stock assessment. Part I Manual. *FAO Fish. Tech. Pap*., 306(1): 337 pp.

Sreenivasan, P. V. 1979. Food and feeding habits of the scad *Decapterus dayi Wakiya*. *J. Mar. Biol. Ass. India*, 21(1&2): 97 – 102.

Sreenivasan, P. V. 1987. Maturity and spawning in *Decapterus dayi Wakiya*. *J. Mar. Biol. Ass. India*., 23(1&2): 19 - 28.

Srinath, M. 1990. Letters to the editor. *ICLARM Fishbyte*, 9(1): 2.

Stansby, M. E. 1981. Reliability of fatty acid values purporting to represent composition of oil from different species of fish. *J. Am. Oil Chem. Soc*., 58: 13 - 16.

Suda, A. 1973. Development of fisheries for non-conventional species. *J. Fish. Res. Board Canada*, 30(12) Part 2: p. 2121 - 2158.

Suriah, A. R., S. H. Teh., N. Osman, M. D. Nik. 1995. Fatty acid compositions of some Malaysian fresh water fish. *Food Chem.*, 54: 45 - 49.

*Swynnerton, G. H. and E. B. Worthington. 1940. Notes on the food of fish in Haweswater (Westmorland). *J. Anim. Ecol*., 9: 183 – 187.

Takagi, K., A. Yatsu, M. Moku and C. Sassa. 2006. Age and growth of lantern fishes, *Symbolophorus californiensis* and *Ceratoscopelus warmingii* (Myctophidae), in the Kuroshio – Oyashio Transition Zone. *Ichthyological Research*, 53: 281 – 289.

*Tanaka, S. 1956. A method of analysing the polymodal frequency distribution and its application of the length distribution of porgyi *Taius tumifrons* (T&S). *Bull. Tokai Regional Fisheries Res. Lab*., 14: 1 – 12.

*Tanaka, S. 1960. Studies on the dynamics and the management of fish populations. *Bull. Tokai Regional Fisheries Res. Lab*., 28: 1 – 200.

Tandon, K. K. 1960 a. The food and feeding habits of *Selaroides leptolepies* (Curvier and Valencienes). *Curr. Sci*., 29(2): 62 – 63.

Tandon, K. K. 1960 b. Biology and fishery of 'chooparai' *Selaroides leptolepies* (Curvier and Valencienes). I – Food and feeding habits. *Indian J. Fish*., 7(1): 82 – 100.

Tanimata, N., O. Yamamura, Y. Sakurai and T. Azumaya. 2008. Dietary shift and feeding intensity of *Stenobrachius leucopsarus* in the Bering sea. *Journal of Oceanography*, 64: 185 – 194.

Taning, A. V. 1928. Synopsis of the scopelids in the north Atlantic. *Vidensk. Medd. fra Dansk Naturh. Foren. Bd*., 86: 49 – 69.

Taning, A. V. 1932. Notes on scoppelids from the Dana expedition. *Vidensk. Medd. fra Dansk Naturh. Foren. Bd*., 94: 126 – 146.

*Tesch, F. W. 1968. Age and growth. *In*: W. E. Ricker (Ed.) *Methods for Assessment of Fish Production in Freshwaters*. IBP Handbook No. 3 Blackwell, London.

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

*Thompson, W. F. 1937. Theory of the effect of fishing on the stock of halibut. *Rep. Int. Fish. Comm*., 12.

*Thompson, W. F. 1959. An approach to population dynamics of the Pacific red salmon. *Trans. Amer. Fish. Soc*., 88.

Thompson, W. F. and F. H. Bell. 1934. Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. *Rep. Int. Fish. (Pacific Halibut) Comm*., 8: 49 pp.

Thomson, J. S. 1902. The periodic growth of scales in Gobidae and Pleuronectidae as an index of age. *J. Mar. Biol. Ass*. U. K., N. S. 6: 373 – 375.

Tsarin, S. A. and A. R. Boltachev. 2006. Mesopelagic fishes of the Arabian Sea. *In*: K. Kanse and S. A. Piontkovsky (Eds.) *The Mesoscale Structure of the Epipelagic Ecosystem of the Open Northern Arabian Sea*. University Press, Hyderabad, India. p. 162 – 177.

Tsokur, A. G. 1975. Data on the development of the Malayan headlight fish, *Diaphus malayanus* (Myctophidae, Pisces). *J. Ichthyol*., 15(4): 611 – 622.

Tyler, H. R. and W. G. Pearcy. 1975. The feeding habits of three species of lantern fishes (family myctophidae) off Oregon USA. *Mar. Biol*., 32: 7 – 11.

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

Udupa, K. S. 1976. On the estimation of parameters of Von Bertalanffy growth equation. *Indian J. Fish*., 21: 399 – 425.

Ursin, E. 1968. A mathematical model of some aspects of fih growth, respiration and mortality. *J. Fish. Res. Bd. Can*., 24: 2355 – 2453.

Valinassab, T. 2005. Biomass distribution and pattern of myctophids in the Oman sea. *Iranian Journal of Fisheries Science*, 4(2): 101 – 110.

Valsa, J. P. 1979. Larval development of the lantern fish (Pisces, Myctophidae) *Diogenichthys panurgus* (Bolin 1946). *Bull. Dept. Mar. Sci. Univ. Cochin*, 10: 1 – 18.

Venema, S. C., J. M. Christensen and D. Pault. 1988. Contributions to tropical fishery biology. FAO/DANIDA Fellowship training courses on fish stock assessment in the tropics. Hirshals, Denmark, 5 – 30 May 1986 and Manila, Phillipines, 12 Jan – 6 Feb. *FAO Fish. Rep*., 389: 519 pp.

Venkataraman, G. 1956. Studies on some aspectsof biology of the common anchovy, *Thrissocles mystax* (Bl and Schn.). *Indian J. Fish*., 3(2): 311 – 333.

Venkataraman, G. 1960. Studies on food and feeding relationships on the inshore fishes off Calicut on the Malabar coast. *Indian J. Fish*., 7(2): 275 – 307.

Vipin, P. M., K. Pradeep, R. Ravi, T. J. Fernandez, M. P. Remesan, V. R. Madhu and M. R. Boopendranath. 2011. First Estimate of the Length–Weight Relationship of *Diaphus watasei* Jordan and Starks, 1904 Caught off the Southwest Coast of India. *Asian Fisheries Science*, 24: 453 – 455.

Wallace, R. A. and K. Selman. 1981. Cellular and dynamic aspects of oocyte growth in teleosts. *American Zoologists*, 21: 325 - 343.

Wang, Y. J., L. A. Miller, M. Perren and P. B. Addis. 1990. Omega-3 fatty acids in Lake Superior fish. *J. Food. Sci*., 55(l): 71 - 73.

*Weber, M. 1913. Die Fische der ‘Siboga’ Expedition. *Siboga Exped. Rept.*, 57: 1 – 710.

West, G. 1990. Methods of assessing ovarian development in Fishes: a review. *Aust. J. Mar. Freshwater Res.*, 41: 199 - 222.

*Williams, V. R. and T. A. Clarke. 1982. Reproduction, growth and other aspects of the biology of gold spot herring *Herklotsichthys quadrimaculatus* (Clupeidae) a recent introduction to Hawai. *U. S. National Mar. Fisheries Serv. Fishery Bull.*., 80: 587 - 597.

Windell, J. T. 1968. Food analysis and rate of digestion. *In*: W. E. Reckeer (Ed.) *Methods for Assessment of Fish Production in Fresh Waters*. 1st edition, Blackwell Scientific Publications, Oxford, p. 197 – 203.

Windell, J. T. and S. H. Bowen. 1978. Methods for study of fish diets based on analysis of stomach contents. *In*: T. Bagnel (Ed.) *Methods for Assessment of Fish Production in Fresh Waters*. 1st edition, Blackwell Scientific Publications, Oxford, p. 219 – 226.

Wisner, R. L. 1971. Description of eight new species of myctophid fishes from the eastern Pacific Ocean. *Copeia*, 1: 39 – 54.

Wisner, R. L. 1974. Descriptions of five new species of myctophid fishes from the Pacific, Indian and Atlantic Oceans. *Occas. Pap. Calif. Acad. Sci*., 110: 1 – 37.

Wisner, R. L. 1976. The taxonomy and distribution of lantern fishes (family Myctophidae) of the Eastern Pacific Ocean. *U. S. Navy Ocean Res. Devel. Acitivity, NORDA Report*, 3: 299 pp.

*Wood, H. 1930. Scottish herring shoals. Prespawning and spawning movements. *Scotland Fish. Bd. Sci. Invest*., 1: 1 - 17.

*Yong, M. Y. and R. A. Skillman. 1971. A computer program for analysis of polymodal frequency distribution (ENORMSEP), FORTRAN, IV, *U.S. Fish. Bull*., 73(3): 681 pp.

*Yoshida, H. O. 1964. Skipjack spawning in the Marquesas and Tuamotu Archipelago. *U. S. National Mar. Fish. Serv. Fishery Bull..*, 65: 479 - 488.

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

Young, J. W., S. J. M. Blaber and R. Rose. 1987. Reproductive biology of the three species of mid water fishes associated with the continental slope of Eastern Tasmania, Australia. *Mar. Biol.*, 95: 323 – 332.

