Myctophids of Western Indian Ocean with special reference to Eastern Arabian Sea

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Myctophids of Western Indian Ocean with Special Reference to Eastern Arabian Sea

Ph. D. Thesis in Marine Sciences

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Front Cover

A Headlight Fish (Diaphus sp.)

CERTIFICATE

This is to certify that the thesis entitled "**Myctophids of Western Indian Ocean with special reference to Eastern Arabian Sea**" is an authentic record of the research work carried out by Ms. Meera K.M. (Reg. No.: 4324), under my scientific supervision and guidance at the Centre for Marine Living Resources & Ecology (CMLRE), Kochi, in partial fulfilment of the requirements for award of the degree of Doctor of Philosophy of the Cochin University of Science & Technology and that no part thereof has been presented before for the award of any other degree, diploma or associateship in any University. Further certified that all relevant corrections and modifications suggested during the pre-synopsis seminar and recommended by the Doctoral Committee have been incorporated in the thesis.

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March, 2018

<u>DECLARATION</u>

I hereby declare that the thesis entitled "**Myctophids of Western Indian Ocean with special reference to Eastern Arabian Sea**" is an authentic record of research work conducted by me under the supervision of Dr. V. N. Sanjeevan, Former Director, Centre for Marine Living Resources & Ecology (CMLRE), Kochi and no part of it has been presented for any other degree or diploma in any University.

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Meera K. M.

Dedication

To My family

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LIST OF ACRONYMS & ABBREVIATIONS

ANOSIM	-	Analysis of Similarities test
AS	-	Arabian Sea
BT	-	Bottom of thermocline
CCA	-	Canonical Correspondence Analysis
CCAMLR	-	Convention Area of the Commission for conservation of Antarctic Marine Living Resources
CT	-	Cosmos Trawl
CTD	-	Conductivity, Temperature, and Depth
DO	-	Dissolved oxygen
DSL	-	Deep scattering layer
DVM	-	Diurnal vertical migration
EAS	-	Eastern Arabian Sea
EIO	-	Equatorial Indian Ocean
GCA	-	Gut content Analysis
GSI	-	Gonado Somatic Index
IDVM	-	Inverse Diurnal vertical migration
IRI	-	Index of relative importance
Kn	-	Relative Condition Factor
Lat	-	Latitude
Long	-	Longitude

LWR	-	Length weight relationship
MT	-	Mid Water Trawl
NEAS	-	North Eastern Arabian Sea
nMDS	-	non metric multidimensional scaling
No DVM	-	Non migrating Diurnal vertical migration
OMZ	-	Oxygen Minimum Zone
PERMANOVA	-	Permutational Multivariate Analysis of Variance
PRIMER	-	Plymouth Routines in Multivariate Ecological Research
PSU	-	Practical Salinity Unit
SEAS	-	South Eastern Arabian Sea
SIMPER	-	Similarity percentage
SIM	-	Spring inter monsoon
SL	-	Standard Length
SM	-	Summer monsoon
SSS	-	Sea Surface Salinity
SST	-	Sea Surface Temperature
STNAS	-	Sub Tropical Northern Arabian Sea
IO	-	Indian Ocean
STSWIO	-	Sub Tropical South Western Indian Ocean
TSWIO	-	Tropical south western Indian Ocean

TT	-	Top of thermocline
TWAS	-	Tropical Western Arabian Sea
TWIO	-	Tropical Western Indian Ocean
W	-	Observed Weight
W^	-	Weight calculated from length
WEIO	-	Western equatorial Indian Ocean
WIO	-	Western Indian Ocean
WM	-	Winter monsoon
WORMS	-	World Register of Marine Species

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Chapter - 1

GENERAL INTRODUCTION

1.1 Introduction

The pelagic habitat between the sunlit layers (upper 200 m) and the seafloor is the largest and least-understood environment on our planet (Webb *et al.,* 2010). Hardy (1956) vertically divided the pelagic part of global ocean into epipelagic, mesopelagic and bathypelagic zones. Epipelagic zone is the surface illuminated zone (~ 200 m depth) of the sea where enough light is available to carry out photosynthesis (the euphotic zone). The mesopelagic zone (middle pelagic or twilight zone) extends from a depth of ~ 200 m to ~ 1000 m below the ocean surface (Trujillo *et al.,* 2010) where solar radiation is too low for effective photosynthesis (Behrenfeld 2010). This layer is characterized by the presence of marine species that perform diel vertical migrations between shallow and deep waters for feeding and predator avoidance. Bathypelagic zone extend vertically between 1000 m and 4000 m depths and is totally dark (aphotic zone). Bathypelagic species in general remain in deep waters as adults (Proud *et al.,* 2017).

The major portion of earth's surface is occupied by open oceans and deep seas (> 200 m depth) which harbors wide variety of known biota which is equipped for life in a highly dynamic environment. Increasing customer demand for fish coupled with high human population growth have led to the search cheap source of protein thereby intensifying the exploitation of marine ecosystem. World per capita fish consumption increased from an average of 9.9 kg in the 1960s to 14.4 kg in the 1990s and 19.7 kg in 2013 to 20.5 kg in 2017. Preliminary estimates point towards an increase in per capita fish consumption in the coming decades. In addition to the population growth, the other factors that have contributed to rising consumption include reductions in wastage, better utilization, improved distribution channels, growing demand linked to population growth, rising incomes, urbanization and International trade (FAO 2016, 2018). Since the human activities are more concentrated on the coastal waters the coastal resources are over exploited and therefore to meet the increasing nutritional demands, alternate sources from deep Sea and open Oceans need to be searched. Krill, cephalopods and fishes in the mesopelagic realm are most promising potential resources at present (Gulland 1971; Okutani 1977) to resolve this issue.

The mesopelagic zone has been defined in different ways based on depth, temperature and light regimes. Depth seems to be the best criterion. Proud *et al.,* (2017) defined over 60 distinct provinces of mesopelagic organisms based on acoustically sensed Deep-Scattering Layer (DSL) characteristics (depth, vertical extent, and acoustic backscattering intensity) which include mesopelagic fish, defined as fishes that live in the mesopelagic zone (Pillai *et al.,* 2009). Sayre *et al.,* (2017) stratified the ocean into physically and chemically distinct areas, based on analysis of temperature, salinity, oxygen, nitrate, phosphate and silicate. They identified 37 "Ecological Marine Units" (EMUs) of which six are mesopelagic units, seven are bathypelagic units and the remaining 24 are epipelagic units. Sutton *et al.,* (2017) proposed a biogeographical classification scheme for the mesopelagic zone, in to

Eco regions. Eco regions are areas of ocean that contain geographically distinct assemblages of natural communities and species (Spalding *et al.,* 2007). The biogeographic classification defines 33 eco-regions depicting the daytime distribution of large scale mesopelagic faunal communities. Of the 33 eco-regions recognized, 20 are oceanic while 13 are distant neritic. In neritic eco-region biome, oceanic circulation is modified by interaction with continental topography and associated coastal winds (Sutton *et al.,* 2017). The neritic eco-regions included here contain a high proportion of pseudo-oceanic species, i.e. species from primarily mesopelagic families whose distributions are centered along continental shelf breaks.

Oceans are the venue for quite few peculiar phenomena on which our knowledge is limited. One such Phenomenon is the migratory Deep Scattering Layer (DSL) of mesopelagic and epipelagic depths in all world Oceans which caught the attention of many workers since its discovery in 1942 (Duvall and Christensen 1946; Eyring *et al.,* 1948; Raitt 1948). The biotic components of the DSL include macrozooplankters like amphipods, chaetognaths, copepods, doliolids, euphausiids, isopods, lucifers, medusa, ostracods, pteropods, salps, siphonophores, jelly like substances, larval forms like alima larvae, decapod larvae, Phyllosoma larvae etc., and micro nektons such as pelagic shrimps, crabs, cephalopods, leptocephalus, fish juveniles and mesopelagic fishes belonging to families myctophidae, photicthyidae, gonostomidae, sternopthydiae, bregmacerotidae, melanostomidae, stomidae, astron esthidae, nemicthydae, trichiuridae, idiacanthidae etc. (Menon 2002). The mesopelagic fishes constitute 1000 million tonnes of biomass in the world oceans (Irigoien *et al.,* 2014). Beebe (1935) was the first fishery biologist to observe myctophid fishes in the mesopelagic zone.

The family myctophidae commonly known as lantern fishes makes up about 65% of all mesopelagic fishes and has a global biomass estimated at 660 million tons (Hulley 1994). These fishes are an integral part of the trophodynamics of oceanic ecosystems around the world (Hudson, 2012). Myctophids are the most species-rich family in the mesopelagic communities of world's oceans (Gjosaeter and Kawaguchi 1980). They are an ancient family of fish, living on earth since at least the early Eocene period (≤ 55.8 million years ago) (Miller *et al.,* 2002; Prokofiev 2006). Family Myctophidae comprise of 230-250 species (Moser and Ahlstrom 1974; Balu and Menon 2006; Catul *et al.,* 2011) distributed in all the world's oceans (Gjosaeter and Kawaguchi 1980; Dalpadado and Gjosaeter 1988a,b; Cherel *et al.,* 2010). Though individuals of myctophids are most often smaller than 10 cm (Clarke 1978; Kinzer and Schulz 1985; Dalpadado and Gjosaeter 1987; Gartner Jr *et al.,* 1987; Collins *et al.,* 2008), occasionally species >15 cm are recorded (Balu and Menon 2006; Collins *et al.,* 2008; Shreeve *et al.,* 2009). Myctophids have a life span from one year (Catul *et al.,* 2011) to more than five years (Gjosaeter 1973a,b) and are characterised by rapid growth, early maturity, short life span and high mortality rates (Childress *et al.,*1980; Gjoaseter and Kawaguchi 1980; Prutko 1987).

The characteristic large eyes of myctophids are adapted to visual detection of prey and predators, and communication through bioluminescent flashes in dark waters at several hundred meters depth (Warrant and Locket 2004). The fish abdomen is covered by bioluminescent photophores used for counter illumination (Case *et al.,* 1977), intraspecific communication such as sexual signaling (Herring 2007; Haddock *et al.,* 2010), illuminating their surroundings and inducing bioluminescent signals by their prey (Haddock *et al.,* 2010). These photophores are important species/ genus-specific characteristics of the myctophids (Moser and Ahlstrom 1974).

During the day myctophids live at great depths, but at night they migrate to surface waters where they feed. They are capable of crossing density gradients such as thermocline and halocline that generally inhibit mixing and thus invade epipelagic zone during night. Some species show size stratification with depth and some including adults and juveniles are non-migratory. Many myctophids exhibit strong diel vertical migrations (Badcock 1970; Badcock and Merrett 1976; Karnella 1987; Badcock and Araujo 1988; Bekker and Chuvasov 1988) believed to be feeding migrations, during which they are subjected to wide environmental changes in temperature, salinity, dissolved oxygen etc.

Information on the feeding ecology and trophic position of these fishes is critical to the understanding of ecosystem food webs and modelling of large-scale ecological processes in the ocean. Diel vertical migration of myctophids and other mesopelagic fishes has been well documented by Badcock (1970). Badcock and Merrett (1976) also reported that most of these fishes are nocturnal feeders in the epipelagic zone (Holton 1969; Gjoaseter 1973; Merrett and Roe 1974; Clark 1978; Gorelova 1974, 1978). Many mesopelagic fishes seem to be opportunistic feeders, feeding on any prey of suitable size. It is obviously an advantageous habit in a food poor environment (Hartmann and Weikert 1969; Merrett and Roe 1974). Zooplankton is reported to be the most common prey in which crustaceans play the most important role (Collard 1970; Nakamura 1970; Clarke 1973; Hopkins and Baird 1973; Gorelova 1974;). Though myctophids generally occupy a tertiary trophic level, feeding primarily on crustacean zooplankton, they are also known to feed on gelatinous zooplankton, pteropods, and other non-crustacean prey including other fishes (Kinzer 1982; Sameoto 1988; Hopkins *et al.,* 1996; Moku *et al.,* 2000).