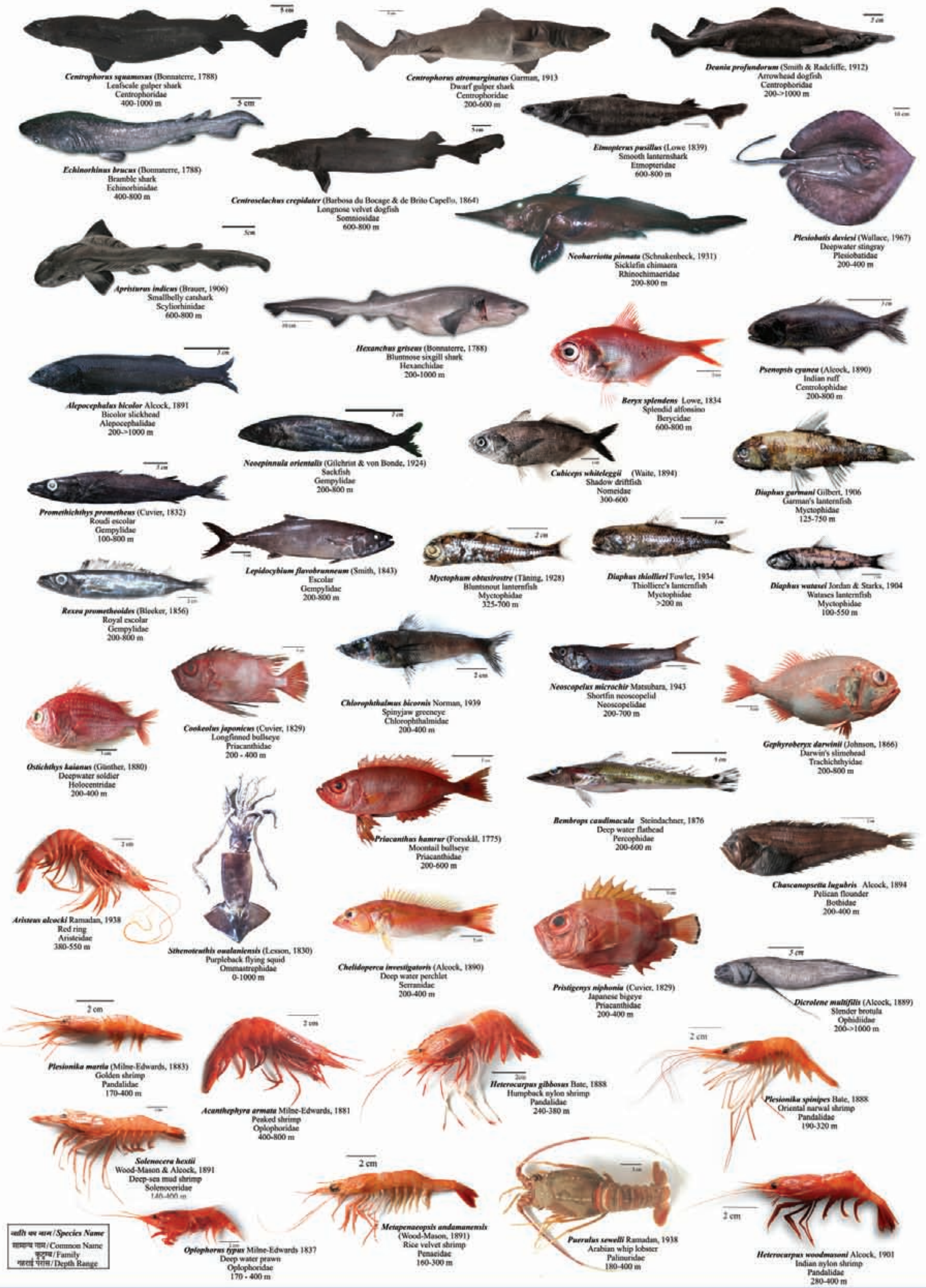
Zurbrigg, R. E. and W. B. Scott. 1972. Evidence for expatriate populations of lantern fish *Myctophum punctatum* in the northwest Atlantic. *J. Fish. Res. Bd. Can.*, 29: 1679 – 1683.

---

*Not referred to in original

# PUBLICATIONS

# भारत की गभीर सागर मात्स्यिकी संपदाएं
# DEEP-SEA FISHERY RESOURCES OF INDIA





तैयारी : डॉ. एन. जी. के. पिल्लै, यू. गंगा, हाशिम मंजब्रयाकत, सी.पी. रजूल षानिस, के. के. बिनीष, के. वी. अखिलेश, मंजु सेबास्टियन और एन. बेनी, वेलापवर्ती मात्स्यिकी प्रभाग, केंद्रीय समुद्री मात्स्यिकी अनुसंधान संस्थान, पी. बी. सं. 1603, कोच्ची -682 018

Prepared by: Dr. N. G. K. Pillai, U. Ganga, Hashim Manjebrayakath, C.P. Rajool Shanis, K.K. Bineesh, K.V. Akhilesh, Manju Sebastine and N.Beni

Pelagic Fisheries Division, Central Marine Fisheries Research Institute, P.B.No.1603, Cochin-682 018



डॉ. जी. सैदा राव, निदेशक, सी एम एफ आर आइ द्वारा प्रकाशित Published by: Dr. G. Syda Rao, Director, CMFRI

Courtesy: Ministry of Earth Sciences /Centre for Marine Living Resources and Ecology (CMLRE) funded Projects - *Assessment of myctophid resources in the Arabian Sea and development of harvest and post harvest technology* and *Assessment of fishery resources in the continental slope of Indian EEZ and Central Indian Ocean.*

Design & Layout : P.R. Abhilash

*Indian J. Fish., 60(4) : 7-11, 2013*

# Myctophid fishery along the Kerala coast with emphasis on population characteristics and biology of the headlight fish, *Diaphus watasei* Jordan & Starks, 1904

MANJU SEBASTINE, K. K. BINEESH, E. M. ABDUSSAMAD AND N. G. K. PILLAI
*Central Marine Fisheries Research Institute, Kochi - 682 018, Kerala, India*
*e-mail:manju_seb@yahoo.com*

## ABSTRACT

Myctophids form bycatch in deep sea shrimp trawls with an annual average catch of 2668 t during 2009 - 2011 in Kerala coast. Fishery occurred almost round the year with peak during November - February. Fishery and biology of the dominant species, *Diaphus watasei* was monitored. Peak spawning and recruitment of the species was during January-August. Growth parameters $L_\infty$ and K are estimated as 15.06 cm and 0.8 per year respectively. These values indicate that the species growth is relatively fast. Natural mortality estimate (M) is 1.21, total mortality (Z) 1.68 and fishing mortality (F) 0.47. The exploitation rate (E) is low being 0.279. These indicate that the stock is at its initial stage of exploitation and there is large scope for enhancing their commercial exploitation. The stock abundance, biomass and distribution of the resource need to be assessed. These factors have to be taken into consideration while planning for exploitation of myctophids in future.

Keywords: Exploitation rate, *Diaphus watasei,* Growth, Mortality, Myctophids

**Introduction**

Myctophids are the most ubiquitous fishes in the world oceans with the total biomass estimated being 600 million t (Hulley, 1994). They are also called as lanternfishes owing to the presence of photophores on the ventral, lateral and head regions of the body. Myctophiformes includes two families namely myctophidae and neoscopiliade. Myctophids are small to medium sized (3-35cm) mesopelagic fishes with compressed body, large eyes, large jaws and terminal mouth. Genus *Diaphus* are commonly called as head light fish due to the presence of secondary photophores on the head. The Indian Ocean harbours a rich fauna of lanternfishes both in number and biomass (GjØsaeter and Kawaguchi, 1980). GLOBEC (1993) estimated 100 million t of myctophids from the Arabian Sea. Wide occurrence of *Diaphus* spp. from the eastern and north-eastern Arabian Sea has been reported (FAO, 1997; Balu and Menon, 2006). A study carried out by the Central Marine Fisheries Research Institute during 1997 - 2002, estimated a biomass of 100,000 t of myctophids along the Indian EEZ of Arabian Sea, dominated by *Diaphus* sp. (Balu and Menon, 2006).

Finfishes constitute a sizable portion of the deep-sea shrimp trawl bycatch, which demands only very low price and are often discarded in the sea at the time of catch. Along the south-west coast of India, lantern fish (order, myctophiformes) forms a major portion (20-35%) of the bycatch in the deep sea shrimp trawls (Bineesh *et al*., 2009). These fishes, when landed are mostly used for fishmeal or manure production.

Blindheim *et al*. (1975) reported a large concentration of myctophids along certain parts of the south-west coast of India and stated that they had been commercially exploited at certain localities. There is only limited information on the commercial exploitation of lanternfishes. Fishermen in Suruga Bay, central Japan used *Diaphus* spp. as food (Kubota, 1982). Commercial fishery for *Diaphus coeruleus* and *Gymnoscopelus nicholski* (edible species) in the south-west Indian Ocean and southern Atlantic began in 1977 and catch by former USSR countries reached 51,680 t in 1992, after which the fishery ceased due to decrease in catch. Despite this, the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) still permits Total Allowable Catch (TAC) of 2,00,000 t for this resource from the area under its jurisdiction. Industrial purse seine fishery for *Lampanyctodes hectoris* was developed in South African waters and closed in the mid 1980s due to processing difficulties caused by the high oil content in the fish (FAO, 1997). Lanternfishes are harvested commercially only off South Africa and in the sub-antarctic (Nafpaktitis *et al*., 1977; Hulley, 1994).

Though *Diaphus watasei* formed the dominant component of the lanternfish catch, their biological and population characteristics are least studied. The present study aimed to gather scientific information on the above aspects of *D. watasei*.

## Materials and methods

Data on effort, catch and species composition of myctophids were collected at weekly intervals from commercial deep-sea shrimp trawlers operated from Kollam and Kochi coasts during 2009 - 2011. Biology, length and weight composition of the common species, *D. watasei* in the landings were studied. Reproductive and feeding biology of 1481 specimens within the size range of 4.26 – 14.32 cm standard length (SL) were recorded. Standard length of the fish was used in all studies, unless otherwise mentioned. Length-weight relationship was determined by the method of least squares using the logarithmic forms of the exponential equation $W = aL^b$, where W=weight (g), L=length (cm) and 'a' and 'b' are constants (Pauly, 1983). The correlation coefficient was determined to know the degree of association of the two variables. The variation between the regression coefficients (b) in male and female was tested using ANACOVA (Analysis of covariance). Food and feeding was studied following the method proposed by Natarajan and Jhingran (1961). Monthly length frequency data for the period was used for the estimation of von Bertalanffy growth parameters $L_\infty$ and K by ICLARM's FiSAT software (Gayanilo *et al*., 1997). Age at zero length ($t_o$) was estimated as in Bertalanffy (1934) and size at first capture ($L_c$) as in Pauly (1984). Natural mortality (M) was estimated using Pauly's empirical formula (Pauly, 1980). Total mortality (Z) and exploitation rate (E) were estimated from the catch curve as per Pauly (1983) and exploitation ratio (U) from the relation $U = F/Z * (I\text{-}e^{-Z})$; where, F is the fishing mortality. Optimum age of exploitation was estimated following Krishnankutty and Qasim (1968).

## Results

### *Fishery and fishing area*

Myctophids form bycatch in the deep sea shrimp trawlers. The operation area was between off Kollam and off Kasargode, along the south-west coast of India ($8^0$20'-$12^0$38'N; $74^0$20'-$76^0$25'E). Fishing was carried out during day time at depths of 270-500 m. Annually an average of 2667 t of myctophids were landed during the study period 2009 - 2011 (Table 1; Fig. 1). Catch rate was estimated as 6.3 - 9.5 kg $h^{-1}$ with an average of 7.9 kg $h^{-1}$. Fishery occurred year-round with peak fishing during November and February.

Catch comprised of five species *viz*., *Diaphus watasei* (74.23%), *Neoscopilus microchir* (20.57%), *Benthosema fibulatum* (1.94%), *Diaphus garmani* (1.69%) and *Myctophum obtusirostre* (1.58%) (Fig. 2). *D. watasei* and *N. microchir* were available round the year whereas, other species occurred only seasonally. *D. watasei* was found to be dominant among the myctophids.

Table 1. Estimated catch of myctophids (t) from the deep sea shrimp trawlers off Kerala during 2009-11

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 391.96 | 443.58 | 189.57 | 153.39 | 120.26 | 0 | 0 | 15.22 | 65.62 | 265.73 | 393.25 | 382.09 | 2420.67 |
| 2010 | 440.54 | 433.36 | 145.59 | 171.93 | 8.54 | 0 | 0 | 21.66 | 157.24 | 354.11 | 456.50 | 420.07 | 2610.01 |
| 2011 | 432.53 | 479.73 | 213.20 | 162.68 | 180.85 | 0 | 0 | 18.53 | 73.80 | 272.13 | 486.90 | 408.16 | 2972.27 |
| Average | 421.68 | 452.22 | 182.79 | 162.67 | 103.22 | 0 | 0 | 18.47 | 98.89 | 297.32 | 445.55 | 403.44 | 2667.65 |

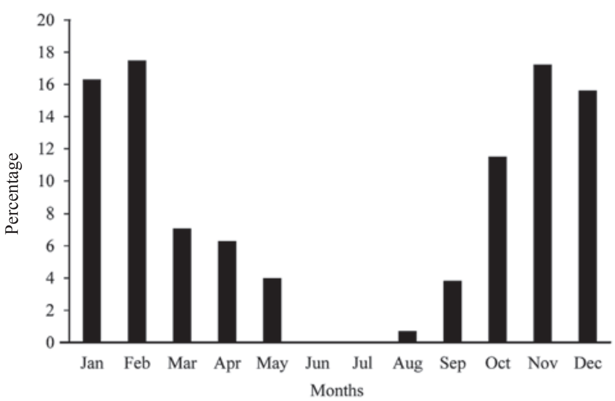



Fig. 1. Seasonal pattern in the myctophid catch by deep sea shrimp trawlers during 2009-11

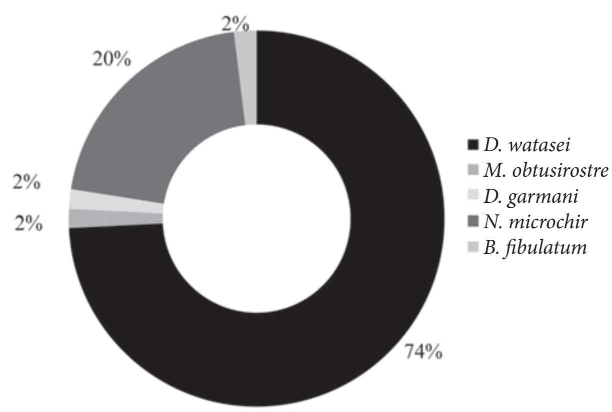



Fig. 2. Species composition of myctophids

*Size composition and length-weight relationship of Diaphus watasei*

Catch was supported by fishes ranging in size 4.26-14.32 cm, with a mean of 9.56 cm and weight ranged from 1.03 to 37.83 g, with a mean of 12.37 g. The length-weight relationships derived are:

Males : Log W = 0.013912+2.953861* Log L (r = 0.848153)

Females : Log W = 0.010052+3.063181* Log L (r = 0.957939)

Pooled : Log W = 0.011442+3.023246* Log L (r = 0.908653)

The length-weight relationship differed significantly between males and females of the species (ANCOVA, p=0.005). The co-efficient indicate that the species follow an isometric growth pattern.

*Size composition of other species*

*B. fibulatum, D. garmani* and *M. obtusirostre* were in the size range of 1.5 - 9 cm, with short and deep body. *N. microchir*, which belongs to the family neoscopilidae had a size range of 4 - 19 cm, with elongate and slightly compressed body.

*Population parameters of Diaphus watasei*

*Growth and age*

Estimates of growth parameters, $L_\infty$ and K by FiSAT were 15.06 cm and 0.8 per year respectively. Age of the species at zero length ($t_o$) was estimated as -0.0284 years. The estimated K value is relatively small indicating relatively longer life span. They were estimated to attain 9, 12, 13.5 and 14.5 cm respectively by the end of 1st, 2nd, 3rd and 4th years (Fig. 3). It will take more than 3.5 years to reach the $L_{max}$ (14.5 cm).

Size at first capture ($L_c$) of *D. watasei* in trawl was estimated as 7.92 cm and optimum size of exploitation ($L_{opt}$) as 9.1 cm. Age corresponding to size at first capture estimated was 9 months and age at optimum exploitation is one year.

*Maturity and spawning*

The catch was dominated by adults (51.05%), the rest being sub-adults. Mature and spent fishes dominated the catch during January, May and August (44, 43 and 68% of the catch respectively). During other seasons, occurrence of matured and spent fishes is relatively low, indicating January-August as the peak spawning season for the species along the Kerala coast.

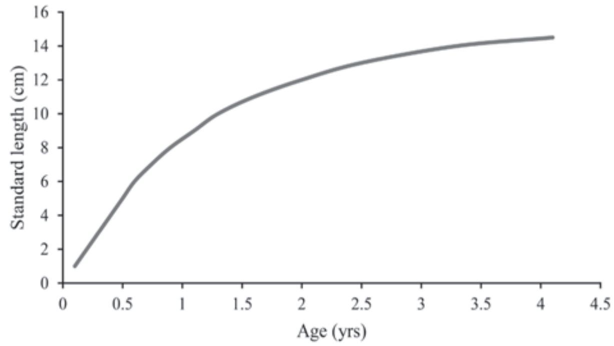



Fig. 3. Growth curve of *D. watasei*

Mature specimens were observed from 5.5 cm size onwards, but size at first maturity on logistic curve was 10.12 cm (Fig. 4). Age of the fish at this size is 1.4 years, indicating that they attain sexual maturity and spawn after one year growth.

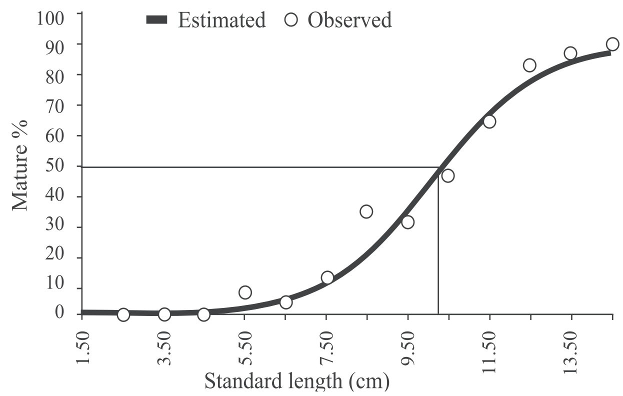



Fig. 4. Logistic curve for determining size at maturity of *D. watasei*

*Fecundity*

Relative fecundity (fecundity per gram body weight) of the fish determined by examining gravid gonads (stage V and VI) ranged between 542 and 1442 with a mean of 850.

*Feeding habit and prey*

Gut observation indicated that myctophids are carnivorous in feeding habit. Food was constituted by deep sea prawns, deep sea squids, small mesopelagic fishes and foraminiferans. Crustaceans constituted 68% followed by cephalopods (21%), fishes (5%) and other miscellaneous organisms (6%).

*Predators*

*D. watasei* was observed in the guts of yellowfin tuna *(Thunnus albacares), Chauliodus solani, Psenopsis cyanea, Neoepinnula orientalis, Chlorophthalmus bicornis* and *Priacanthus hamrur.*

*Stock, mortality and exploitation rate*

Total stock from the point of fishery was estimated as 8676 – 9779 t with an average of 9270 t. Estimate of total mortality (Z) in the population during the period was 1.68, natural mortality (M) being 1.21 and fishing mortality (F) 0.47. Exploitation rate was very low being 0.279. Total loss from the population due to fishing is only 28% and that by natural causes is 72%.

**Discussion**

Myctophids, dominated by *D. watasei* form only an incidental catch in deep sea shrimp trawls. Earlier studies show that *D. watasei* is a good source of protein, fat and PUFA, hence it could well be a potential source of alternative protein and fat for future (Manju *et al*., 2011). At present, there are no buyers for the resource, except the fish meal industry. Their enormous biomass may make them suitable for much greater commercial exploitation in future (Nafpaktitis *et al*., 1977; Hulley, 1994). An understanding of the biology and population parameters of the component species is very essential for development of fishery sustainable exploitation strategy in future.

Length-weight relationship of *D. watasei* indicated isometric growth whereas, Vipin *et al*. (2001) reported isometric growth in females and positive allometric growth in males. Estimate of the size at maturity was larger than the size at first capture and optimum size of exploitation, but since the exploitation rate is very low, there is no immediate threat to the stock. Low values for estimates of fishing mortality and exploitation rates indicate that removal from the stock by fishing was only nominal from the present fishing grounds. The results indicate that the stock is almost at virgin state and remains grossly underexploited. Since the extent of distribution and abundance of the stock in the ecosystem remains to be ascertained, sustainable yield could not be estimated. Generally non-conventional and non-target resources are under low fishing pressure and have low values for exploitation rates (Abdussamad *et al*., 2011). The database developed from the present study will form primary information on the population characteristics of the species. Hence, detailed studies are required to arrive at conclusive estimates for stock as well as potential yield of the resource, which are essential for management of the resource.

**Acknowledgements**

The work has been funded by Centre for Marine Living Resources and Ecology (CMLRE) and we sincerely acknowledge their support. The authors are indebted to the Director, Central Marine Fisheries Research Institute, Kochi for the facility and help. The support from Mr. Sahaya Kaintin in providing fish samples is greatly acknowledged

**References**

Abdussamad, E. M., Joshi, K. K., Balasubramaniam, T. S., Beni, N., Habeeb Mohamed, O. M. M. J. and Jeyabalan, K. 2011. Snake mackerel fishery of the Tuticorin coast of Gulf of Mannar with emphasis on population characteristics of the sackfish, *Neoepinnula orientalis* (Gilchrist & von Bonde 1924). *Indian J. Fish.,* 58 (3): 9-12

Balu, S. and Menon, N. G. 2006. Lantern fish - a potential deep sea resource. *Marine Ecosystem, ENVIS*, 5(1): 3 - 5.

Bertalanffy, L. V. 1934. Unter suchungen uberdie Gesetzlichkeiten des waswasdestums I. Allgemeine Grundlagen der Theorie. *Roux Arch. Entwicklungsmech. Org.,* 131: 613-653.

Bineesh, K. K., Manju Sebastine, Akhilesh, K. V., Rajool Shanis, C. P., Hashim, M., Pillai, N. G. K. and Ganga, U. 2009. Diversity of mesopelagic fishes in the deep-sea prawn trawlers from south-west coast of India with notes on myctophids. *Book of Abstracts, 20th All India Congress of Zoology.* Cental Institute of Fisheries Education, Mumbai, p. 167.

Blindheim, J., Chakraborthy, D. and Menon, M. D. 1975. The pelagic fishery resources off the south-west coast of India. In: Shankar, J. V., Sen, D. P., Rao, P. B. R., Potty, V. H., Ranganath, K. A., Rao, B. S. N. and Sastry, M.V. (Eds.), *fish processing industry in India*. Cental Food Technology Research Institute, Mysore, p. 3 - 11.