Mesopelagic fish seem to reduce competition by partitioning the resources among themselves in several ways. Some species are selective feeders, preferring a specific prey type or size disproportionate to the abundance of prey items in the environment (Samyshev and Schetinkin 1973; Hopkins and Baird 1973). More opportunistic species may minimize competition by feeding at different depths and by showing ontogenetical differences where larger fish take larger prey than do the smaller fish (Clarke 1973 and 1978; Hopkins and Baird 1973; Merrett and Roe 1974; Tyler and Pearcy 1975). Planktivorous organisms such as myctophids, can reduce predation and feeding scarcity by performing diel vertical migrations or DVM (Holton 1969; Kinzer and Schulz 1985; Kinzer *et al.,* 1993, Scheuerell and Schindler 2003). DVM is performed by a wide range of taxa (Neilson and Perry 1990; Pearre 2003), commonly referred to as a trade-off between feeding opportunities and predation risk induced by changes in light levels (Clark and Levy 1988; Cohen and Forward 2009; Ringelberg 2010). However, factors such as hunger (Pearre 2003), size (Busch and Mehner 2012) oxygen levels (Kinzer *et al.,* 1993), energy reserves (Hays *et al.,* 2001), currents (Bennett *et al.,* 2002) and temperature (Wurtsbaugh and Neverman 1988; Sogard and LO 1996) may further influence the migration and vertical distribution of individuals. In normal DVM (NDVM), organisms hide from visual predators in deep and dark waters during daytime, before ascending towards the surface to feed during night (Neilson and Perry 1990). Myctophids are known to perform NDVM from daytime depths of several hundred meters towards the surface at night (Holton 1969; Dalpadado and Gjosaeter 1987, 1988; Moku *et al.,* 2000; Collins *et al.,* 2012; Olivar *et al.,* 2012). NDVM myctophids and other mesopelagic fish are likely important components of the biological pump, transporting particulate organic material from the euphotic zone to deeper parts of the water column (Pakhomov *et al.,*1996; Radchenko 2007; Hernandez-Leon *et al.,* 2010; Robinson *et al.,* 2010). However, non-migrating Diurnal Vertical Migration components (NoDVM) of myctophid populations are also commonly found in the mesopelagic zone (Pearcy *et al.,* 1979; Gjosaeter 1984; Gartner Jr *et al.,* 1987; Moku *et al.,* 2000; Collins *et al.,* 2008; Godo *et al.,* 2009; Olivar *et al.,* 2012). Many of these NoDVM components of myctophid populations have been identified through use of trawl sampling or hull mounted echo sounders in short-term studies (Pearcy *et al.,* 1979; Gjosaeter 1984; Gartner Jr *et al.,* 1987; Moku *et al.,* 2000; Collins *et al.,* 2008; Olivar *et al.,* 2012).

The first documentation of inverse DVM (IDVM) in myctophids distributed in the mesopelagic zone throughout day and night was recently published (Kaartvedt *et al.,* 2009). The group of individuals performing IDVM ascended towards the upper mesopelagic zone during daytime and descended towards deeper waters during night, and it was hypothesized that this was due to daytime feeding on Calanus overwintering between ~200–300 m (Kaartvedt *et al.,* 2009). IDVM is most frequently observed in zooplankton, but has also been described for several fish species (Ohman *et al.,* 1983; Neilson and Perry 1990; Pearre 2003; Tester *et al.,*2004), although rarely (Jensen *et al.,* 2011).

Extensive work has been done on DVM in myctophids, mainly in relation to their diet, distribution of prey or swimming behaviour (Clarke 1978; Kinzer and Schulz 1985; Moku *et al.,* 2000; Kaartvedt *et al.,* 2008; Dypvik *et al.,* 2012a, b). However, with the exceptions of Kaartvedt *et al.,* (2009) and Staby (2010), who addressed the behavior of potential predators on mesopelagic fish and findings of mesopelagic fish in the stomach content of piscivores, predator behaviors and the predation risk experienced by myctophids and other mesopelagic fish has seldom been studied in detail. Piscivorous predators have frequently been observed in the habitat of myctophids (Giske *et al.,* 1990; Staby 2010), but except for an apparent attack on myctophids at mesopelagic depths (Kaartvedt *et al.,* 2012), knowledge on their behavior and influence on myctophid behavior is limited.

Hopkins *et al.,* (1996) found that myctophids were the most important consumers in the Gulf of Mexico assemblage consisting of 164 species representing 16 families of midwater fishes and ingesting 31% of the total prey biomass consumed daily by the assemblage. In the eastern Gulf of Mexico, a low-latitude myctophid community consumed 8-16% of the total copepod daily production and 2% of the overall zooplankton biomass each night (Hopkins and Gartner 1992). Gorelova (1984) estimated that myctophids may consume 2-31% (average 10%) of the zooplankton standing stock daily in the equatorial Pacific. A wide range of daily consumption has been estimated for myctophids, generally falling within 1-6% of body weight for adults (Sameoto 1988;

Pahkomov *et al.,* 1996; Brodeur and Yamamura 2005). While myctophids are important predators, they are also important prey for higher order predators such as marine mammals, sea birds, and piscivorous fishes (Hopkins *et al.,* 1996; Beamish *et al.,* 1999; Pusineri *et al.,* 2008; Pereira *et al.,* 2011). The diet of stomiid fishes in a Gulf of Mexico assemblage was comprised mainly of fishes (83% of abundance), of which myctophids represented 42% (Hopkins *et al.,* 1996). Mycto phids have also been identified in the diets of swordfish, albacore tuna, common dolphin, striped dolphin and beaked whales, constituting as much as 50% of the diet by mass (Pusineri *et al.,* 2008; Pereira *et al.,* 2011). Beamish *et al.,* (1999) postulated that myctophids may constitute up to 90% of the diets of northern fur seal, Dall's Porpoise, Pacific white-sided dolphin, and northern right whale dolphin in the subarctic Pacific. Additionally, myctophids formed a notable component of the diet of many sea birds in this area, including several species of puffins, murres, and kittiwakes (Beamish *et al.,* 1999).

Many myctophid species make daily vertical migrations up to the epipelagic zone at night to feed on zooplankton, and migrate to deeper water (~300-1000 m) during the day where they digest their food. While metabolizing this surface-derived food at depth, myctophids egest large, fast-sinking, carbon-rich faecal pellets, respire carbon dioxide, and excrete dissolved organic carbon and dissolved organic and inorganic nitrogen. This "active transport" of organic and inorganic nutrients may be an important component of the biological pump (collectively the vertical export of surface-derived nutrients to depth by vertically migrating zooplankton and fishes, 'passive' sinking of dead phytoplankton aggregates and of faecal pellets, and physical mixing of dissolved organic matter) and subsidizes the metabolic demands of deep-sea organisms in an extremely food-limited environment (Vinogradov 1962; Hidaka *et al.,* 2001; Wotton and Malmqvist 2001; Steinberg *et al.,* 2000, 2008). Hidaka *et al.,* (2001) found the respiratory flux due to vertically migrating micronekton in the western equatorial Pacific (biomass corrected for assumed gear sampling efficiency of 14%) to be between 15-30 mg C m^{-2} d^{-1}, which accounted for 28-55% of the sinking particulate organic carbon (POC) flux, while the gut flux (material consumed near the surface that is egested as faecal pellets at depth) accounted for 2-3% of POC flux. Respiratory and gut fluxes due to migrant myctophids accounted for approximately 14-26% and 1-2%, respectively, of the POC flux. Wilson *et al.,* (2009) reported that carbonate production within the intestines of marine fishes, which is released via excretion, contributes 3-15% of total oceanic carbonate production. Thus myctophids form the dominant group of vertically migrating fishes and account for the greatest proportion of fish biomass in the epipelagic zone at night (Maynard *et al.,* 1975; Hopkins 1984) and have the potential to export significant amounts of organic and inorganic carbon to the deep sea.

Myctophids are dioecious and a number of genera also exhibit sexual dimorphism. In some genera (e.g. *Benthosema, Hygophum* and *Myctophum),* males possess a supra-caudal luminescent gland (just in front of tail on the upper surface of body), while females possess an infra-caudal gland (in front of tail on lower surface). In the diverse genus *Diaphus,* most species have enlarged luminescent glands on their heads (called supra-orbital glands or "headlights"), which are typically much larger in males. Males and females of the monotypic genus *Notolychnus* can be distinguished by the noticeably larger eyes of the males. Another pattern of dimorphism is found in some species such as *Ceratoscopelus warmingii* and *Electrona antarctica,* in which males are distinctly smaller than females at maximum size (Gartner, 2008). Females are oviparous and both sexes are non-guarding pelagic spawners. The females typically produce 100–2000 unfertilized eggs per spawn (Balu and Menon 2006). But there are species with fecundity up to 25,800 per spawn (Flynn and Paxton 2012). Spawning in some species may continue year around. Although there are exceptions to the rule, lower latitude species tend to spawn year-round, whereas higher latitude species typically spawn during a restricted period once in a year. The lower latitude species tend to live 1 year or less, whereas higher latitude species may live 3-4 years (Gartner 2008). Myctophids are also subjected to parasitic infection in natural habitats. Some of the common parasites affecting the myctophid species include siphonostomatoid copepod like *Sarcotretes sp*., which attach to muscles and kidneys of the fishes (Cherel and Boxall 2004; Karlsbakk 2008) and *Cardiodectes medusaeus*, which penetrates its head into the heart of the myctophids (Perkins 1983; Sakuma *et al.,* 1999).7 Nematodes like Diphyllobothrium larva (Karlsbakk 2008; Klimpel *et al.,* 2008) and Tetraphyllidea larva (*Scolex pleuronectis)* were found on *Lampanyctus macdonaldi* (Klimpel *et al.,* 2006) and a hydroid parasite (*Hydrichthys sp*.) was found to infest *Diaphus theta*, *Tarletonbeania crenularis* and *Lampanyctus sp*. (Mc Cormick *et al.,* 1967).

1.2 Myctophids of World Oceans

Distribution range of Lantern fish extends from Arctic to Antarctic waters and from surface layers at night to depths exceeding 2000 m (Nafpaktitis *et al.,* 1977) during day. The family also includes species known as pseud oceanic, associated with continental shelf and slope regions and in the neighborhood of oceanic islands (Hulley 1981). Continental slopes encompass a wider set of physical niches, and provide an environment for the development of a recognizable and trophically dependent community of benthic and benthopelagic fish (Haedrich *et al.,* 1980). The down-slope zonation of lantern fish may result from the combined effects of depth and water column structure (Hulley 1992).

The majority of current knowledge on Atlantic myctophids resulted from the study of the collections of the Woods Hole Oceanographic Institution (WHOI) (Nafpaktitis *et al.,* 1977) and *Institut für Seefischerei* (Hulley 1981). In the south western Atlantic (0º-60ºS), 79 myctophid species under 22 genera were recorded (Parin and Andriyashev 1972; Parin *et al.,* 1974). Konstantinova *et al.,* (1994) and Figueroa *et al.,* (1998) described the distribution of 40 of these species, with respect to the water masses between 40º30'- 47º00'S. Off the coasts of Suriname and French Guiana, 15 species from 7 genera were reported (Uyeno *et al.,* 1983). In the Eastern Central Atlantic, Wienerroither *et al.,* (2009) reported 52 species from the Canarian archipelago. Figueiredo *et al.,* (2002) and Santos (2003) reported 37 species from off south eastern and southern Brazil (22º-34ºS), with sampling effort concentrated from 100 to 500 m., although this number is lower than the 41 species recorded off south eastern and southern Brazil between 22-34ºS species

(Figueiredo *et al.,* 2002; Bernardes *et al.,* 2005). Eastern and south-south eastern Brazilian waters share 12 of 16 myctophid genera. Regarding the four genera exclusive within each area, broad or tropical genera (*Centrobranchus*, *Diogenichthys*, *Lampadena*, *Notolychnus*) occur between 11-22º S, while cold water genera associated with the subtropical currents (*Electrona*, *Gymnoscopelus*, *Lampichthys*, *Scopelopsis*) occur between 22-34ºS. Clarke, 1973 reported 47 species under 18 genera from Hawaii, Gartner *et al.,* (1987), 49 species under 17 genera from eastern Gulf of Mexico (GOM) and Ross *et al.,* (2010), 38 species under 17 genera from north-central GOM. Collectively, Brazilian waters have a high diversity of myctophids (79 species, 23 genera - Menezes *et al.,* 2003) comparable to that registered in the North Atlantic (82 species, 20 genera: Nafpaktitis *et al.,* 1977). The occurrence of larger myctophids from Atlantic with increasing depth has been documented for myctophid fishes caught in trawls (Clarke 1973; Willis and Pearcy 1980).

Fishes of the family Myctophidae, are often the dominant component of micronektonic communities in the North Pacific, achieving very high abundances. They dominate the fish biomass in oceanic waters of the Northeast Pacific (Pearcy 1977; Gjosaeter and Kawaguchi 1980; Beamish *et al.,* 1999), and their transport on to continental shelves represents an important flux of energy into these systems, as represented in food web models of the California Current (Field *et al.,* 2006) and biomass estimations (Beamish *et al.,* 1999; Brodeur and Yamamura 2005). Three lanternfish species (*Tarletonbeania crenularis*, *Stenobrachius leucopsarus*, and *Diaphus theta)* form the bulk of micronekton found in the North Californian Current. These 3 species were reported to account for two thirds of all fishes collected in Isaac-Kidd Midwater trawl tows in the upper 200 m off Oregon, USA (Pearcy 1964, Pearcy *et al.,* 1977). The three species of mesopelagic fishes viz., *Lampanyctus leucopsarus, Diaphus theta, Tarletonbeania crenularis* dominated in the Pacific Ocean. Barnett (1983) studied species structure and temporal stability of mesopelagic fish assemblages in the Central Gyres of the North and South Pacific Ocean in 1983 and identified 9 myctophids viz *Ceratoscopelus warmingii*, *Triphoturus nigrescens*, *Lampanyctus sp*., *Notolychnus valdiviae, Benthosema suborbitale, Bolinichthys longipes, Lampanyctus steinbecki, Diaphus mollis, Lobianchia gemellarii* in North gyre and 8 myctophids *Notolychnus valdiviae, Ceratoscopelus warmingii, Lampanyctus steinbecki, Diogenichthys atlanticus, Lampanyctus niger, Scopelopsis multipunctatus, Lampadena urophaos, Bolinichthys photothorax* in the South gyre. Sassa *et al.,* 2004a studied assemblages of vertical migratory mesopelagic fish in the transitional region of the western North Pacific and found that myctophidae family was the most speciose with representing 17 species in their study. In subarctic and mixed waters of the northern part of the Pacific Ocean, myctophids comprise 80 to 90% of the total catch of micronekton (Gjosaeter and Kawaguchi 1980). Mesopelagic fish, *Stenobrachius leucopsarus* collected from this area comprises both migratory and non-migratory populations (Pearcy *et al.,* 1977). *Diaphus theta* is abundantly distributed in the subarctic and transition water of the North Pacific (Watanabe *et al.,* 1999). Wang and Chen (2001) reported 40 species of myctophids from the Taiwan and the Tungsha Islands, out of which 17 species were first records from this area.