FAO 1997. Review of the state of world fishery resources: marine fisheries. *FAO Fisheries Circular No. 920*., Rome, FAO, 173 pp.

GjØsaeter, J. and Kawaguchi, K. 1980. A review of the world resources of mesopelagic fish. *FAO Fish. Tech. Pap*., 193: 151 pp.

Gayanilo, Jr. F. C., Sparre, P. and Pauly, D. 1997. The FAO-ICLARM stock assessment tools (FiSAT) user's guide. *FAO computerised information series: fisheries.* FAO, Rome, Italy.

GLOBEC (Global Ocean Ecosystem Dynamics) 1993. *Implementation plan and workshop report for U. S. GLOBEC Studies in the Arabian Sea.* Report No. 3, Scientific steering committee coordinating Office, USA, 89 pp.

Hulley, P. A. 1994. Lanternfishes. In: Paxton, J. R. and Eschmeyer, W. N. (Eds.), *Encyclopedia of fishes*. Academic Press, San Diego, p. 127-128.

Krishnan Kutty, M. and Qasim, S. Z. 1968. The estimation of optimum age of exploitation and potential yield in fish populations. *J. Cons. Perm. Int. Explor. Mer.,* 32 (2): 249-255.

Kubota, T. 1982. Food of lanternfishes in Suruga Bay, Central Japan. In: Melteff, B. R. and Neve, R. A. (Eds.), *Proc. North Pacific Aquaculture Symposium*. University of Alaska, p. 275 - 283.

Manju, S., Chakraborty, K., Bineesh, K. K., Pillai, N. G. K., Abdussamad, E. M. and Vijayan, K. K. 2011. Proximate composition and fatty acid profile of myctophid (*Diaphus watasei* Jordan & Starks, 1904) from the Arabian Sea. *Indian J. Fish*., 58 (1): 103-107.

Nafpaktitis, B. G., Backus, R. H., Craddock, J. E., Haedrich, R. L., Robinson, B. H. and Karnella, C. 1977. Family myctophidae. In: Gibbs Jr. R. H. (Ed.), *Fishes of the Western North Atlantic*. *Mem. Sears Found. Mar. Res*., 1. Pt. 7.

Natarajan, A. V. and Jhingran, V. G. 1961. Index of preponderance method of grading the food element in the stomach analysis of fishes. *Indian J. Fish*., 8: 54-59.

Pauly, D. 1980. A selection of simple methods for the assessment of tropical fish stocks. *FAO. Fish. Circular,* No. 729, FIRM/ 129: 54 pp.

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks. *FAO. Fish. Tech. Paper,* 234: 1-52.

Pauly, D. 1984. Length converted catch curves: A powerful tool for fisheries research in the tropics (Part II). *Fishbyte*, 2 (1): 17-19.

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 south-west cast of India. *Asian Fish. Sci.,* 24 : 453-455.

Date of Receipt : 20.01.2012
Date of Acceptance : 22.04.2013

*Indian J. Fish., 58(1) : 103-107, 2011*

# Note

# Proximate composition and fatty acid profile of the myctophid *Diaphus watasei* Jordan & Starks, 1904 from the Arabian Sea

MANJU SEBASTINE, KAJAL CHAKRABORTY, K. K. BINEESH, N. G. K. PILLAI
E. M. ABDUSAMAD AND K. K. VIJAYAN
*Central Marine Fisheries Research Institute, P. B. No. 1603, Kochi - 682 018, Kerala, India*
*e-mail: manju_seb@yahoo.com*

## ABSTRACT

The edible portion of *Diaphus watasei,* a benthopelagic fish collected off Quilon, south-west coast of India was analysed for proximate composition and fatty acid profile. The fleshy part of the fish was found to contain 15.62% protein, 11.71% fat, 0.47% minerals, 0.28% soluble carbohydrate and 0.01% crude fibre. The dry matter in the fish was found to be about 28%. Monounsaturated fatty acids (MUFA) were found to have the highest (36.7%) share among total fatty acids followed by saturated fatty acids (SFA) (33.3%) and polyunsaturated fatty acids (PUFA) (25.5%). The abundant fatty acids were found to be oleic acid, palmitic acid, docosahexaenoic acid, stearic acid, myristic acid, linolenic acid, eicosapentaenoic acid and palmitoleic acid. The most predominant fatty acid was recorded as oleic acid which contributed 32% to the total fatty acids. Docosahexaenoic acid formed the single largest component of PUFA (9.33%) followed by γ linolenic acid (3.97%) and eicosapentaenoic acid (3.83%). The ω-3 PUFA contributed about 70% of the total PUFAs. The most important ω-3 PUFAs were EPA and DHA that contributed 73% to the total ù -3 polyunsaturated fatty acids.

Keywords: Arabian Sea, *Diaphus watasei*, Fatty acid profile, Myctophids, Proximate composition

Fishes constitute a major portion of the deepsea shrimp trawl by-catch, which demands only very low price and are often discarded in the sea at the time of catch/sorting. These by-catches, when landed are mostly used for fishmeal or manure production. Along the south-west coast of India, lantern fish (myctophiformes) forms a major portion (20-35%) of the fish by-catch in the deepsea shrimp trawls (Bineesh *et al*., 2009). GLOBEC (1993) revealed the existence of large quantity of myctophid stock in the Arabian Sea which is mainly contributed by a single species, *Benthosema pterotum,* which has an estimated biomass of 100 million t in the world oceans. GjØsaeter and Kawaguchi (1980) reported that Indian Ocean has a rich fauna of lanternfishes both in number of species and biomass. Wide occurrence of *Diaphus* spp. from the eastern and north-eastern Arabian Sea has been reported (FAO, 1997; Balu and Menon, 2006). A study carried out by the Central Marine Fisheries Research Institute (CMFRI), during 1997-2002, estimated a biomass of 100,000 t of myctophids along the Indian EEZ of Arabian Sea, dominated by *Diaphus* sp. (Balu and Menon, 2006). Blindheim *et al*. (1975) reported a good concentration of myctophids from certain parts of the south-west coast of India and stated that they had been commercially exploited at certain localities. There are only a few examples of commercial exploitation of lanternfishes; fishermen in Suruga Bay, central Japan used large quantities of *Diaphus* spp. as food (Kubota, 1982). Commercial fishery for *D. coeruleus* and *Gymnoscopelus nicholski* (edible species) in the south-west Indian Ocean and southern Atlantic began in 1977 and catch by former USSR countries reached 51,680 t in 1992, after which the fishery ceased. Despite this, the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) still permits a 2,00,000 t TAC (Total Allowable Catch) for this fishery in its jurisdiction area. An industrial purseseine fishery for *Lampanyctodes hectoris* in South African waters closed in the mid 1980s due to processing difficulties caused by the high oil content of the fish (FAO, 1997). Polyunasaturated fatty acids (PUFAs) are important structural components of cell membranes, and are useful in growth and development of human beings (Chakraborty *et al*., 2010). PUFAs, especially of longer chain length, *viz*., EPA and DHA were reported to be found abundant in marine fish, and have beneficial properties to the prevention of atherosclerosis and other diseases. Therefore, newer species of marine fishes need to be explored as potential healthy food items for better nutrition and health.

Attempts were made in India to utilise fish from the shrimp trawler by-catch, effectively by formulating various products acceptable to consumers (Gopakumar *et al*., 1976), however no detailed biochemical studies with respect to proximate and fatty acid composition have been carried out on deepsea myctophids to understand their nutritional value and use as healthy food items. An understanding of the proximate composition and fatty acids of the species is important, particularly during processing and product development. The study presents the proximate composition and fatty acid profile of one of the dominant deepsea myctophid species, *D. watasei*.

Specimens of *D. watasei* were collected from commercial deepsea shrimp trawlers operated off Quilon, along the south-east coast of Arabian Sea (9-11º N; 72-76º E) during September 2009 at depths of 250 - 400 m. *D. watasei* is a small fish, usually attain a maximum size of 15 - 30 cm with elongate and slightly compressed body. They are similar to anchovies in appearance. Fish samples were transported to laboratory in insulated container with ice and maintained at -22 ºC. Fishes ranging in size from 70 - 130 mm SL (standard length) and 10 - 24 g wet weight were used for analysis. The samples were cleaned in distilled water and scales as well as skin were removed before analysis. Skeletal muscles from dorsal fin to caudal fin of the body were collected and minced well in a mixer to get a homogenous sample.

*Proximate composition analysis*

Moisture content of the samples was analysed by drying the samples of known weight at 60 $^0$C in hot air oven overnight until constant weight, followed by drying for 2 h in a hot air oven at 100 $^0$C (AOAC, 2006). Total nitrogen content (crude protein) was determined by micro Kjeldhal method and the result was multiplied by 6.25 to arrive at the crude protein percentage. Fat was estimated by Soxhlet apparatus using petroleum ether (60 - 80 $^0$C boiling point). Crude fiber is determined following the fraction remaining after refluxing with standard solution of $H_2SO_4$ (1.25% w/v) and NaOH (1.25% w/v) for 30 min, under controlled condition. Acid insoluble ash and nitrogen free extract were determined following AOAC (2006) methods.

*Fatty acid analysis*

The fatty acid composition of the sample was determined as described by Bligh and Dyer (1959) with suitable modification (Chakraborty *et al*., 2007). Fat extracted using methanol : chloroform mixture (2:1, v/v), were saponified and trans-esterified yielding fatty acid methyl esters (FAME). These esters were extracted with n-hexane/water mixture (1:2, v/v). After removal of the aqueous layer, the n-hexane layer was passed through $Na_2SO_4$, concentrated *in vacuo*, reconstituted in petroleum ether, and stored at -20 °C until required for analyses. A Perkin Elmer Auto System XL, Gas chromatograph (Perkin Elmer, USA) equipped with a flame ionisation detector (FID) was used for analysis of the fatty acids. The esterified fatty acids were analysed by gas liquid chromatography with FID detector and compared with fatty acid methyl ester standards (Supelco FAME 37 standard).

*Proximate composition*

The average meat yield from *D. watasei* was 47.25%. The proximate composition of the fish muscle is given in Table 1. The mean moisture content of the meat was 72% of the wet body weight. The protein (15.62% wet weight) and fat (11.71% ww) contents were fairly high. The mean ash content was 0.47% of w/w.