Sabourenkov (1990) reported 20 species of myctophids in the sub-Antarctic and the Antarctic area. The most abundant species were *Electrona carlsbergi, E. antarctica, Protomyctophum anderssoni,* and *Gymnoscopelus nicholsi.* These species predominate over other myctophids both in the sub-Antarctic and Antarctic, and in some places around the Southern Ocean form dense concentrations. In the Antarctic waters to the south of the Antarctic Convergence, 35 species of myctophids are found, i.e. within the CCAMLR Convention Area (Hulley 1990). Of these 35 species, 11 have circumpolar distributions and are mainly widespread from the Antarctic Polar Front zone (APF) to the edge of the Antarctic continental slope. Other species have more restricted distribution and are found in localized areas in APF waters (eight species in the Atlantic sector of the Southern Ocean, 13 species in the Indian Ocean sector and four species in the Pacific sector). The total biomass of myctophids in Antarctic waters is estimated to be 70-200 million tonnes (Lubimova *et al.,*1987). Myctophids apparently represent the second largest (after krill) and most widely distributed biological resource in Antarctic waters. Four species of myctophids *Krefftichthys anderssoni, Electrona antarctica, Electrona carlsbergi and Gymnoscopelus nicholsi* having circumpolar distribution, contribute the bulk of the biomass.

Iwami and Kubodra (1990) recorded the distribution patterns of 15 species of myctophids from Western Indian Ocean and related areas of Antarctic Ocean (30°S-69°S and 54°E-30°E) and classified them into four types based on their distribution; (1) endemic to the Antarctic water (2) distributed in the northern part of the Antarctic water and the Sub-Antarctic water (3) distributed in the Sub-Antarctic water; (4) distributed in the Subtropical waters. *Electrona antarctica* and *Gymnoscopelus opisthopterus* show the pattern of Type 1. Species representing the Type 2 distribution pattern were *Krefftichthys anderssoni, Protomyctophum bolini* and *Gymnoscopelus braueri. Protomyctophum parallelum, Protomyctophum tenisoni* and *Lampanyctus achirus* were found only in the Sub-Antarctic water and belong to Type 3. The rest 7 species, *Benthosema suborbitale, Bolinichthys indicus, Ceratoscopelus* warmingii, *Gonichthys barnesi, Hygophum hygomii, Lampanyctus pusillus* and *Lobianchia dofleini,* have never been recorded south of the Antarctic Convergence and represented the pattern of Type 4.

1.3 Myctophids of Indian Ocean:

Distribution and abundance of myctophids in the Indian Ocean region have been studied by several authors and they have reported that the myctophids form a major component in the mesopelagic fishes (Gjosaeter 1984; GLOBEC 1993; Valinassab *et al.,* 2007; Catul *et al.,* 2010; Vipin *et al.,* 2012). Myctophids form an important component of the acoustically dense Deep Scattering Layers (DSL) (Shotton 1997; Menon and Venogopal 2004; Balu and Menon 2006). The abundance of myctophids in the Indian Ocean, mentioned in the International Indian Ocean Expedition (IIOE; 1959-1965) was confirmed by acoustic and trawl survey's by R/V DR.FRIDTJOF NANSEN during 1975-1976 (Gjosaeter 1981a,b). These studies estimated a total biomass between 8-20 million tons in the whole Gulf of Oman. The Arabian Sea has one of the world's largest myctophid resource dominated by a single species, *Benthosema pterotum.* The US GLOBEC (1993) reported high concentrations of this species along the Western and Central Arabian Sea and estimated its biomass to be around 100 million tonnes.

Valinassab (2005) reported the life span of this species as less than one year and concluded that 100 million tonnes of *B. pterotum* perish and sink downward yearly. Though the biomass of this species in Arabian Sea was later (2001) revalidated to 48 million tons, it is now recognized that *Benthosema pterotum* is the largest single species stock of fish in the world (Gjøsæter 1984; U.S GLOBEC 1993; FAO 1997a; Valinassab *et al.,,* 2007; Karuppasamy *et al.,* 2008b). Other myctophid species like *Benthosema fibulatum, Diaphus spp., Myctophum spinosum* and *Symbolophorus evermanni* were occasional in number, more common than *B. pterotum* in the Gulf of Aden (Gopakumar *et al.,* 1983; Gjosaeter 1984; FAO 1997) and Eastern Arabian Sea (Karuppasamy *et al.,* 2008a). Along the southern Omani and north-eastern Somali coast, *Benthosema fibulatum* dominated trawl collections and acoustic survey records. The Oman fish diversity was studied by Jufaili *et al.,* (2010) and reported 9 species of myctophid fishes from Oman waters. In the eastern Arabian Sea, *Diaphus arabicus* and *Hygophum proximum* are common forms (Gjosaeter 1984; Kinzer *et al.,* 1993; FAO 1997a, b). Along the coast of Pakistan, myctophid concentrations consist almost exclusively of *B. pterotum* with densities decreasing towards the west (FAO 1997a, b). Survey in the western Indian Ocean estimated the presence of 97 species of myctophids belonging to 23 genera (Nafpaktitis 1982).

Benthosema pterotum is the dominant species in the Western and Northern Arabian Sea, followed by *Benthosema fibulatum* and *Diaphus* spp. (Gjosaeter 1977). In the Gulf of Oman, the acoustic measurements indicated a density of 25-63 *B. pterotum* per m^2 surface area (Gjosaeter 1977). Gjosaeter (1977) reported a catch rate of 20 t h^{-1} of myctophids from the seas off Oman (20°-24°N lat and 57°-67°E long) at a depth of 130 m during day time operations of pelagic trawl. Myctophid catches exceeding 400 $kg.h^{-1}$ were obtained from several stations located in north-western Arabian Sea (0°- 26°N; 43°-67° E long). Dalpadado and Gjosaeter (1993) reported the presence of 16 species of myctophids in the area 07°06'-08°27'N lat; 79°29'- 81°59'E long, off Sri Lanka, during the cruises with R.V. "Dr. Fridtjof Nansen". Kinzer *et al.,* (1993) reported the presence of 11 species of myctophids from 18°- 24°30'N lat; 62°- 67°E in the Arabian Sea. *Diaphus arabicus* was the dominant species between18° and 24°N, contributing 66-73% of the myctophid samples, in terms of numbers (Kinzer *et al.* 1993). Observations on the mesopelagic fishes taken by mid water trawl in the equatorial region (03°S-03°N lat; 76°-86°E long) of Indian Ocean shows that the average catch of myctophids was higher from the southern side of the equator as compared with to the northern side (Jayaprakash 1996).

The ecology of the mesopelagic fauna in the eastern Indian Ocean was studied by Legand and Rivaton 1967, 1969. Similar ecological studies covering the more southerly parts of the western Indian Ocean were carried out by Bradbury *et al.,* (1971) and Makshtas and Ryabtsev (1973). Aspects on the distribution and ecology of the myctophidae from the Western and Northern Arabian Sea and abundance of lanternfish (myctophidae) in the Western and Northern Arabian Sea were carried out by Gjosaeter 1977 and 1981a. According to this study myctophid catch estimates were higher in spring than in summer and autumn. Catch rates as high as 20 tonnes/hour of trawling were recorded from pelagic trawl operations in this area.

Potential exploitable micronektons from the Deep Scattering Layers (DSL) of the Indian EEZ was studied by Menon (2004). He found that myctophids appear in large shoals / swarms in the North West part of Indian EEZ with a decreasing trend from north to south. Echo sounder records show that many myctophids aggregate in compact layers, especially during daytime when they are relatively quiescent in depths below 200 - 400 m. Jayaprakash (1996) studied mesopelagic fishes from equatorial waters contiguous to Indian EEZ and recorded 12 myctophid species from the area. 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. Vipin *et al.,* (2012) reviewed myctophid resources of Indian Ocean and reported 137 species in the Indian Ocean, and Karuppusamy *et al.,* (2010) reported 13 species of which five are from the eastern Arabian Sea. Balu and Menon (2006) estimated a biomass of 100,000 tonnes of myctophids within the Indian EEZ of Arabian Sea, dominated by *Diaphus spp*. (Menon 2002). Raman and James (1990) reported 31% of the DSL catch from Indian waters were myctophids, with south east coast contributing 64% and north east coast 34%. Kinzer *et al.,* (1993) studied aspects of horizontal distribution and diet of myctophid fish in the Arabian Sea (17°N-26°N and 68°E- 52°E) with reference to the deep water oxygen deficiency. Species numbers exhibited a south-north decline in diversity, with only half of the fish taxa occupying the north eastern region and found that *Diaphus arabicus* was the dominant species both in the south and north.

Karuppasamy *et al.,* (2006, 2008 a,b and 2010) published works on distribution and biology of myctophids in the Indian EEZ of Arabian

Sea. Pillai *et al.,* 2009 studied by-catch from deep sea shrimp trawlers operated off Kollam, south-west coast of India and found that the major components in the by-catch include myctophids. Boopendranath *et al.,* (2009) studied myctophids in the by-catch of deep sea shrimp trawls operating in off Kollam coast and found that four species belonging to family myctophidae viz; (*Diaphus watasei, D. luetkeni, Myctophum spinosum and M. obtusirostre*) were obtained as main by catch. Bineesh *et al.,* (2010) recorded *Diaphus garmani* from Indian waters for the first time. Fernandez *et al.,* (2011) studied by catch discards of deep sea shrimp trawlers and approaches for their utilization from Sakthikulangara and Neendakara harbors and found that myctophids obtained as by catch can be utilized for making many value added products. Fernandez *et al.,* (2015) studied discards from deep sea shrimp trawlers operating off south west coast of Kerala and found that they contribute 32% of total discards during 2009-2010. Sebastine *et al.,* (2013) studied myctophid fishery along the Kerala coast with emphasis on population characteristics and biology of the headlight fish, *Diaphus watasei*. Vipin *et al.,* (2011, 2015) studied length weight relationships of *Diaphus watasei* and *Myctophum spinosum* caught off the Southwest Coast of India.

Blindheim *et al.,* (1975) reported a large concentrations 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 *Diaphus coeruleus and Gymnoscopelus nicholsi* (edible species) in the southwest Indian Ocean and southern Atlantic began in 1977 and catch by former USSR reached 51,680 t in 1992, after which the fishery ceased due to decline in catch. The Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) estimated 200,000 t TAC (Total Allowable Catch) for this resource in its jurisdiction area (CCAMLR Convention Area). Industrial purse seine fishery for *Lampanyctodes hectoris* was developed in South African waters and closed in the mid-1980s due to processing difficulties associated with the high oil content in the fish (FAO 1997a). Lantern fishes are harvested commercially only along off South Africa and in the sub-Antarctic waters (Nafpaktitis *et al.* 1977; Hulley 1994). Oman started trial fishing of myctophids in 1996, 1998 and stopped it as the running cost was too high for viable returns from the fishery. Shaviklo (2012) reported the initiation of commercial fishery for the myctophid fishes in the Persian side of the Oman Sea. Myctophid is a good source of protein and fat, hence it could well be a potential source of alternative protein and fat. At present myctophid is not commercially exploited in India, although myctophid by-catch is used for preparing fish meal by some local populations (Sebastian *et al.,* 2013)

Biochemical analysis of myctophids have been attempted by several workers. Myctophids are high in proteins and mineral content, variably lower in lipids and uniformly low in carbohydrates (Lekshmy *et al.,* 1983; Nair *et al.,* 1983; FAO fisheries 1997a; Phleger *et al.,* 1999; Lea *et al.,* 2002; Goode and Bean 1984) which indicates its nutritional importance. A number of studies have evaluated the lipid content of vertically migrating myctophids and found that they include triglycerides, believed to serve primarily as an energy store and wax esters mainly used for buoyancy. Gopakumar *et al.,* (1983) reported that lantern fishes are a good source of potassium, sodium and calcium. Gopakumar *et al.,* (1983) and Nair *et al.,* (1983) have conducted studies on processing and utilization of lantern fish (*Benthosema pterotum*) collected from the Gulf of Oman. The main products developed from the lantern fish were dried products, fishmeal and fish hydrolysate. Haque *et al.,* (1981) described a method for fish meal production from the myctophid *Benthosema pterotum* from Gulf of Oman. Nagouchi (2004) reported that, based on the bio- chemical character of each lantern fish species, they can be utilized for production of (i) feed for aquaculture (ii) surimi from minced meat and (iii) cosmetics and lubricating oil from body fats. The quality of the highly refined wax was evaluated as equal to the quality of commercial purified wax from Orange Roughy. The quality of the sulphurised lantern fish wax was equal to the quality of commercial lubricating and cutting oils (Noguchi 2004). Shaviklo (2012) reported commercial fishing of myctophids in the Persian side of the Oman Sea, which began in recent years, exclusively for fish meal production in an onshore fish processing company located in Qheshm Island, south of Iran. Studies show that both fish meal and hydrolysate from lantern fish can be used for fish, poultry and animal feed and as an excellent protein supplement with beneficial effects. Wax esters comprised 86.2-90.5% of the total lipid. Globally, several attempts have been made to utilize lantern fishes as human food, but no successful product development has been reported.

Though the possibility that lantern fishes could support significant fisheries globally, only few attempts have been made in this direction in the South Western Indian Ocean especially and in the

Eastern Arabian Sea. The present work aim the identification of myctophid resources from Deep scattering Layer of Western Indian Ocean (WIO), understand their distribution patterns and report on their occurrence, abundance, feeding and reproductive behavior. This study is expected to provide a base line data on various ecological and biological aspects which are essential to evaluate their viability for exploitation, either directly or indirectly for human consumption or product development. Since researchers all over anticipate the emergence of myctophid fishery in future, knowledge along these lines will be of relevance in the management of this fishery.

1.4 The Study Area: The study area is the Western Indian Ocean (WIO). To study the spatial distribution patterns of myctophid species, the study area was divided in to 4 regions (Figure 2.1) according to the presence/absence of myctophids in the sampling stations and the physical, chemical and biological attributes of each region.

The four regions are North Eastern Arabian Sea (NEAS- 22-16°N and 65-70°E), South Eastern Arabian Sea (SEAS- 16-6°N and 67-76°E), Western Equatorial Indian Ocean (WEIO- 6°N- 6°S, 60-70°E) and South Western Indian Ocean (SWIO- 6°S-16°S and 55-78°E). Most lantern fishes are broadly tropical in distribution and are influenced by changes in environmental factors as readily as near shore fishes, such as being entrained by fronts or transported by currents (Backus et al., 1982; Backus and Craddock 1982; Bekker 1985; Brandt 1981; Craddock *et al.,* 1992; Figueroa *et al.,* 1998; Gorbunova *et al.,* 1985; Hulley 1992; John and Erasmi 2000; Konstantinova *et al* 1994; Koubbi *et al* 1991; Rojas *et al.,* 2002; Zelck and Klein 1995).

Arabian Sea (AS) is located in the tropical region and bounded on the north by land mass. Seasonally reversing monsoons caused by north-easterly winds (winter or northeast monsoon) during November to February and strong south westerly winds (summer or southwest monsoon) during June to September shape the surface circulation and other dynamical features of this sea. As a result, AS forms biologically one of the most productive regions of the world's Ocean and its geographical location makes this basin a unique oceanographic entity. Associated with the wind reversal, surface currents of the Arabian Sea also undergo seasonal reversal and a strong seasonality is also seen in the mixed-layer depth and phytoplankton biomass. The development of Somali Current and the associated upwelling along the coastal regions of Somalia, Arabia and the southern part of the west coast of India during Summer Monsoon (SM) makes the sea highly productive. The intense winds of the Findlater Jet and the associated wind curl drive upward Ekman pumping that makes the AS upwelling along the coast of Arabia extend several hundred km offshore (Bruce 1974; Smith and Bottero 1977; Swallow 1984; Bauer *et al.,* 1991). This takes place through open-ocean upwelling and lateral advection in summer (Bauer et al., 1991) and convective mixing due to surface cooling and sinking of the dense surface waters in winter (Banse and McClain 1986; Madhupratap et al., 1996a). In summer increased primary productivity in the Eastern AS is generally connected to the coastal area south of 15°N, and in winter to the north of 15°N (Krey and Babenerd 1976; Brock *et al.,* 1991; Banse 1994). Another interesting feature is the presence of permanent Oxygen Minimum Zone (OMZ) which occurs between 150-1000 m depth (Wyrtki 1971; Qasim 1982; Swallow 1984; Naquvi1991, 1994). The

OMZ eco-regions are defined by values of less than 0.5 ml l^{-1} dissolved oxygen concentration (hypoxia), a value that limits the distribution of many mesopelagic taxa (Vinogradov 1997; Childress and Seibel 1998). Most areas of AS OMZ are indeed suboxic (DO levels <0.2 ml L^{-1} (Naqvi 1991, 1994).

The open waters of AS sustain high primary productivity almost throughout the year. High surface productivity leads to considerable flux of organic particles to deep water (Nair *et al.,* 1989) and high rates of oxygen consumption by bacteria degrading the sinking organic matter. High oxygen utilization rates combined with the low oxygen content of waters entering the Arabian Sea from the east (Swallow, 1984) generates a thick (150-1000 m) OMZ, with oxygen content less than 0.2 ml L^{-1} (Naqvi 1991, 1994). The core of this OMZ occurs at intermediate depths of about 200-500m. In the Arabian Sea, the OMZ is more pronounced in the central northern areas and acute oxygen deficiency is experienced in coastal waters only during summer upwelling (Naqvi, pers. comm). The spatial variations in the above-mentioned processes result in a north south gradient in the OMZ, with larger oxygen deficiencies occurring in the north. These features make the Arabian Sea an interesting and almost unique area to analyze patterns of horizontal and vertical distributions of flora and fauna (Olson *et al.,* 1993). The Arabian Sea OMZ is also famous for the largest stock of mesopelagic lantern fish (myctophids) associated with the upper boundary of OMZ or inhabiting this zone (Piontkovski and Al-Oufi 2014).

The first reference to the OMZ and its relation to zooplankton in the Arabian Sea was by Sewell and Fage (1948), followed by

Vinogradov and Voronina (1961). The northern Arabian Sea is a paradox with regard to mesozooplankton in the upper layers: its biomass remains almost invariant despite seasonal variations in the primary productivity regime (Madhupratap *et al.,* 1992, 1996a, b; Van Couwelaar 1997; Baars and Oosterhuis 1998; Baars 1999). The high zooplankton biomass in the Arabian Sea also apparently sustains a large biomass of mesopelagic fishes such as myctophids (Gjosaeter, 1984). Patterns of horizontal distribution of myctophid species depend up on the oxygen conditions of the area (Kinzer *et al.,* 1993).

In equatorial waters, the zonal thermocline and nutricline shoal toward the west rather than the east as in the Pacific and Atlantic oceans, a consequence of the Indian Ocean lacking easterly trade winds. The Equatorial Indian Ocean (EIO) is also strongly influenced by oscillations and perturbations that do not occur in other ocean basins, such as the Wyrtki Jets, the Madden-Julian Oscillation, and the Indian Ocean Dipole (International CLIVAR Project Office, 2006). The oxygen concentration of EIO is found to be greater than 0.5ml/1 in all areas (Stramma *et al.,* 2008). Because of high oxygen content, the diversity of myctophids are high in the EIO (Kinzer *et al.,* 1993).

1.5 Objectives

The present study aims to:

i. Create a baseline inventory on the taxonomy, systematics, and diversity of myctophids in Western Indian Ocean with Special reference to Eastern Arabian Sea.
ii. To delineate factors influencing distribution of myctophids as well as their distribution and abundance in the WIO especially in the EAS.

iii. To study the biology of myctophids

1.6 Outline of the thesis

The thesis is divided into six chapters, as below:

Chapter 1: Provides a general introduction to the research topic and explain how and why myctophid fishes of the mesopelagic realm are important. Summary of myctophid research conducted by researchers in world ocean, Indian Ocean sand Arabian Sea are provided. The Chapter also explains the study area and its environmental settings. The relevance of studying the myctophids of WIO and the objectives of the study are provided.

Chapter 2: The sampling strategy adopted and the rationale behind it is are outlined. Methods adopted in analysis of samples and data are explained.

Chapter 3: A brief systematic account of the species collected in the present study is provided. The chapter also contains updated checklists for myctophid species from WIO. A brief account of family Myctophidae and its classification scheme based on de Busserolles *et al.,* (2013) is provided. The total number of myctophid species in the Western side of Indian Ocean alone is now revalidated to 159 as against the previous record of 146 species from both western and Eastern Indian Ocean.

Chapter 4: The environmental settings, distribution and abundance of myctophids in the study area (NEAS, SEAS and WEIO covering (22°N-16°S and 60°E-78°E) are described. Correlations of myctophid assemblages in the three regions with environmental variables are stated.

Chapter 5: Deals with the biology of some abundant myctophids collected from the Eastern Arabian Sea. Biological aspects on Length weight relationship, Gut content analysis and reproductive biology are explained.

Chapter 6: The salient findings of the study are summarized in Chapter 6 and conclusions are derived.

Chapter - 2

STUDY AREA, SAMPLING AND ANALYSIS

2.1 Study Area

The Western Indian Ocean has a surface area of about 30 million km^2, equivalent to 8.1 per cent of the global ocean surface of which approximately 6.3% is shelf area, and encompasses regions with greatly differing oceanographic and fishery resource characteristics (Ye 2011). Western Indian Ocean bounded by a line commencing on the southeast coast of India at 77°00'E longitude where the boundary between the States of Kerala and Tamil Nadu meet at the sea; to south latitude 45°00'S; running west along parallel 45°00'S from 77°00E longitude to 30°00'E longitude; north to the coast of southern Africa; in a north easterly direction along the east coast of the African continent to the northern entrance to the Suez Canal; running in a south easterly direction along the east coast of the Red Sea; thence round the Arabian Peninsula and along the coast of Iran, Pakistan and India to the point of departure. As per FAO (2018) the Western Indian Ocean includes the following subareas. Red Sea (Sub area 51.1), Gulf (Sub area 51.2), Western Arabian Sea (sub area -51.3), Eastern Arabian Sea (Subarea 51.4), Somalia, Kenya and Tanzania (Sub area 51.5), Madagascar and Mozambique Channel (Sub area 51.6), Oceanic (Subarea 51.7), Mozambique (Subarea 51.8). The present study is concentrated on FAO sub areas 51.3, 51.4 and 51.7.

The present study area is restricted to Western Indian Ocean (WIO) west of 77°E Long extending from 23.5°N to 16°S, Long 55°E.). Based on preliminary observation and analysis, the study area was divided in to 7 sectors namely the Tropical Western Arabian Sea (TWAS) from 6°N to 23.5°N Lat., North Eastern Arabian Sea (NEAS) from 16°N to 23.5°N Lat.,South Eastern Arabian Sea (SEAS) from 6°N to 16°N; Western Equatorial Indian Ocean (WEIO) 6°N-6°S,Tropical South Western Indian Ocean (TSWIO) from 6°S-23.5°S Lat, Sub Tropical South Western Indian Ocean (STSWIO) from 23.5°S-45°S Lat. and Sub Tropical Northern Arabian Sea (STNAS), the area north of 23.5°N. (Figure 2.1). As we could not extend the survey to STSWIO and STNAS due to logistic reasons, these two sub-regions are not included in the present study.

To study the spatial distribution patterns of myctophid species, the study area was divided in to 4 regions on the basis of presence/ absence of myctophid species in the sampling stations. The Species presence-absence data were subjected to multivariate statistical analyses using ANOSIM (Analysis of Similarities test in Primer 6+). The pair wise test showed significance only between pairs of NEAS-SEAS, NEAS-WEIO, NEAS-TSWIO, SEAS-WEIO, and SEAS-TSWIO. There was no significant difference in myctophid species composition between the regions WEIO and TSWIO and therefore these two sub-regions were clubbed and represented as WEIO. Based on this, the study area were fixed as the North Eastern Arabian Sea (NEAS- 22-16°N and 65-70°E), South Eastern Arabian Sea (SEAS- 16-6°N and 67-76°E) and Western Equatorial Indian Ocean (WEIO- 6°N- 16°S,60-70°E).