Table 1. Proximate composition of *D. watasei* (on % wet weight basis)

| Parameters * | Wet tissue weight (%) |
|---|---|
| Dry matter | 28.09 $\pm$ 0.04 |
| Crude protein | 15.62 $\pm$ 0.08 |
| Crude fat | 11.71 $\pm$ 0.09 |
| Crude ash | 0.47 $\pm$ 0.03 |
| Crude fiber | 0.01 $\pm$ 0.00 |
| Acid insoluble ash | Negligible |
| Soluble carbohydrate | 0.28 $\pm$ 0.02 |

* AOAC (2006)

*Fatty acid composition*

The fatty acid composition of the fish muscle showed more unsaturated fatty acids (62.2%) than saturated fatty acids (33.28%) (Fig. 1). Major fatty acids present in the fish muscle are given in Table 2. The monounsaturated fatty acids (MUFA) formed the major fatty acids (36.66%) followed by saturated fatty acids (SFA) 33.28% and polyunsaturated fatty acids (PUFA) 25.54%. The percentage of monoenes, dienes and polyenes was 36.66%, 1.49% and 24.05%, respectively of the total fatty acids. The more abundant fatty acids were oleic acid, palmitic acid,

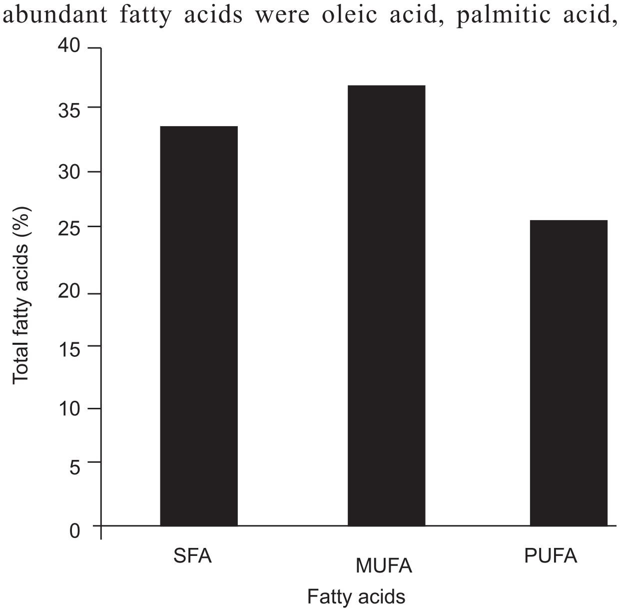



Fig. 1. Percentage of muscle fatty acids of *D. wataesi*

docosahexaenoic acid, stearic acid, myristic acid, linolenic acid, eicosapentaenoic acid and palmitoleic acid. Oleic acid (C18:1n9, 32.03%) was found to be the most prominent. Among the saturated fatty acids palmitic acid (C16:0, 18.03%) was found to be the principal fatty acid. Docosahexaenoic acid (DHA) (C22:6n3, 9.33%), linolenic acid, both γ (GLA) and α (ALA) (C18:3n6 and C18:3n3, 3.97% and 3.47%, respectively) and eicosapentaenoic acid (EPA) (C20:5n3, 3.83%) constitute the principal components of PUFA (Fig. 2.). The fish contain 18.09% of ω-3 fatty acids and 7.45% of ω-6 fatty acids. ω-3 PUFA contributed nearly 70% of the total PUFAs. The most important ω-3 PUFAs, namely EPA and DHA contributed to 73% of the total ω-3 polyunsaturated fatty acids. The fish had a higher ω-3/ω-6 ratio of 2.43.

Table 2. Fatty acid composition of *D. watasei*

| Fatty acids | Total fatty acids (%) |
|---|---|
| Saturated fatty acids (SFA) | |
| C12:0 | 0.05 ± 0.00 |
| C14:0 | 4.42 ± 0.03 |
| C15:0 | 0.47 ± 0.02 |
| C16:0 | 18.30 ± 0.92 |
| C17:0 | 0.77 ± 0.05 |
| C18:0 | 9.22 ± 0.06 |
| C22:0 | 0.05 ± 0.00 |
| Total SFA | 33.28 |
| Monounsaturated fatty acids (MUFA) | |
| C14:1n7 | 0.10 ± 0.01 |
| C16:1n7 | 3.68 ± 0.02 |
| C18:1n9 | 32.03 ± 1.27 |
| C24:1 | 0.85 ± 0.0 |
| Total MUFA | 336.66 |
| Polyunsaturated fatty acids (PUFA) | |
| C18:2n6 | 1.05 ± 0.21 |
| C18:3n6 | 3.97 ± 0.13 |
| C18:3n3 | 3.47 ± 0.16 |
| C20:2n6 | 0.44 ± 0.04 |
| C20:3n6 | 0.33 ± 0.02 |
| C20:4n6 | 1.66 ± 0.09 |
| C20:5n3 | 3.83 ± 0.21 |
| C22:5n3 | 1.46 ± 0.08 |
| C22:6n3 | 9.33 ± 0.17 |
| Total PUFA | 25.54 |

Increase in human population and an increased demand for low value food fishes to meet the nutritional requirement has made myctophids a possible potential resource for exploitation and utilisation. Studies have revealed the abundance of *Diaphus* spp. in the eastern and north-eastern Arabian Sea, where the concentration of *Benthosema pterotum* increases along the Pakistan coast (FAO, 1997) Observations from the present study also indicate that *D. watasei* dominated the trawl catch along the south-west coast of India. Several studies have assayed the chemical composition of myctophids and other mesopelagic fishes (Ayyappan *et al*., 1976; Menon, 1976; Gopakumar *et al*., 1983; Ackman, 1990; Suriah *et al*., 1995; Seo *et al*., 1996; Phleger *et al*., 1999; Seo *et al*., 2001). From nutritional point of view, myctophids are high in proteins, variable in lipids and uniformly low in carbohydrates. Studies have evaluated the lipid content of vertically migrating myctophids and found that they include both triglycerides, which is believed to serve primarily as an energy store, and wax esters, mainly used for buoyancy (FAO, 1997). Gopakumar *et al*. (1983) attempted the prime work in myctophids from the Arabian Sea and estimated biochemical composition of, *B. pterotum* from the Gulf of Oman and Aden, and reported 16.1 g protein per 100 g wet tissue weight and 3.4 g fat per 100 g wet tissue weight. They concluded that lantern fish resembles most marine fish with regard to biochemical composition and can be used as food for both human and animals. Seo *et al*. (1996) analysed lipid level in myctophids as 0.5 - 21.7% of total weight. Suda (1973) reported myctophids had oil extraction efficiency of 110 $lt^{-1}$. Myctophids are essentially crustacean zooplankton feeders and the environmental conditions *viz*., temperature, salinity, availability of food in different seasons *etc* have significant influence on the proximate composition of fish. Ayyappan *et al*. (1976) estimated protein, lipid and ash content of miscellaneous edible fish

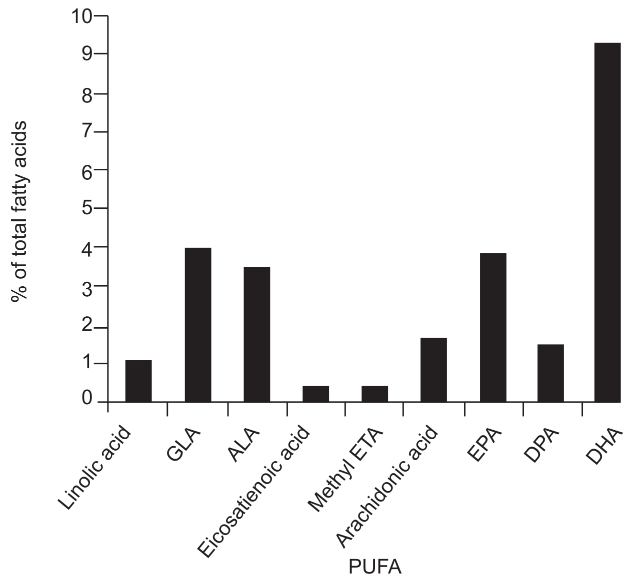



Fig. 2. Percentage of PUFA with respect to total muscle fatty acids in *D. watasei*

from shrimp trawlers and recorded a range of protein from 16.02 - 20.77%, lipid from 0.3 - 5.31% and ash from 3.2 - 5.6%; most of the species recorded high lipid content and low moisture content. In the present study, the protein composition recorded was within the range reported for edible fish (15.62% ww), whereas lipid content registered higher value (11.71% ww) and mineral content was very meagre (0.47% ww).

Fishes are often classified on the basis of their fat content into lean (fat content below 5%), medium fat (5 -10%) and fatty fish (>10%) (Suriah *et al*., 1995). According to Ackman (1990), fishes can be classified as high fat fish where average fat content is more than 8%. Fairly high levels of fat makes myctophids a 'fatty species' and the taste of the fish seems to be largely depending on the fat content. There may be slight difference in the lipid levels and fatty acid content in the same species depending on the sex, age, size, maturity, season, food availability, geographical variation, salinity and water temperature (Stansby, 1981; Piggott and Tucker, 1990). Phleger *et al*. (1999) stated that most of the body lipids of myctophids are stored in the flesh of the fish (68 - 92%). Earlier works (Seo *et al*., 1996; Saito and Murata, 1996; Phleger *et al*., 1999) revealed that myctophids have high content of monoene fatty acids in the lipids and the present study also supports this. Oleic acid is the major fatty acid followed by palmitic acid which is similar with the study by Saito and Murata (1996). Study by Seo *et al*. (1996) proved that palmitic acid and DHA were the major fatty acids in tropical myctophids where as oleic acid and palmitic acid were predominant in the temperate water species, though oleic acid was the major fatty acid of total lipids in myctophids. Fatty acid profile of *Diaphus theta* and *Diaphus gigas* (Saito and Murata, 1996) from the northern Pacific Ocean showed high levels of monounsaturated fatty acids followed by saturated fatty acids and polyunsaturated fatty acids, but both the species showed low level of PUFA (*D. theta*, 20.7% and *D. gigas,* 9.6% of total fatty acids) as compared with that of the present study with an average PUFA of 25.54%. This is not in agreement with the report by Ackman (1989) that the tropical and sub-tropical species are reported to contain lower levels of PUFA than temperate species. Phleger *et al*. (1999) studied the composition of wax ester and triacylglycerol in eleven species of myctophids and found that, wax ester dominated species contained lower levels of PUFA than in triacylglycerol-rich species and estimated a high amount of triacylglycerol with an average of 74% of total lipids in *Diaphus* spp. The total ω-3 fatty acids were found to be higher than the ω-6 where, this is factual in most of the marine fishes especially DHA and EPA (Wang *et al.,* 1990). As in the case of marine fishes, this species is also rich in DHA, EPA and ALA, which are the major components of omega 3 fatty acid which is one of the essential nutrient for humans.

*Diaphus watasei* has high protein as well as fat content and hence it could well be a potential source of alternative protein and fat. At present *D. watasei* is not commercially exploited in India, although it is used for preparing fish meal by selected local populations. Since *D. watasei* has high fat content, there is a possibility of fatty acid rancidity during the production of fish meal and hence before processing oil can be extracted so that rancidity can be minimised. Also the fish is not suitable for long time freezing and cold storage due to fatty acid oxidation. In view of the beneficial nutritive value, *D. watasei* is suitable for direct consumption. Since most myctophid resources are subjected to non-predatory mortality, with the biomass ending up with decomposition, attempts can be made to encourage targeted exploitation of these valuable resource which can be utilised as a source of cheap animal protein.