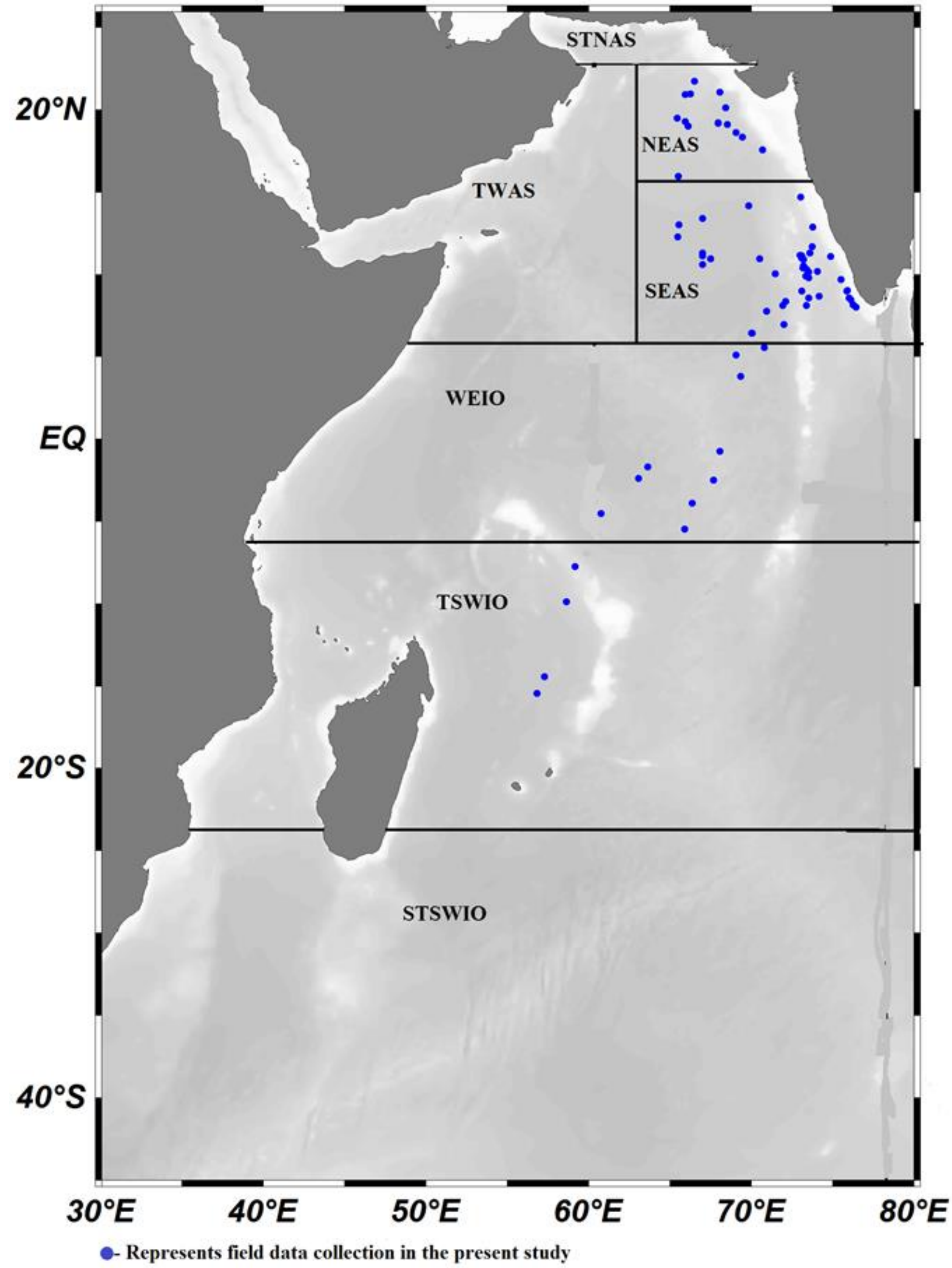


Figure 2.1 : Study Area showing sub-regions and sampling stations.

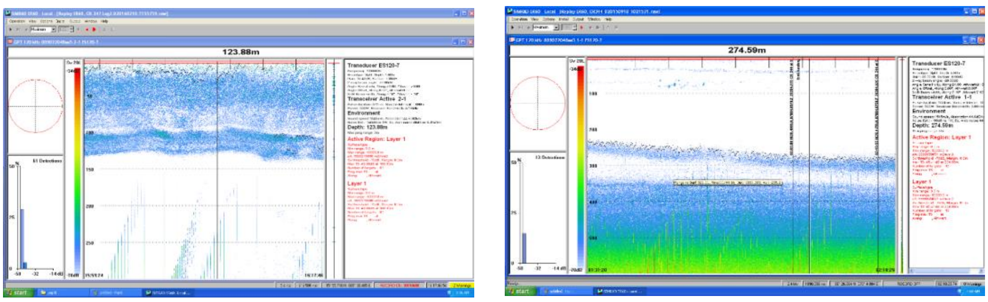
For further validation, the presence-absence data of species between the regions were analyzed by PERMANOVA test (Primer 6+), using Kulzsinsky resemblance. Multivariate analyses revealed that species composition was distinct in the three regions (PERMANOVA pseudo F=8.17, p=0.001), namely NEAS, SEAS and WEIO. The PERMANOVA test showed no difference in species composition in WEIO and SWIO, confirming the possibility of clubbing these two sub-regions as a single unit (WEIO). For studying the biological aspects, few abundant species obtained from Eastern Arabian Sea (NEAS+SEAS) (22-6°N& 65°-78°E) were considered.

2.2 Sampling

The sampling sites represent 74 stations across the NEAS, SEAS and WEIO open ocean with spatial and depth variability depending up on the thickness and Day and night migration of Deep scattering layer (Table 2.1). Out of total 74 stations surveyed, at 8 stations the myctophid catch were negligible or nil during the study period and therefore only 66 stations were considered for further analysis. The surveys were designed to collect random samples from the study area covering three major seasons namely summer monsoon(SM, June-October), winter monsoon (WM, November-February) and spring inter-monsoon (SIM, March-May). Lack of vessel availability forced us to restrict sampling in NEAS to WM and restrict WEIO sampling to SM. The selection of trawl stations were made at random in such a way to ensure coverage of different depth strata's, time as well as geographical extensions in every cruise.

Collection of field data was done exclusively on-board the Fishery Oceanographic Research Vessel (FORV) *Sagar Sampada* (Fig-2.2a-2.2e) of the Centre for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Sciences (MoES). The 72m OAL vessel is equipped with instruments and gears for undertaking myctophid surveys, such as Conductivity, Temperature and Depth profiler (CTD SBE,911^{+}) of Sea Bird, triple frequency Simrad EK-60 (38 KHz, 120 KHz and 200 KHz), Broad Band (75Khz) Acoustic Doppler Current Meter (ADCP) of RDI-OS2 make, Integrated Trawl Instrumentation (ITI) System of Simrad make, Multi Plankton Net (MPN) of Hydrobios and gears such as Issac-Kid Midwater Trawl (IKMT), Cosmos mid water trawl (K.C. Denmark) and other mid-water trawls designed by Central Institute of Fisheries Technology (CIFT). The winch capacity of the vessel permits operations only up to 1000 m depth and so the maximum depth coverage in the present study is restricted to 1000 m.

Figure 2.2 : a) Research Platform FORV *Sagar Sampada*,
b) Screenshot of ITI sensor interphase during net operation



c) Screenshot of Echo records during operation

d) Cod end of CT net immediately after landing of catch on board research vessel.

e) Sorted myctophids and mesopelagic fish.

Field data collections were carried out during the years 2013 to 2016. Data for the present study were gathered from 6 cruises of FORV-SS (SS-313, 320, 325, 342, 344 and 347) covering 74 stations through 141 days of cruise participation.

Fishing depths and areas suitable for mid water trawling operations were delineated through Acoustic surveys using SIMRAD EK 60 with either 38 KHZ or 120 KHZ depending up on the depth of DSL. Trawl depth were identified parallel to the Deep scattering layer depth and thickness, either during day or during night and scanning was performed prior to all operations in order to get a clear picture about the Deep scattering layer. All the cruises during the survey were multidisciplinary in nature and therefore Continuous monitoring of Deep scattering layer was not possible due to the operations of RDI 75kHz Ocean Surveyor Acoustics Doppler Current Profiler (ADCP) causing frequency interferences with EK-60. DSL was located for a hauling lasting 30 minutes. Though the trawl dragging time was fixed as 30 minutes, quite often the trawls were to be hauled up earlier or later due to the migration of DSL and due to the prevailing current pattern.

2.2.1 Details of Gears used for Sampling.

Midwater trawls have been reported to be appropriate for catching myctophids (Gjosaeter 1984; Shilat & Valinassab 1998; FAO 2001). Main design requirements for midwater trawls are high stability, largemouth opening, low turbulence and low drag and fast towing speed (Scharfe 1969; McNeely 1971; Parrish 1975; Hameed and Boopendranath 2000). Mainly two types of mid water trawls, namely 49.5m Cosmos Trawl and 45m mid water trawl were employed for sampling of myctophids from the study area. Trial mid water trawls (28.5 m) were used in *Sagar Sampada* during 5 stations. Myctophid fishing operations were conducted using a 49.5 m experimental krill midwater trawl of Danish origin (Cosmos Trawl, Hirtshals, Denmark). The four equal panel two bridle krill trawl was fabricated of polyethylene (PE) outer netting and polyamide (PA) inner lining with a coded mesh size of 10 mm. The gear was rigged with 40 floats of 270 mm diameter along the headline and about 80 kg of iron link chain along the foot rope. Double sweeps of 98 m, 350 kg bunched chain depressors and 5 m^2 Suberkb otter boards/ thyboron were used for the operations. Krill trawl is provided with an inner lining of polyamide netting in the belly sections from square to codend with mesh size ranging from 31.4 to 19.6 mm and codend mesh size of 10 mm (Boopendranath *et al.,* 2010).

Cosmos Krill trawl is most widely used for the commercial fishing of Krills and myctophids. One Cosmos trawl designed to match the specifications of *FORV Sagar Sampada* was procured from K.C.Denmak and utilized in the present studies (Figure 2.3a). In addition, the CIFT designed 45 m four equal panel myctophid trawls made up of HDPE are equally good for the commercial fishing of myctophids (Boopendranath *et al.,* 2012). This 45 m four equal panel myctophid trawl was designed by CIFT taking into consideration all the available information on the biological and behavioral characteristics of the myctophid species and fishing conditions, and specifications of the vessel (*FORV Sagar Sampada*). Design drawings and specifications were prepared as per conventions of FAO (1978) and recommendations of ISO (1975). Based on the design developed, two prototype 45 m myctophid trawls were fabricated for operation in the depth range of 100-1000 m, in Arabian Sea, from FORV *Sagar Sampada* (Figure 2.3b). The gear was rigged with 40 floats of 270 mm diameter along the headline and about 100 kg of iron link chain along the foot rope. Double sweeps of 98 m, 350 kg bunched chain depressors and 5 m^2 Suberkrub otter boards were used for the operations. Belly sections of CIFT trawl, ranges in mesh size from 60 to 25 mm with a codend mesh size of 25 mm (Boopendranath *et al.,* 1998, 2012).

Few 28.5 m four equal panel trial myctophid trawls were also designed and fabricated by scaling down the existing 45m myctophid trawl net for use on board FORV as well as CIFT Research Vessel, Matsyakumari II. Belly sections of CIFT trawl ranges in mesh size from 60 to 25 mm with a codend mesh size of 25 mm similar to the 45 m myctophid trawl (Figure 2.3c). The Performance evaluation of the 28.5 m four equal panel myctophid trawl was carried out on board *Sagar Sampada* using Thyboron trawl door (Type-7) each weighing 700kg and depressor weighing 150 kg at a depth range of 120-2230 m. During *FORV Sagar Sampada* operations the trawl was dragged at speeds between 0.5–3 knots depending on the depth and resistance from currents. The ratio of the wire paid out (warp paved out) to depth was approximately 3:1. All hauls were made during sunlit and sunset hours. Simultaneous to the collection of myctophid samples, observations were also made on physicochemical characteristics of seawater (temperature, dissolved oxygen, salinity) as per standard procedures using the on-board CTD (SBE 911 Plus).

2.3 Taxonomic analysis

Myctophid samples landed on board by midwater trawl operations were sorted up to species level. After preliminary identification, representative specimens for each species were preserved in 5% formaldehyde, and brought to the shore laboratory for taxonomic identification and voucher specimen deposition with the CMLRE Referral Centre. Taxonomy of major was carried out with appropriate meristic counts and morphometric measurements were made by caliper to the nearest millimeter on preserved specimens in the shore laboratory. The species identities were established based on taxonomic keys, as well as descriptions available in monographs and recent literature. Identities were ascertained and confirmed after a detailed comparison of morphometric and meristic features, with its type specimens. Species taxonomy was retrieved and updated from the World Register of Marine

Species (WoRMS), Fish Base and Catalogue of Fishes. Voucher specimens for each species collected from the study area were given a unique code and deposited with the Referral Centre, CMLRE- Kochi.

2.3.1 Estimation of biomass

Myctophid samples from mid water trawl operations were sorted and segregated to species level to the best extent possible. Catch in weight (Cw) of each myctophid species was taken using weighing balance with an accuracy of 0.1 g for obtaining its biomass.

Biomass (b) kg/km^2

Where

Cw = Catch in weight (kg)

a = swept area (km^2)

The "*swept area*" or the "effective path swept" is defined as the area which is the length of the path times the width of the trawl. The swept area, a, is estimated as:

$a = D \times hr \times X^2$

Where: D = Distance covered by trawl (estimated in nm and converted to km).The distance covered by the trawl (D) estimated in units of nautical miles (nm), calculated using the formula:

$$D = 60 \times \sqrt{(Lat1-Lat2)^2 + (Lon1-Lon2)^2 \times \cos^2(0.5 \times (Lat1+Lat2)}$$

Where:

Lat1 = latitude at start of haul (degrees)

Lat2 = latitude at end of haul (degrees)

Lon1 = longitude at start of haul (degrees)

Lon2 = longitude at end of haul (degrees)

hr = Head-rope length (m), 49.5 m for CT, 45 m for 45 m four equal panel MT and 28.5 for 28.5m four equal panel MT.

X^2 = The fraction of the head-rope length, (hr), which is equal to the width of the path swept by the trawl.
The (hr * X^2), known as "wing spread", is the effective horizontal trawl opening.

The ‘wing spread’ varies with hauling speed, weather conditions, current velocity and direction as well as warp length, and is therefore not well defined. Even though the ‘wing spread’ had been monitored using remote sensing transducers (Simrad: Net sonde), it varied with hauling speed, weather conditions, current velocity and direction and warp length. Hence in the present study the value of the fraction of head-rope length, X^2 is taken as 0.5, suggested as the best compromise for tropical waters by Pauly (1983).

Biomass of each station was calculated using swept area method by Spare and Venema (1998) integrated to represent the thickness of DSL (m^2). Biomass of the area were computed in 2 X 2° grid interval (Details are provided in chapter 4). No previous works on estimation myctophid biomass using these nets are available from the literature. An attempt is made to estimate the biomass of myctophid from NEAS and SEAS in chapter 4. Biomass estimates of only NEAS and SEAS are figured out in the present study. The area covered and number of stations were inadequate for reliable biomass estimation of WEIO.

2.3.2 Biology of Myctophids

For length weight relationship study specimens preserved in 5% formaldehyde on board and transported to the laboratory were utilized for further analysis. The fishes were then measured for Standard Length (from tip to snout to the posterior end of the last vertebra) to the nearest millimetre and wet weight to the nearest gram. Samples were then cut open to determine their sex and stage of maturity. They were then separated into immature, males and females. In some species single sex was dominant among the collected sample. In such cases pooled data (sexes combined) was only taken for the analysis. Comparison of seasonal variations in the length-weight relationships were not considered in the study, since the samples were collected during different seasons from NEAS (WM) SEAS (SM) and WEIO (SM). *Benthosema fibulatum, Diaphus thiollierei ,Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus arabicus, Diaphus garmani, Diaphus jenseni, Hygophum proximum, Myctophum spinosum, Lampanyctus turneri* were collected from NEAS during winter monsoon *Diaphus lucidus, Diaphus coeruleus, Diaphus perspicillatus, Diaphus watasei*, were collected from SEAS during summer monsoon and *Lampanyctus nobilis, Diaphus antonbruuni, Diaphus fulgens, Lampanyctus tenuiformis, Diaphus luetkeni, Diaphus brachycephalus* used for study were collected from WEIO during Summer monsoon. Regression analysis was performed separately on each group to obtain the values of 'a' and 'b' .The relationship between weight (W; g) and standard length (SL; cm) is denoted as

$$W = aLb,$$

where a is the intercept and b the allometric coefficient.This represents a general linear equation and the value of 'a' and 'b' were estimated by the method of least square regression (Zar, 1984). Regression analysis was performed after log transformation of data, and results are given at 95% confidence intervals (95% CI). Values of b significantly different from 3 indicate that growth in weight is relatively faster than that in length (positive allometry b>3) or lower (negative allometry b<3).

Mathematically the values of the intercept, a, indicated the expected weight at SL 1 cm (Oliveira *et al.,* 2012). Analysis of covariance (ANCOVA) was carried to find any significant change in the length-weight relationship between the sexes (Karuppasamy *et al.,* 2008b) and t–test was used to find if the slope of the regression lines are significantly different from isometry. Both Microsoft EXCEL 2013 and R version 3.4.3 were used for the data analysis.

Myctophid samples for food and feeding analysis were obtained from *FORV Sagar Sampada* collections of NEAS (during winter monsoon) and SEAS (during summer monsoon). *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus arabicus, Diaphus garmani, Diaphus jenseni, Lampanyctus turneri and Symbolophorus evermanni* collected from NEAS during winter monsoon and *Diaphus coeruleus, Diaphus perspicillatus, Diaphus watasei* collected from SEAS during summer monsoon were taken for this study. The operations were performed using 49m cosmos trawl and 45m 4 equal panel myctophid trawl. The samples obtained from different stations from cruises were pooled for data analysis. Samples collected on board were preserved in 5% formaldehyde and transported to the laboratory for further analysis. Based on visual examination of the distention of the stomachs and the amount of food contained in them they were graded as fully filled, Three quarter filled, half-filled and one quarter filled, to study the intensity of feeding (Meera *et al.,* 2018). Empty stomachs in general were very less and not considered for further analysis. The stomachs were removed from the fish for detailed analysis of the food contents. In order to examine gut content, the gut of 759 specimens (2cm–20cm LS) were removed (from the anterior end of the oesophagus to the pyloric valve).

The contents were carefully separated and examined under a binocular microscope, counted and weighed to the nearest 0.01 mg. Organisms in the gut were identified up to group level (Hartel 1985; FAO 1998). In the gut content analysis of samples from day and night collections of EAS no much difference in the dietary composition of day and night samples were observed. In our data night collections were more prominent than day collections, as most of the trawl operations were conducted during night. In view of this only pooled data are used for the analysis. Only prey occurring in the esophagus and the gut were analyzed in this study, and those found in the mouth were not considered. Relative measures of food items were quantified (Pinkas *et al.,* 1971) using the Index of Relative Importance (IRI):

$$IRI = (N+W)\ O$$

Where N is percentage of a particular food in the gut contents,
W is percentage of food weight and O is percentage of frequency of occurrence.

Samples of *Benthosema fibulatum, Bolinichthys longipes, Cerat oscopelus warmingii, Diaphus arabicus, Diaphus jenseni, Diaphus thiollierei, Hygophum Proximum* were collected from NEAS using Cosmos trawl catches of *FORV Sagar Sampada* during the period January to February 2016. Standard Length, sex and stage of Gonadal maturity of the individual fish preserved in 5% formalin were taken. The standard length (SL) of all specimens were measured to the nearest 0.1mm. In the laboratory Body weight (BW) was determined to the nearest 0.1g, and gonadal weight (GW) was measured to the nearest 0.001gm using an electric balance (Kern & SOHNGMBH B72336 GERMANY).

Sex was determined for all specimens by macroscopic and microscopic observation of the gonad morphology using a stereomicroscope. In all species studied here, males have a markedly smaller gonad than females, as reported for several other myctophids from subtropical-tropical to sub-Arctic waters (Clarke 1983; Young *et al.,* 1987; Gartner 1993; Moku 2000; Sassa *et al.,* 2014). Therefore, with the exception of sex ratio data and Gonadal stages, other sex related parameters were analyzed for females only. The length related Chi-square analysis of sex ratio was carried out following Rao (1983).Standard length (SL) to the nearest millimeter and total weight (TW) to the nearest milligram were recorded for each fish. Sex was determined by examining the gonads and by inspecting the presence of supracaudal light organ, Head light organs and small size of myctophids were found only in mature males (Hulley 1986a). Sexual maturity of the fish gonadal stages were analyzed both macroscopically and microscopically. Maturity stages of ovaries were classified based on the morphological appearance. The six-stage classification of gonad was used to quantify the maturity stages, which included visual quantification on the basis of shape and colour of the gonads and the extent to which the ovary occupies the gut cavity (Qasim 1973). Gonad weight (GW, nearest 0.001 g) and Body weight (BW−GW, g) were recorded. The relative ovary weight or Gonad Somatic Index (GSI) was calculated using the formula of Barber and Blake (2006).

$$GSI = GW/BW \times 100$$

Fishes belonging to the maturity stage III onwards were considered as mature fish and used for calculating the length at first maturity. The ovaries of fish collected for the estimation of fecundity were preserved in 5% buffered formalin. Fecundity was studied by gravimetric method based on weighing the ova. After segregating sub samples from the ovarian tissues, the ova were thoroughly washed and spread on a blotting paper to dry in air. The total number of ova so collected was then weighed and random samples were counted and weighed (Venkataramanujan and Ramanathan 1994). The total number of ova in the ovaries was then obtained from the equation:

$$F = nG/g$$

Where, F= fecundity; n = number of ova in the sub samples; G = total Weight of the ova and g = weight of the sub sample in the same unit.

For measuring Ova diameter, ova was placed in a glass slide and observed under stereo microscope. Individual specimens were examined under 10 to 115 X magnifications using Leica S8 APO trinocular stereomicroscope and Leica MZ 16 stereomicroscope. Photographs as well as measurements were taken under Leica DFC 425 Image viewer. Due to preservation in formaldehyde eggs lacked symmetry.

2.4 Data Analysis

In the present study, all the 74 stations are represented by a 5 digit numeric code in which the first three digits represent the *FORV Sagar Sampada* Cruise number and last two digits indicate the sampling station number. In the alphabetic codes used for statistical analysis N represent NEAS, S for SEAS and E for WEIO. Deep scattering layer was identified from echo soundings and sampling depths were fixed accordingly. Three major seasons, summer monsoon (SM), winter monsoon (WM) and Spring Inter monsoon (SIM) were considered but due to lack of full seasonal coverage of the three sampling regions, a seasonal comparison was not attempted. Statistical software, PRIMER 6+ (Plymouth Routines in Multivariate Ecological Research) and R version 3.4.3 were primarily used for statistical analysis. SURFER-11, Oceanic Data View 4 were used to plot and visualize the region. Biodiversity and community structure analysis were carried out using PRIMER-6 (Clarke and Warwick 2001). The number of species collected in each sample was used as a direct measure of diversity in the present study. A diagrammatic method for estimating species richness was also adopted, by using a species-area curve or species accumulation curve (Clarke & Warwick 2001), which depicts the cumulative number of species observed as each sample is added. The plot reaches its upper asymptote when majority of the species in a community have been obtained, and is therefore also used to test sampling sufficiency (Clarke and Warwick 2001; Khan 2006). Accumulation curves indicate the rate at which species are added (Magurran 2013). Several methods have been developed to extra polate the actual species accumulation curves to estimate total species richness, of which Chao 2 as well as Jacknife estimators (1 & 2) have been used in the present study. The Chao's (1984) estimators are based on the numbers of rare species, of which Chao-2, is modified for use with presence-absence data (Colwell and Coddington 1994).

$$S_{Chaos2} = S_{Obs} + Q1^2 / \ 2Q_2$$

Where $SObs$ indicates the number of observed species, $Q1$ is the number of species that occur only in one sample and $Q2$ is the number of species that occur in exactly two samples.

In general, Chao's estimators provide minimum estimates of species richness, and assume homogeneity among samples (Magurran 2013). Jacknife estimators also predict species richness on the basis of presence-absence data and place emphasis on rare species. The first order estimator (Jacknife-1) employs the number of species that occur only in one sample, while the second order estimator (Jacknife-2) also takes into account species that occur in exactly two samples (Burnham & Overton 1978, Heltshe and Forrester 1983).

$$S_{Jack1} = S_{obs} + Q1\ (m-1/m)$$

$$SJack1 = Sobs + [Q_1\ (2m-3)/m - Q_2\ (m-2)^2/m\ (m-1)]$$

Where $SObs$ indicates the number of species observed, $Q1$ is the number of species that occur only in one sample, $Q2$ is the number of species that occur in exactly two samples and m is the total number of samples. The species accumulation curve was plotted and estimators were calculated using PRIMER-6 package (Clarke and Gorley 2006). To elu cidate the distribution patterns of myctophids across the Western Indian Ocean, the data on distribution of myctophids species was subjected to multivariate analyses using the PRIMER 6 package. Bray-Curtis similarity was calculated based on square-root transformed data. Since multiple sampling gears were used in the present study, the species distribution data was taken as presence or absence, rather than quantitative data. The degree of similarity between stations on the basis of species occurrence was calculated using the Kulczynski index (Kulczynski 1927, Clarke and Warwick 2001), which is ideal for elucidating ecological patterns using presence-absence data (Faith *et al.,* 1987). Euclidean distance measures among sites were computed based on the measured environmental parameters (log-transformed and normalised data). Alpha-diversity indices, viz. species richness (Margalef's index, d), Species equitability (Pielou's index, J'), and species diversity (Shannon-Weiner index, H') were computed for each sampling area using DIVERSE tool. Dominance plot tool was used to get a picture on the cumulative dominance over the total species observed in each samples. Species richness and rarefaction are measures of total number of species present in a given number of individuals, while species equitability or evenness shows how evenly the individuals are distributed among the different species and species diversity shows the distribution of species in a given number of individuals. The Shannon-Weiner diversity index (H'), incorporates taxonomic separation between the species.

The spatio-temporal variations in abundance of myctophids and regions were tested using Analysis of Similarity (ANOSIM) and to validate the data Permutational Multivariate Analysis of Variance (PERMANOVA) in the PERMANOVA+ add-on for PRIMER-6 was used. Similarity matrixes were used for cluster analysis and for non-metric multidimensional scaling (n-MDS) ordination, average linkage of regions (Ludwig and Reynolds 1988) was employed. Numerical abundance (Number/km^2) data matrix of myctophids, prepared from the species composition at each sampling site, was used as input for analysis using PRIMER software. Sampling sufficiency in the study area was tested using species accumulation plot. The plot generated by this tool shows the number of new species added to the total species list with addition of samples. Based on observed curve pattern in the species accumulation plot, species predictors (such as Chaos1, Chaos2, Jacknife1, Jacknife2 estimators) in PRIMER 6 were used to estimate the number of species which could be encountered in the study area, when the sampling approach to infinity (reviewed in Magurran 2013).

An attempt was also made to link selected myctophid species abundance with the measured environmental variables using Canonical Correspondence Analysis (CCA). The Past software version (3) use a subset of important species, identified using SIMPER in PRIMER-6. This analysis is a linear function of the two sets variables (abiotic and biotic) so that the correlation between the two functions is maximized (Poore and Mobley 1980). Geometrically, the method looks at the relative positioning of the subjects in the two-dimensional space, the variables with the highest coefficients in each of these linear functions are assumed to define that function and hence the key features relating the two data sets may be assessed from a pair of coefficient vectors (Poore and Mobley 1980). The CCA plot was useful in determining which environmental factor influenced the distribution of the selected species.