## Acknowledgements

The work has been funded by the Central Marine Living Resources and Ecology, Kochi. The authors are indebted to the Director, Central Marine Fisheries Research Institute, Kochi for his support. The support from technical staff and scholars of Marine Biotechnology Division, CMFRI, Kochi in sample analysis is gratefully acknowledged.

## References

Ackman, R. G. 1989. Fatty acids. In: Ackman, R. G. (Ed.), *Marine biogenic lipids, fats and oils*. CRC press, p. 103 - 138.

Ackman, R. G. 1990. Seafood lipids and fatty acids. *Food Rev. Int*., 6(4): 617.

AOAC 2006. *Official methods of analysis*. 18th edn., Association of Official Analytical Chemists, AOAC, USA, 2000 pp.

Ayyappan, M. P. K., Shenoy, A. V. and Gopakumar, K. 1976. Proximate composition of 17 species of Indian fish. *Fish. Technol.*, 13(2): 153 - 155.

Balu, S. and Menon, N. G. 2006. Lantern fish - a potential deep sea resource. *Marine Ecosystem, ENVIS*, 5(1): 3 - 5.

Bineesh, K. K., Manju Sebastine, Akhilesh, K. V., Rajool Shanis, C. P., Hashim, M., Pillai, N. G. K. and Ganga, U. 2009. Diversity of mesopelagic fishes in the deepsea prawn trawlers from south-west coast of India with notes on myctophids. *Book of Abstracts, 20th All India Congress of Zoology,* CIFE, Mumbai, p. 167.

Bligh, E. G. and Dyer, W. J. 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.*, 3: 911 - 917.

Blindheim, J., Chakraborthy, D. and Menon, M. D. 1975. The pelagic fishery resources off the south-west coast of India. In: Shankar, J. V., Sen, D. P., Rao, P. B. R., Potty, V. H., Ranganath, K. A., Rao, B. S. N. and Sastry, M. V. (Eds.), *Fish processing industry in India*. CIFTRI, Mysore, p. 3 - 11.

Chakraborty, K., Vijayagopal, P., Chakraborty, R. D. and Vijayan K. K. 2010. Enrichment of eicosapentaenoic acid concentrates from sardine oil by bacterial (*Bacillus circulans*) lipase isolated from seaweed *Turbinaria conoides*. *Food Chem.,* 120: 433 - 442.

Chakraborty, R. D., Chakraborty, K., Radhakrishnan, E. V. R. 2007. Variation in fatty acid composition of *Artemia salina* nauplii enriched with microalgae and baker's yeast for use in larviculture *J. Agric. Food Chem.,* 55: 4043 - 4051.

FAO 1997. Review of the state of world fishery resources: marine fisheries. FAO Fisheries Circular No. 920, FAO, Marine Resource Service, Fisheries Resources Division, Fisheries Department. *FAO Fisheries Circular* No. 920, Rome, FAO, 173 pp.

GjØsaeter, J. and Kawaguchi, K. 1980. A review of the world resources of mesopelagic fish. *FAO Fish. Tech. Pap*., 193 : 151 pp.

GLOBEC (Global Ocean Ecosystem Dynamics). 1993. *Implimentation plan and workshop report for U. S. GLOBEC studies in the Arabian Sea.* Report No. 3, Scientific steering Committee coordinating Office, USA, 89 pp.

Gopakumar, K., Shenoy, A. V., Ayyappan, M. P. K., James, M. R. and Iyer, K. M. 1976. Speciality products from miscellaneous trash fish. In: Shanker, J. V., Sen, D. P., Rao, B. P. R., Potty, V. H., Ranganath, K. A., Rao, S. B. N. and Sastry, V. M. (Eds.), *Fish processing industry in India*. Association of food scientists and technologists, India, p. 68 - 70.

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: 17 - 19.

Kubota, T. 1982. Food of lanternfishes in Suruga Bay, Central Japan. In: Melteff, B. R. and Neve, R. A. (Eds.), *Proc. North Pacific Aquaculture Symposium*. University of Alaska, p. 275 - 283.

Menon, M. D. 1976. Handling and processing of pelagic fish in India. In: Shankar, J. V., Sen, D. P., Rao, P. B. R., Potty, V. H., Ranganath, K. A., Rao, B. S. N. and Sastry, M. V. (Eds.) *Fish processing industry in India*. CIFTRI, Mysore, p. 12 - 15.

Phleger, C. F., Nealson, M. W., Mooney, B. D. and Nicholes, P. D. 1999. Wax esters versus triacylglycerols in myctophid fishes from the Southern Ocean. *Antartic Sci.*, 11(4): 436 - 444.

Piggott, G. M. and Tucker, B. W. 1990. *The effect of technology on nutrition*. Marcel Dekker Inc., New York, USA, 362 pp.

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

Seo, H. S., Endo, Y., Fujimoto, K., Watanabe, H. and Kawaguchi, K. 1996. Characterisation of lipids in myctophid fish in the subartic and tropical Pacific ocean. *Fish. Sci.*, 62(3): 447 - 453.

Seo, H. S., Endo, Y., Moku, M., Kawaguchi, K. and Fujimoto, K. 2001. Wax ester biosynthesis in the liver of myctophids fishes. *Lipids*, 36(4): 389 - 393.

Stansby, M. E. 1981. Reliability of fatty acid values purporting to represent composition of oil from different species of fish. *J. Am. Oil Chem. Soc*., 58: 13 - 16.

Suda, A. 1973. Development of fisheries for non-conventional species. *J. Fish. Res. Board Canada*, 30(12) Part 2: 2121 - 2158.

Suriah, A. R., Teh., S. H., Osman, N. and Nik, M. D. 1995. Fatty acid compositions of some Malaysian fresh water fish. *Food Chem.*, 54: 45 - 49.

Wang, Y. J., Miller, L. A., Perren, M. and Addis, P. B. 1990. Omega-3 fatty acids in Lake Superior fish. *J. Food. Sci.,* 55(l): 71 - 73.

Date of Receipt : 27.07.2010
Date of Acceptance : 16.02.2011

*J. Mar. Biol. Ass. India,* **52** (1) : 109 - 112, January - June 2010

**Short Communication**

# First record of the Garman's lanternfish Diaphus garmani (*Family: Myctophidae*) from Indian waters

*K. K. Bineesh, Manju Sebastine, K. V. Akhilesh and N. G. K. Pillai

*Central Marine Fisheries Research Institute, P. B. No. 1603, Ernakulam North P. O., Cochin-682 018, Kerala, India. *E-mail: bineeshmarine@yahoo.com*

**Abstract**

The myctophid *Diaphus garmani* is recorded for the first time from Indian waters. Three specimens (54-59 mm standard length) were collected from deep sea shrimp trawlers off Quilon, southwest coast of India, between 80 -110 N and 740-760 E, at depths from 250 to 450 m.

**Keywords:** *Diaphus garmani*, first record, southwest coast of India, Myctophidae

## Introduction

Lanternfish of the family Myctophidae are found in all the oceans, with 32 genera and 240 species (Nelson, 2006). An important characteristic of myctophids is the presence of luminescent organs called photophores along the ventral body surface and head. For species identification, different patterns of photophores have been used along with meristic data. These fishes have species-specific diel vertical migration patterns (Watanabe *et al*., 1999). Like many other mesopelagic fishes, myctophids are an important constituent of the diet of commercially important oceanic fishes and marine mammals (Jackson *et al*., 1998).

Investigations on the myctophid fauna of the western and northern Arabian Sea were carried out by R/V Dr. *Fridfjof Nansen* during 1975-1981 and 1983-84 (Gunnar *et al*., 1999). Studies on distribution and abundance of Myctophidae in the EEZ of India were carried out by FORV *Sagar Sampada* during 1985-1986 (Mini and James, 1990). About 55 species of myctophids are known from the Arabian Sea including its southern part of the Indian Ocean (Nafpaktitis, 1978). Karuppasamy *et al.,* (2006) reported 27 species of myctophids from the Indian EEZ. Somvanshi *et al.* (2009) reported 5 species of myctophids from the southwest coast of India.

*Diaphus* is the most speciose of the myctophid genera, with 70–75 known species (Nafpaktitis *et al.,* 1995). The members of this genus can be assigned to two distinct groups on the basis of the presence or absence of a suborbital (So) luminous organ and an inner series of broad-based, forward-hooked teeth on the posterior part of the premaxilla (Nafpaktitis, 1978). *Diaphus garmani* is a small diaphid fish, which attains a maximum length of about 60 mm.

## Material and Methods

Three specimens of *D. garmani* (Fig. 1) were collected in April 2009 from a commercial deep-sea shrimp trawler which operated from 250 to 450 m depth in the outer shelf of southwest coast of India between $8^0$N - $11^0$N and $74^0$E - $76^0$E. Identification was based on the luminous organs on the head, number of fin rays, gill rakers and morphometric characters (Nafpaktitis, 1978). Photophore nomenclature follows Hulley (1984). The specimens of *D. garmani* were deposited in the National Biodiversity Referral Museum, CMFRI, India under the accession Number GB.27.1.5.25.

Fig. 1. *Diaphus garmani,* 54 mm SL

## Results and Discussion

***Description:*** Peculiar characters of this fish which makes it different from other species are the position and size of Dorsonasal (Dn), Ventronasal (Vn) and Suprapectoral (PLO). Dn is small directed anterolaterally. Descriptive characters of the fish are: origin of dorsal fin over base of ventral fin; origin of anal fin behind end of base of dorsal fin; base of adipose fin directly over end of base of anal fin; PLO distinctly nearer to lateral line than to base of pectoral fin; Supraventral (VLO) midway between lateral line and base of ventral fin; SAO (Supraanal organ) on a straight line, $SAO_2$ slightly behind line through centers of supra anal ($SAO_1$) and $SAO_3$; $SAO_3$ at lateral line; anterior anal ($AOa_1$) abruptly elevated, directly above $AOa_2$; last AOa also elevated; posterolateral (Pol) in contact with lateral line; posterior anal ($AOp_1$) over end of base of anal fin; first three precaudal (Prc) evenly spaced, forming a gently arc; $Prc_3$-$Prc_4$ interspace enlarged with $Prc_4$ about 1.5 times its diameter below midlateral line; a vertically elongated, rough rectangular luminous scale at PLO.

Table 1. Morphometric measurements and meristics of *Diaphus garmani*

| Measurements | Off Japan, 32 specimens (25.5-53.0 mm SL)* | Sulu Sea, 6 specimens (52.0-59.5 mm SL)* | South China Sea, 1 specimen (40.0 mm SL)* | Atlantic, 45 specimens (27.5-48.0 mm SL)* | Present study, 3 specimens (53.4-58.9 mm SL) |
|---|---|---|---|---|---|
| Head length | 26.5-30.7 | 26.2-28 | 27.9 | 27.6-30.4 | 27.8-31.3 |
| Head depth | 21.6-25.0 | 22.3-23.4 | 23.7 | 21.4-24.2 | 22.5-24.5 |
| Eye diameter | 6.9-8.7 | 6.9-7.6 | 7.5 | 6.9-8.8 | 7.0-7.4 |
| Upper jaw length | 19.4-22.6 | 19.3-20.3 | 21.9 | 20.0-22.3 | 20.3-24.6 |
| Body depth | 20.8-24.1 | 22.4-23.4 | 22.9 | 22.2-24.7 | 22.4-23.4 |
| Caudal depth | 9.2-12.9 | 10.4-11.6 | 10.7 | 10.3-12.2 | 10.6-11.4 |
| Predorsal length | 40.8-44.0 | 40.7-41.9 | 42.9 | 41.1-44.7 | 40.4-41.4 |
| Preventral length | 40.4-44.7 | 39.1-44.1 | 42.4 | 39.8-44.9 | 39.7-43.7 |
| Prepectoral length | 27.4-30.5 | 26.2-29.2 | 28.4 | 27.6-30.3 | 28.3-30.1 |
| Preanal length | 59.3-63.3 | 59.9-64.6 | 59.6 | 59.1-63.1 | 60.1-61.7 |
| Preadipose length | 76.2-80.2 | 77.2-80.5 | 79.8 | 77.8-81.8 | 79.2-80.7 |
| Upper jawlength/E.D | 2.4-3.1 | 2.6-2.9 | 2.6 | 2.4-3.2 | 2.5-2.8 |
| H.D/ED | 3.3-4.1 | 3.5-4.0 | 3.3 | 3.3-4.3 | 3.2-3.8 |
| Dorsal fin base length | 17.7-21.2 | 17.3-20.4 | 20.4 | 18.8-22.4 | 19.2-20-8 |
| Anal fin base length | 17.5-21.3 | 10.0-20.6 | 20.2 | 19.7-22.6 | 18.8-20.1 |
| Dorsal fin ray | 14 (13-15) | 15 (14-16) | 15 | 15 (14-16) | 15 |
| Anal fin ray | 15 (14-17) | 15 (14-16) | 15 | 16 (15-17) | 15 |
| Pectoral fin ray | 12 (11-12) | 11-12 | 11 | 12 (11-12) | 12 |
| Gill rakers on first arch | 7 (6 or 8, rarely 5) + 1+13-14 (rarely 12) = 20-23 (rarely 18) | 7+1+14 (13)=22(21) | 7+1+13=21 | 7 (6 - 8)+ 5 (4-6very rarely 7) =12( 11-13, very rarely 14) | 7+1+14=22 |
| AO photophores | 6-8+5-6 (rarely 4)=11-13 (rarely 14) | 6-7+5-6= 11, 12 | 6+6=12 | | 7+4 |
| Lateral line scales | 37-38 | 37-38 | | 38-39 | 38 |

*Source, Kawaguchi and Shimizu (1978)

***Morphometric and meristic characteristics:*** Number of fin rays (all soft): dorsal - 15, pectoral -12, pelvic - 9, anal - 15 and caudal - 20. Gill rakers on first arch - 22 (8+14). Photophores were counted as follows: PVO – 2 (Subpectoral organ), PO – 4 (Pectoral organs), VO – 3 (Ventral organs), SAO - 3, AOa - 7, AOp - 4 and Prc - 4. Lateral line organs - 38. Morphometric measurements of the specimens are presented in Table 1. Other morphometric and meristic data of these specimens are similar to those collected from the Southeast Asian seas recorded by Kawaguchi and Shimizu (1978).

Other records of occurrence of the species include Eastern Atlantic: Canary Islands, off Senegal; Western Atlantic: west of 30°W between 36°N and 10°S; Indo-West Pacific: off East Africa, Comoro Islands and west coast of Madagascar; off Japan south of 40° N, southeast Asian seas, Australia and New Zealand; Eastern Pacific: near Hawaii, and off Acapulco, Mexico and South China Sea; Western Indian Ocean: between 16° S and 26° S and off Sri Lanka (Fig. 2) (Nafpaktitis, 1978; Dalpadado and Gjosaeter, 1993, Froese and Pauly, 2007). The specimens reported here widen the known distribution of this species to the southwest coast of India.

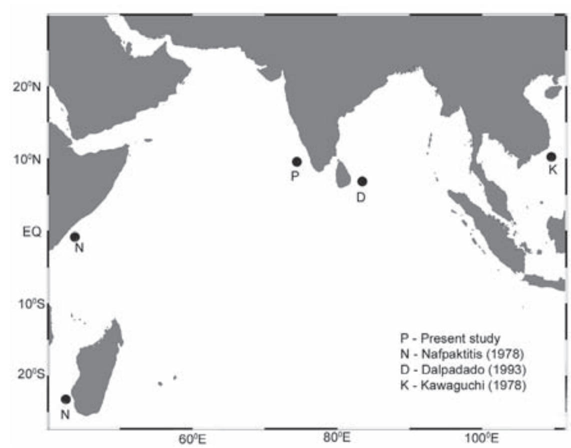



Fig. 2. Map showing distribution records of *Diaphus garmani*

*Diaphus garmani* is the tenth species of the genus *Diaphus* to be recorded from the Indian waters after *D. problematicus*, *D. effulgens*, *D. fragilis*, *D. perspicillatus*, *D. aliciae*, *D. lucidus*, *D. phillipsi*, *D. signatus*, *D. watasei* (Karuppasamy *et al*., 2006), *D. thiollieri* (FAO, Smith and Heemstra.1986)

## Acknowledgements

We are grateful to Dr. G. Syda Rao, Director, Central Marine Fisheries Research Institute, Kochi for the support. We are also grateful to Dr. V. N. Sanjeevan, Director, Centre for Marine Living Resources and Ecology and the Ministry of Earth Sciences, India for providing funding support. We also express our thanks to Mr. Ravi, fishing master of the trawler for providing the specimens.

## References

Dalpadado, P. and J. Gjosaeter. 1993. Lanternfishes (Myctophidae) in Sri Lankan Waters. *Asian Fisheries Society,* 9: 161 – 168.

Jackson, G. D., J. F. McKinnon, C. Lalas, R. Ardern and N. G. Buxton. 1998. Food spectrum of the deepwater squid *Moroteuthis ingens* (Cephalopoda: Onychoteuthidae) in New Zealand waters. *Polar Biol.,* 20: 56 - 65.

FAO. 1997. Review of the state of world fishery resources: marine fisheries. Marine Resources Service, Fishery Resources Division. FAO Fisheries Circular. No. 920. Rome, 173 p.

Froese, R. and D. Pauly. (Eds.). 2007. FishBase. World Wide Web electronic publication. www.fishbase.org., version (09/2009).

Gunnar, S., G. Bianchi and T. Stromme. 1999. The Dr. Fridtjof Nansen Programme. 1975-1993. *FAO Fish. Tech. Pap.,* No. 391, 434 pp.

Hulley, P. A. 1984. Myctophidae. *In*: P. J. P. Whitehead, M. Hureau, J. Nielsen and J. Tortonese (Eds.) *Fishes of the Northwest Atlantic and the Mediterranean*, Vol. 1, Paris, p. 429 - 483.

Karuppasamy, P. K., K. Balachandran, G. Simmy, S. Balu, P. Vimala and N. G. Menon. 2006. A checklist of fishes collected by IKMT from the DSL survey in the Indian EEZ of Arabian Sea. *Indian Hydrobiology*, 9(2): 311 - 316.

Kawaguchi, K. and H. Shimizu. 1978. Taxonomy and distribution of the lanternfishes, genus *Diaphus* (Pisces, Myctophidae) in the western Pacific, eastern Indian Ocean and the southeast Asian Seas. *Bulletin of the Oceanographic Research Institute*, University of Tokyo 10: 1 - 145.

Mini R. and P. S. B. R. James. 1990. Distribution and abundance of lanternfishes of the family Myctophidae in the EEZ on India. *In*: K. J. Mathew (Ed.) *Proceedings of the second workshop on scientific results of FORV Sagar Sampada,* Cochin, India, p. 285 - 290.

Nafpaktitis, B. G. 1978. Systematics and distribution of lanternfishes of the genera *Lobianchia* and *Diaphus* (Myctophidae) in the Indian Ocean. *Natural History Museum of Los Angeles County Science Bulletin,* 30: 1 - 92.

Nafpaktitis, B. G., D. A. Robertson and J. R. Paxton. 1995. Four new species of the lanternfish genus *Diaphus* (Myctophidae) from the Indo-Pacific. *New Zealand J. Mar. Fresh.,* 29: 335 - 344.

Nelson, J. S. 2006. Fishes of the World, 4$^{th}$ edn. John Wiley and Sons, New York, 601 pp.

Smith, M.M and P.C. Heemstra.1986. (Ed). Smith's Sea fishes. Newyork: Springer-Verlag. 1047 pp.

Somvanshi, V. S., M. K. Sajeevan and J. Rajasekharan Nair. 2009. Systematics, distribution and abundance of myctophid resources off the south west coast of India. *In*: E. Vivekanandan *et. al.,* (Ed.) *Book of Abstracts - Marine Ecosystem Challenges and Opportunities*. Marine Biological Association of India, p. 42 - 43.

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

Received : 11.03.10
Accepted : 15.05.10

# Lanternfishes (Myctophids): by-catch of deepsea shrimp trawlers operated off Kollam, south-west coast of India

N. G. K. Pillai, K. K. Bineesh, Manju Sebastine and K. V. Akhilesh
*Central Marine Fisheries Research Institute, Kochi*

## Introduction

By-catch and discards have received a great deal of scientific attention, their minimisation being a goal of marine fisheries management (Powers, 2006). The Nordic workshop (Nordic Council of Ministers, 2003) defined by-catch as "the proportion of the catch which is taken on the board, or brought to the surface by the vessel and which is subsequently thrown back to sea, dead or dying or likely to die". Most of the earlier studies deal with optimisation of fishing efficiency and minimisation of fishing impact, but by-catch and discards data have rarely been used to learn about the distribution, abundance and biology of the incidental species being caught, although several recent studies have indicated the informative value of by-catch concerning food habits (Koen Alonso *et al.,* 2001), feeding ecology (Rheeder and Sauer, 1998) and recruitment indices (Payne *et al.,* 2005).

According to FAO discard database, during 1992 - 2001, yearly average discards were estimated as 7.3 million t of which Indian Ocean accounted for about 9%. Mesopelagic fishes are common by-catch in many of the world's fisheries targeting deepsea shrimp species. Shrimp trawl fisheries generate a higher proportion of discards than any other fishery type (Alverson *et al.,* 1994) and account for more than one third of the estimated total global discards from fisheries (Pascoe, 1997). In most cases, the weight of the by-catch exceeds that of the shrimp catch and is comprised of tens or hundreds of species of fish and invertebrates (Stobutzki *et al.,* 2001; Steele *et al.,* 2002). In the past, most of the mesopelagic fish catches were discarded without being properly recorded.