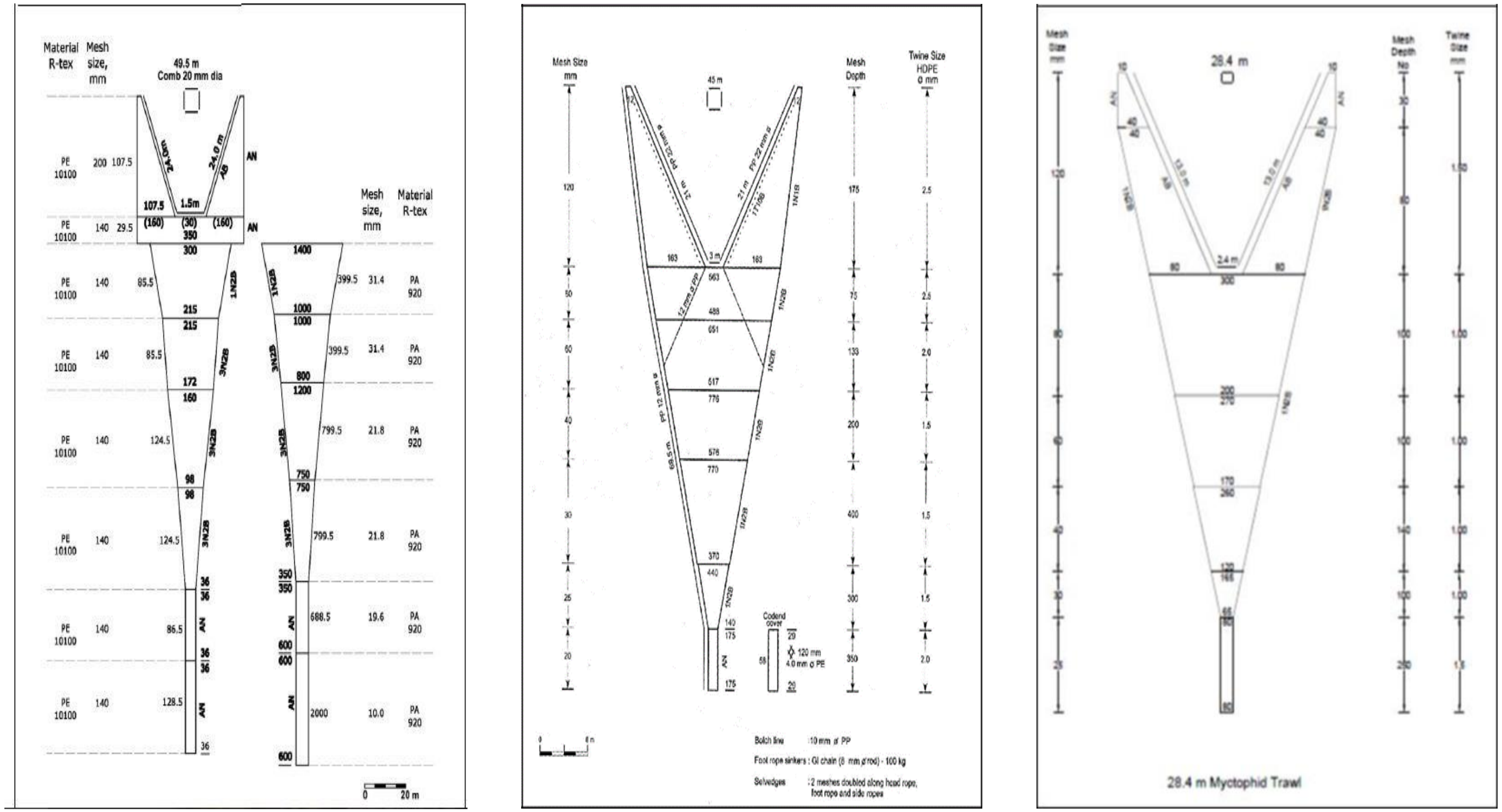


Figure 2.3 a: Trawl design of Cosmos trawl, b: Trawl design of 45m 4 equal panel myctophid trawl, c: Trawl design of 28.5m myctophid trawl.

Table 2.1: Details of sampling locations of Study area

Station No	Station Code	Start Lat (N)	End Lat	Sart Long (E)	End Long (E)	Region	Trawl used	Date	Season	Depth of operation (m)	Statio n depth (m)
31301*	N1	18°37.619' N	18°40.376' N	69°03.492' E	69°05.496' E	NEAS	CT	17-02-2013	WM	327	3372
31302*	N2	19°06.722' N	19°07.299' N	68°31.402' E	68°27.800' E	NEAS	CT	18-02-2013	WM	355	3331
31303*	N3	19°12.833' N	19°12.904' N	67°58.297' E	67°58.297' E	NEAS	CT	19-02-2013	WM	391	3342
31304*	N4	19°10.740' N	19°11.995' N	67°55.443' E	67°56.671' E	NEAS	CT	19-02-2013	WM	282	3300
31305*	N5	19°00.511' N	18°59.493' N	66°06.791' E	66°03.053'E	NEAS	CT	20-02-2013	WM	349	3148
31306*	N6	19°17.840' N	19°16.155' N	65°55.013' E	65°52.059' E	NEAS	CT	20-02-2013	WM	377	3184
31307*	N7	20°56.044 N	20°54.925' N	65°56.529' E	65°54.249' E	NEAS	CT	21-02-2013	WM	372	2500
31308*	N8	20°57.735' N	20°55.762' N	66°19.478' E	66°16.787' E	NEAS	CT	21-02-2013	WM	281	2575
31309*	N9	21°04.195' N	21°07.271' N	68°03.879' E	68°05.591'E	NEAS	CT	22-02-2013	WM	393	2504
32001*	S1	8˚40.764' N	8˚40.764' N	75˚ 58.746' E	75˚59.615' E	SEAS	45 m MT	06-10-2013	SM	99	325
32002#	S2	8˚28.110' N	8˚26.017' N	76˚02.761' E	76˚04.772' E	SEAS	45 m MT	06-10-2013	SM	84	1050
32003*	S3	8˚16.359' N	8˚09.971' N	76˚08.946' E	76˚13.723' E	SEAS	45 m MT	07-10-2013	SM	370	1153
32004*	S4	8˚05.365' N	8˚02.302' N	76˚21.308' E	76˚24.275' E	SEAS	45 m MT	07-10-2013	SM	350	1152
32005*	S5	9˚06.390' N	9˚01.119' N	75˚49.231' E	75˚51.480' E	SEAS	45 m MT	08-10-2013	SM	260	373
32006*	S6	9˚07.990' N	9˚04.334' N	75˚49.541' E	75˚51.785' E	SEAS	45 m MT	08-10-2013	SM	270	381

32007*	S7	11˚14.823' N	11˚11.276' N	72˚550.96' E	72˚57.267' E	SEAS	CT	10-10-2013	SM	223	1861
32008*	S8	11˚04.709' N	11˚01.244' N	72˚01.830' E	73˚04.384' E	SEAS	CT	10-10-2013	SM	287	1912
32009*	S9	11˚16.770' N	11˚13.194' N	72˚56.072' E	72˚59.323' E	SEAS	CT	11-10-2013	SM	320	1862
32010*	S10	11˚07.261' N	10˚58.613' N	75˚06.710' E	73˚10.501' E	SEAS	CT	11-10-2013	SM	290	1891
32011*	S11	10˚36.961' N	10˚33.144' N	73˚11.979' E	73˚12.508' E	SEAS	CT	12-10-2013	SM	300	1871
32012*	S12	10˚24.022' N	10˚20.822' N	73˚18.273' E	73˚21.971' E	SEAS	CT	12-10-2013	SM	400	1961
32013*	S13	10˚13.963' N	10˚10.023' N	73˚28.505' E	73˚30.936' E	SEAS	CT	12-10-2013	SM	350	2150
32014*	S14	11˚22.934' N	11˚19.456' N	73˚32.180' E	73˚34.610' E	SEAS	CT	13-10-2013	SM	330	2230
32015*	S15	11˚46.030' N	11˚42.911' N	73˚40.412' E	73˚43.718' E	SEAS	CT	13-10-2013	SM	300	2134
32016*	S16	12˚54.041' N	12˚52.538' N	73˚46.315' E	73˚47.995' E	SEAS	CT	14-10-2013	SM	275	1030
32017*	S35	11˚06.396' N	11˚01.857' N	74˚52.394' E	74˚55.244' E	SEAS	45 m MT	15-10-2013	SM	350	1132
32501#	S39	14°11.890' N	14°13.560' N	69°47.688' E	69°45.521' E	SEAS	45 m MT	08-03-2014	SIM	330	3933
32502#	S17	13°25.123' N	13°26.425' N	57°02.613' E	67°05.363' E	SEAS	45 m MT	10-03-2014	SIM	260	4063
32503#	S18	11°21.361' N	11°23.062' N	67°00.288' E	66°58.997' E	SEAS	45 m MT	11-03-2014	SIM	270	4280
32504*	S19	10°37.110' N	10°40.280' N	67°00.671' E	67°00.121' E	SEAS	45 m MT	12-03-2014	SIM	100	4365
32505*	S20	10°57.505' N	10°58.435' N	67°00.255' E	67°02.667' E	SEAS	45 m MT	13-03-2014	SIM	110	4323
32506*	S21	10°00.161' N	10°02.194' N	71°29.005' E	71°27.066' E	SEAS	45 m MT	15-03-2014	SIM	100	2903
32507*	S22	11°02.436' N	11°00.450' N	73°10.816' E	73°08.403' E	SEAS	45 m MT	16-03-2014	SIM	345	1964
32508#	S40	10°21.276' N	10°23.170' N	73°09.085' E	73°10.984' E	SEAS	45 m MT	16-03-2014	SIM	250	1885
34214#	S41	08°35.264' N	08°36.374' N	73°30.832' E	73°31.928' E	SEAS	45 m MT	20-07-2015	SM	100	2188
34255*	S42	09°52.55' N	09°53.794' N	73°21.456' E	73°20.020' E	SEAS	CT	28-07-2015	SM	100	2242

34271*	S23	10°10.3090' N	10°11.997' N	74°06.977' E	74°04.280' E	SEAS	CT	30-07-2015	SM	100	2220
34278#	S43	09°46.591' N	09°49.765' N	75°31.267' E	75°33.792' E	SEAS	CT	01-08-2015	SM	60-120	1089
34279#	S24	09°39.5540' N	09°42.984' N	75°31.535' E	75°31.255' E	SEAS	CT	01-08-2015	SM	50-200	1089
344I01*	S31	8˚58.972' N	9˚00.953' N	73˚03.742' E	73˚06.717' E	SEAS	CT	07-09-2015	SM	300-360	1893
344I02*	S32	8˚20.874' N	8˚21.533' N	72˚54.890' E	72˚06.529' E	SEAS	CT	08-09-2015	SM	250-348	3000
344I03#	S33	8˚05.2260' N	8˚06.857' N	71˚52.650' E	71˚55.829' E	SEAS	CT	08-09-2015	SM	200-400	1152
344I04*	S34	07˚45.696' N	07˚45.322N	70˚52.676' E	70˚55.413' E	SEAS	CT	09-09-2015	SM	304-600	4259
344I05*	S44	6˚28.615' N	06˚26.486' N	70˚06.022' E	70˚00.489' E	SEAS	CT	10-09-2015	SM	30-50	3943
344I06*	S45	06˚23.729' N	06˚27.834' N	70˚03.640' E	70˚02.688' E	SEAS	CT	11-09-2015	SM	62-120	3943
344I07*	E1	05˚08.365' N	05˚07.190' N	69˚03.324' E	69˚04.122' E	WEIO	CT	12-09-2015	SM	400-506	3948
344I08*	E2	00˚47.616' S	00˚44.022' S	67˚59.098' E	68˚03.990' E	WEIO	45 m MT	13-09-2015	SM	380-600	1862
344I09*	E3	02˚31.559' S	02˚28.622' S	67˚34.331' E	67˚39.312' E	WEIO	45 m MT	14-09-2015	SM	220-400	2832
344I10*	E4	03˚52.855' S	03˚53.184' S	66˚27.655' E	66˚22.248' E	WEIO	45 m MT	15-09-2015	SM	400	3764
344I11*	E5	05˚26.818' S	05˚27.666' S	65˚57.828' E	65˚52.820' E	WEIO	CT	16-09-2015	SM	400	3618
344ll01*	E6	15˚28.009 ' S	15˚26.541 ' S	56˚ 46.147' E	56˚48.034' E	WEIO	CT	04-10-2015	SM	220	4019
344ll02*	E7	14˚26.208 ' S	14˚24.681 ' S	57˚16.588' E	57˚15.592' E	WEIO	CT	05-10-2015	SM	403	3875
344ll03*	E8	09˚53.021 ' S	09˚51.311 ' S	58˚37.168' E	58˚36.344' E	WEIO	CT	06-10-2015	SM	150	3323
344ll04*	E9	07˚45.275' S	07˚43.355' S	59˚11.025' E	59˚09.451' E	WEIO	CT	07-10-2015	SM	300	1471
344ll05#	E10	04˚31.156' S	04˚30.286' S	60˚46.923' E	60˚45.869' E	WEIO	CT	08-10-2015	SM	100	3946
344ll06#	E11	02˚23.612' S	02˚23.269' S	60˚06.270' E	63˚04.470' E	WEIO	CT	09-10-2015	SM	30-50	4684
344ll07*	E12	01˚41.602' S	01˚41.188' S	63˚39.739' E	63˚38.006' E	WEIO	CT	10-10-2015	SM	330	4400
344ll08*	E14	03˚46.783' N	03˚48.460' N	69˚18.151' E	69˚19.753' E	WEIO	28.4 m MT	11-10-2015	SM	150	3816
344ll09#	E13	05˚31.256' N	05˚34.670' N	70˚48.881' E	70˚47.179' E	WEIO	28.4 m MT	12-10-2015	SM	180	4099