The mesopelagic zone has been defined in different ways based on depth, temperature and light regimes. Depth seems to be the best criterion and mesopelagic fish can be defined as fishes that live in the mesopelagic zone *i.e.*, between 200 and 1000 m depth. Beebe (1935) was the first fishery biologist to observe myctophid fishes in the mesopelagic zone of the ocean. Many fish families fall within this definition, but generally the Myctophidae, Neoscopilidae and Gonostomatidae are dominant. Sternoptychidae, Bathylagidae, Chiasmodontidae, Trichiuridae, Nomeidae and others seem to be fairly important in some areas. In the present paper, the main emphasis has been given to the family Myctophidae.

Myctophids are the most species-rich family of mesopelagic communities in the world's oceans (Gjøsaeter and Kawaguchi, 1980), with an estimated biomass of about 70–200 million t (Lubimova *et al.,* 1987). Family Myctophidae comprises 32 genera with at least 240 species (Nelson, 2006), found in all oceans from near surface to deep waters. They are thought to migrate to the productive epipelagic zone, which contributes to their abundance in the open sea (Watanabe *et al*., 2002). About 55 species of myctophids are known from the Arabian Sea including its southern part of the Indian Ocean (Kornilova and Tsarin, 1993; Tsarin, 1993), with an estimated biomass of 100 million t of *Benthosema pterotum* (US GLOBEC, 1993). Karuppasamy *et al.* (2006) reported 27 species of myctophids from Indian EEZ. Somvanshi *et al.* (2009) reported five species of myctophids from south-west coast of India. Gopakumar *et al*. (1983) studied the fatty acid composition of *B. pterotum* and Lekshmi Nair *et al.* (1983) carried out nutritional evaluation of the fish meal and fish hydrolysates of *B. pterotum* from Gulf of Oman and found them to be of good quality, which could be used as a protein supplement in animal feeds.

The present report describes the myctophid by-catch along with other mesopelagic fish catch by deepsea shrimp trawlers operating in the

Quilon bank ($8^0$ N -$11^0$ N and $74^0$ E -$76^0$ E), Kerala coast. Regular observations were made in the two major fish landing centres, Sakthikulangara, Kollam and Cochin Fisheries Harbour from December, 2008 to May, 2009 and subsamples of by-catch were collected to identify the myctophid species in the deepsea trawl fisheries. The trawlers operating from Neendakara and Cochin Fisheries Harbours have an OAL of 13-16 m with an engine power of 100 to 120 HP and fitted with echosounders, GPS *etc.* (Fig. 1). The shrimp trawls have mesh sizes ranging from 40 mm (in the front part) to 28 mm (in the codend). Based on the usual catches of bottom trawl operation, it was found that shrimps mostly inhabited the uneven bottom surface. The trawlers specifically targeted *Aristeus alcockii, Heterocarpus woodmasoni, Heterocarpus gibbosus, Plesionika spinipes* and *Metapenaeopsis andamanensis*. These trawlers stay back at sea for 9 to 15 days and operate at a depth range of 350 to 450 m. Trawling operations are mainly carried out during early morning as well as late evening and the catches were dominated by deepsea shrimps. The trawling operations extend from 4 to 6 h at a towing speed of 2 knots. Normally in each operation, by-catch contributes about 20 to 40% along with targeted species. Sometimes the by-catch exceeded more than 80% and was discarded without being taken onboard the vessel. So far there is no mechanism to make a reasonable estimate of these discards. Identification of fish species was carried out following Smith and Heemstra (1986) and Fischer and Bianchi (1984).

The major components in the by-catch belonged to the families Rhinochimaeridae, Echinorhinidae, Centrophoridae, Squalidae, Stomiidae, Sternoptychidae, Gonostomatidae, Ateleopodidae, Chlorophthalmidae, Ipnopidae, Evermannellidae, Neoscopelidae and Myctophidae. The identified species are listed in the Table 1.

By-catch comprised considerable quantity of small shrimps and non-conventional deepsea fishes of marketable size (Fig. 2). After onboard sorting, they were brought to the landing centres and sold for nominal price, to be mainly used in fishmeal production (Fig. 3). Of late, due to heavy demand for fish and high cost, some of the species are being used for human consumption, fetching about Rs. 30-45/- per kg. All large sized chondrichthyans belonging to families like Rhinochimaeridae, Echinorhinidae, Centrophoridae and Squalidae are getting high values in the landing centres.

Fig. 1. Deepsea shrimp trawler at Kollam

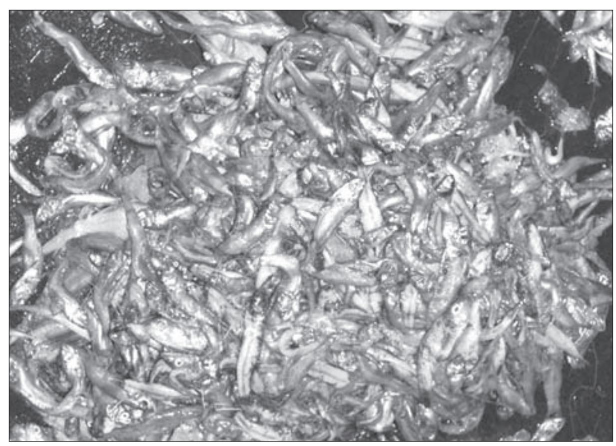


Fig. 2. By-catch and discards

Fig. 3. Low value by-catch landed at Cochin

Among the lanternfishes, benthopelagic myctophids dominated followed by Neoscopilids. *Diaphus* was the most abundant genus followed by

Table 1. Major species observed in the by-catch

| Family | Species |
|---|---|
| Rhinochimaeridae | *Neoharriotta pinnata* (Schnakenbeck, 1931) |
| Echinorhinidae | *Echinorhinus brucus* (Bonnaterre, 1788) |
| Centrophoridae | *Centrophorus* sp. |
| Squalidae | *Squalus* spp. |
| Rajidae | *Dipturus* sp. |
| Notacanthidae | *Notacanthus* sp. |
| Congridae | *Bathyuroconger vicinus* (Vaillant, 1888) |
| Nemichthyidae | *Nemichthys scolopaceus* Richardson, 1848 |
| Alepocephalidae | *Alepocephalus* spp. |
| Stomiidae | *Astronesthes indicus* Brauer, 1902 |
| | *Chauliodus sloani* Bloch & Schneider, 1801 |
| Sternoptychidae | *Polyipnus indicus* Schultz, 1961 |
| | *Polyipnus* sp. |
| Phosichthyidae | *Vinciguerria* sp. |
| Ateleopodidae | *Ateleopus indicus* Alcock, 1891 |
| | *Ijimaia loppei* Roule, 1922 |
| Chlorophthalmidae | *Chlorophthalmus bicornis* Norman, 1939 |
| | *Chlorophthalmus agassizi* Bonaparte, 1840 |
| Ipnopidae | *Bathypterois atricolor* Alcock, 1896 |
| Evermannellidae | *Evermannella indica* Brauer, 1906 |
| Neoscopelidae | *Neoscopelus microchir* (Matsubara, 1943) |
| Myctophidae | *Myctophum obtusirostre* Tåning, 1928 |
| | *Diaphus thiollierei* Fowler, 1934 |
| | *Diaphus watasei* Jordan & Starks, 1904 |
| | *Myctophum fissunovi* Becker & Borodulina, 1971 |
| | *Diaphus garmani* Gilbert, 1906 |
| Macrouridae | *Malacocephalus laevis* (Lowe, 1843) |
| | *Nezumia propinqua* (Gilbert & Cramer, 1897) |
| | *Gadomus* spp. |
| Moridae | *Physiculus roseus* Alcock, 1891 |
| Ophidiidae | *Dicrolene multifilis* (Alcock, 1889) |
| | *Glyptophidium argenteum* Alcock, 1889 |
| | *Glyptophidium* sp. |
| Acropomatidae | *Synagrops* spp. |
| Lophiidae | *Lophiomus setigerus* (Vahl, 1797) |
| Trachichthyidae | *Gephyroberyx darwinii* (Johnson, 1866) |
| Berycidae | *Beryx splendens* Lowe, 1834 |
| | *Beryx* sp. |
| Zeidae | *Zenopsis conchifer* (Lowe, 1852) |
| Setarchidae | *Setarches guentheri* Johnson, 1862 |
| Scorpaenidae | *Pontinus nigerimum* Eschmeyer, 1983 |
| Triglidae | *Pterygotrigla hemisticta* (Temminck & Schlegel, 1843) |
| Priacanthidae | *Priacanthus hamrur* (Forsskål, 1775) |
| | *Heteropriacanthus* sp. |
| Centrolophidae | *Psenopsis cyanea* (Alcock, 1890) |
| Trichiuridae | *Trichiurus auriga* Klunzinger, 1884 |
| Bathyclupeidae | *Bathyclupea* sp. |
| Gempylidae | *Neoepinnula orientalis* (Gilchrist & von Bonde, 1924) |
| Polymixiidae | *Polymixia japonica* Günther, 1877 |
| Ariommatidae | *Ariomma indica* (Day, 1871) |
| Nomeidae | *Cubiceps whiteleggii* (Waite, 1894) |
| | *Cubiceps* sp. |
| Percophidae | *Bembrops caudimacula* Steindachner, 1876 |
| Peristediidae | *Peristedion miniatum* Goode, 1880 |
| Bothidae | *Chascanopsetta lugubris* Alcock, 1894 |
| Samaridae | *Samaris cristatus* Gray, 1831 |
| Cynoglossidae | *Cynoglossus arel* (Bloch & Schneider, 1801) |

*Myctophum* in the family Myctophidae. Among the myctophids, *Diaphus watasei* was the most dominant species. *Diaphus garmani* was recorded for the first time from the Indian waters (Fig. 4). The identified species of the family Myctophidae includes *D. watasei, D. thiollierei, D. garmani, Myctophum obtusirostre* and *M. fissunovi.* Length frequency

Fig. 4. *Diaphus garmani*, 54 mm LS

studies of *D. watasei* was carried out. A total of 90 samples of *D. watasei* were examined and the $S_L$ ranged from 7 to 13 cm with a prominent mode at 10 cm. Gut content analysis of *D. watasei* (n = 86) revealed that stomach of most of the fishes were empty.

In the present study, information on landings of myctophids as a major component in the by-catch of deepsea shrimp trawlers was confirmed. Most of the species obtained were benthopelagic and are available significantly during early morning and late evening which provide information on biology and species compositions. *D. watasei* was the most dominant species observed during the study. Based on the observations of the present study, it is suggested that bottom trawling survey along with midwater trawling should be carried out in order to estimate the actual biomass of myctophids in the Arabian Sea.