344ll10#	S36	06˚57.354' N	06˚58.058' N	72˚01.609' E	72˚00.045' E	SEAS	28.4 m MT	13-10-2015	SM	101	3090
344ll11#	S37	08˚05.306' N	08˚06.354' N	73˚21.256' E	73˚22.682' E	SEAS	28.4 m MT	14-10-2015	SM	55	2222
344ll12*	S38	08˚39.616' N	08˚41.330' N	74˚09.677' E	74˚09.677' E	SEAS	28.4 m MT	15-10-2015	SM	220	2836
347I05#	S25	14˚41.855' N	14˚42.345' N	73˚00.985' E	72˚58.811' E	SEAS	CT	13-01-16	WM	100	678
347I08#	N10	17˚34.067' N	17˚32.100' N	70˚39.903' E	70˚39.143' E	NEAS	CT	21-01-16	WM	200	2265
347I10#	N11	18˚20.880' N	18˚19.544' N	69˚25.550' E	69˚24.905' E	NEAS	CT	22-01-16	WM	110	3021
347I11#	N12	20˚08.671' N	20˚07.202' N	68˚24.407' E	68˚23.360' E	NEAS	CT	23-01-16	WM	100	3079
347I16#	N13	21˚45.447' N	21˚45.392' N	66˚29.867' E	66˚32.314' E	NEAS	CT	25-01-16	WM	100	2130
347II02#	N14	19˚31.129' N	19˚31.848' N	65˚26.695' E	65˚24.086' E	NEAS	CT	08-02-2016	WM	110	2892
347II09#	N15	15˚58.481' N	15˚56.686' N	65˚29.986' E	65˚30.106' E	NEAS	CT	10-02-2016	WM	100	3714
347II16#	S26	13˚01.549' N	13˚02.396' N	65˚31.634' E	65˚33.429' E	SEAS	CT	12-02-2016	WM	120	4082
347II26#	S27	12˚17.255' N	12˚15.975' N	65˚27.965' E	65˚27.021' E	SEAS	CT	14-02-2016	WM	100	4171
347II32#	S28	10˚58.142' N	10˚57.822' N	67˚30.071' E	67˚30.086' E	SEAS	CT	16-02-2016	WM	95	4341
347II36#	S29	10˚57.446' N	10˚55.818' N	70˚31.136' E	70˚32.141' E	SEAS	CT	18-02-2016	WM	120	3308
347II39#	S30	11˚08.141' N	11˚06.012' N	73˚05.481' E	73˚04.944' E	SEAS	CT	20-02-2016	WM	120	1867

(∗) Denotes Day stations, (#) Denotes night stations, CT (Cosmos Trawl), MT (myctophid trawl)

Chapter-3

MYCTOPHIDS OF WESTERN INDIAN OCEAN: SPECIES DIVERSITY & SYSTEMATICS.

3.1 Introduction

Myctophids commonly referred to as the lantern fishes, have a global distribution from sub- Arctic to Antarctic waters and occupy the mesopelagic realm over continental shelves and the open oceans (Kawaguchi and Shimizu 1978). Taxonomic identification of mycto phids to species level were beset with difficulties and challenges in the past, due to inadequate original descriptions, lack of comparative material from wide geographical areas and sexual dimorphism associated with different species. Bolin (1959); Fraser-Brunner (1949); Paxton (1949; 1972; 1979); Moser and Ahlstrom (1970, 1974); Wisner (1974); Hulley (1986a,b,c); Stianssny (1996); Yamaguchi (2000); Poulsen *et al.,* (2013); de Busserolles *et al.,* (2013); Denton (2014); Denton and Adams (2015) had revised family myctophidae based on osteological, morphological, larval characteristics and molecular phylogeny. With the development of comprehensive identification keys to distinguish species from different regions (Kawaguchi and Shimizu 1978; Nafpaktitis 1978; Fischer and Bianchi 1984) much of these problems are now resolved.

Paxton (1979) classified family Myctophidae into 250 species under 35 genera. Nelson (2006) described 235 species of myctophids under 32 genera. Recent taxonomic studies place the number of myctophid species in world oceans as 248, under 33 genera (Bailly 2015; Froese and Pauly 2017; Eschmeyer *et al.*, 2017). Though, family Myctophidae is classified in different ways, for the purpose of present study, the classification scheme of de Busserolles *et al.,* (2013) is adopted (Figure 3.1).

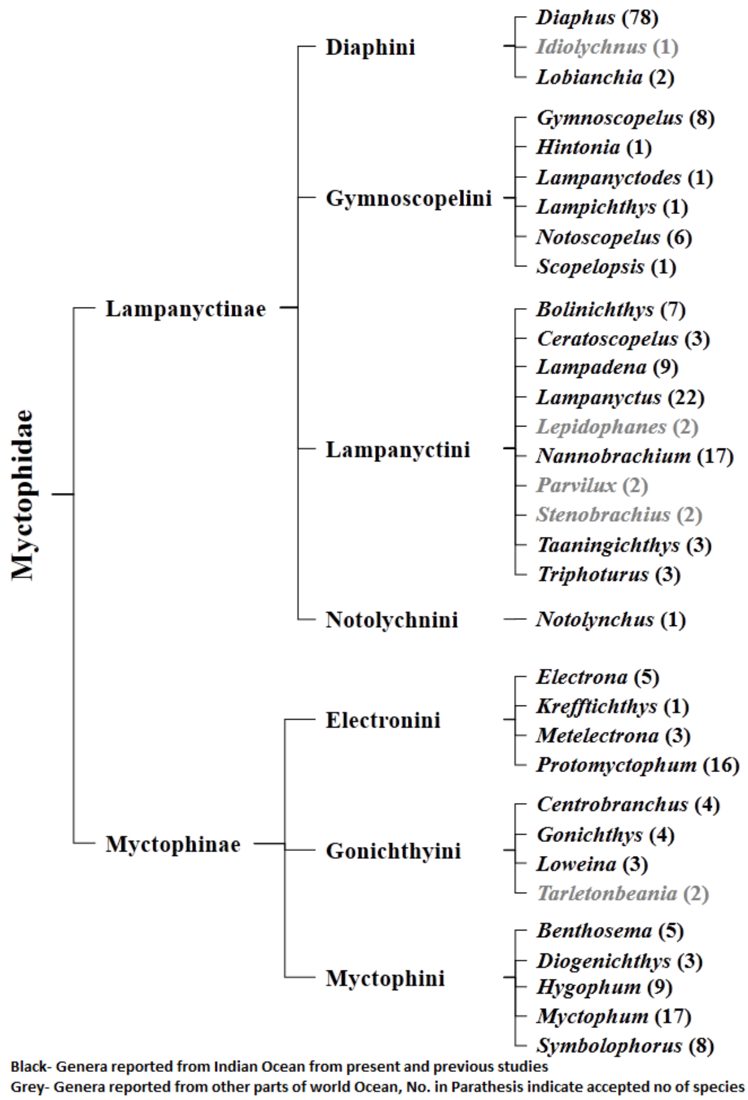


Figure 3.1 : Classification of family Myctophidae

Taxonomic works on myctophids from world oceans are reported by Goode and Bean 1896; Gilbert 1908, 1913; Taning 1928; 1932; Norman 1929; Parr 1929; Frasaer 1949; Bolin 1959; Kulikova 1961; Jordan1963; Bekker 1967a,b; Nafpakitis 1968; 1969,1973, 1974, 1978, 1984; Hulley 1972, 1981, 1984a,b, 1985,1986 a,b,c, 1994, 1995, 1998; Clarke 1973; Wisner 1974; Hartmann and Clarke 1975; Paxton 1963, 1967, 1972, 1974, 1979, 1994, 1999; Nafpaktitis *et al.,* 1977, 1995; Kawaguchi and Shimizu 1978; Fischer and Bianchi 1984; Smith and Heemstra 1986; Dalpadado and Gjosaeter 1993; Nelson 2006; Bailly 2015; Froese and Pauly 2017.

A comprehensive report on the myctophids of Indian Ocean is provided by Nafpaktitis and Nafpakitis 1969. Bradbury *et al.,* (1971) reported 36 species of myctophids in a study on the fauna of equatorial Indian Ocean. Gjosaeter (1977) reported a total of 28 species from Western Arabian Sea in his collections from gulf of Oman (1 species), Pakistan coast (7 species), Arabian coast (16 species), Gulf of Aden (8 species), Somali coast (8 species) and coast of Africa (11 species). Nafpaktitis (1982) reported the presence of 97 species of myctophids under 23 genera in the western Indian Ocean. Tsarin (1983) reported 44 species of myctophids under 14 genera in the epipelagic realm of north western Indian Ocean. Dalpadado and Gjosaeter (1993) reported 16 species from Sri Lankan waters. McGinnis (1982) reported 84 lanternfish species known to occur south of 30°S. Jayaprakash *et al.,* (1996) reported 12 species from equatorial waters (WEIO) of the Indian Ocean.

Pioneering studies on myctophids of Indian waters were done by Alcock (1899). He described 4 myctophid species (*Diaphus coeruleus, D. dumerilii, Benthosema pterotum, and Bolinichthys pyrsobolus)* from Indian waters and reported them under sub genus Myctophum, family Scopelidae. Raman and James (1990) reported eight myctophid genus from the Deep Scattering Layers (DSL) of Indian EEZ. Kinzer *et al.,* (1993) reported the presence of 11 species of myctophids viz., *Benthosema fibulatum, Benthosema pterotum, Bolinichthys longipes, Diaphus arabicus, Diaphus lobatus, Diaphus thiollierei, Diogenichthys panurgus, Hygophum proximum, Lampanyctus macropterus, Myctophum aurolaternatum and Symbolophorus rufinus,* from 18°- 24°30'N lat, 62°- 67°E long, in the Arabian Sea. Menon (2002) reported presence of 27 species of myctophids in the Indian Ocean between 6°-21°N and 67°-76°E. Twenty eight species belonging to 10 genera of myctophids were reported from the Indian EEZ of Arabian Sea by Karuppasamy *et al.,* (2006). Vipin *et al.,* 2012 updated the number of myctophid species in Indian Ocean to 138 species under 27 genera based on previous studies.

In the present chapter, (i) detailed account on the taxonomy and diversity of myctophids in the tropical Western Indian Ocean are presented (ii) the check-list of myctophid species in the Western Indian Ocean is revalidated using primary (present study) and secondary data/ information (Bolin 1946, 1959; Bradbury *et al.,* 1971; Kawaguchi and Aioi 1972 ; Paxton 1972; Gjosaeter 1977; Nafpaktitis 1978, 1984; Kawaguchi and Shimizu 1978; Hulley 1984a,b,1986a,b,c ; McGinnis 1982; Gjosaeter and Kawaguchi 1980; Aglen *et al.,* 1982; Gjosaeter and Tilseth 1983; Alwis and Gjosaeter 1988; Raman and James 1990; Dalpadado and Gjosaeter 1987, 1993; Kinzer *et al.,* 1993; Globec 1993;

Jayaprakash 1996; Zahuranec 2000; FAO 2001; Menon 2002; Valinassab 2005; Karuppasamy *et al.,* 2006; Valinassab *et al.,* 2007; Catual *et al.,* 2010; Hulley and Lutjeharms 1989; Koubbi 2011; Javadzadeh 2012; Vipin *et al.,* 2012; Sebastine *et al., 2013*).

3.2 Methodology

The present study covers the Western Indian Ocean (Part of Indian Ocean west of 77°E Long extending from 24°N to 45°S Lat) which include the Equatorial Indian Ocean (WEIO) extending between 6°N to 6°S, Tropical South Western Indian Ocean (TSWIO) extending from 6°S to 23.5°S; South Eastern Arabian Sea (SEAS; 6°N to 16°N); North Eastern Arabian Sea (NEAS; 16°N to 23.5°N) and sub-tropical Indian Ocean south and north of 23,5°S/N lat. The southern tip of sub-tropical South Indian Ocean is taken as 45°S, as areas south of this are temperate waters that fall within the Convention Area of the Commission for conservation of Antarctic Marine Living Resources (CCAMLR) and therefore is considered as part of the Southern Ocean. Based on preliminary analysis, from the present study the WIO (Indian Ocean west of 80°E) is divided in to 7 sectors namely the Tropical Western Arabian Sea (TWAS) from 6°N to 23.5°N Lat, North Eastern Arabian Sea (NEAS) from 16°N to 23.5°N Lat., South Eastern Arabian Sea (SEAS) from 6°N to 16°N, Western Equatorial Indian Ocean (WEIO) 6°N-6°S,Tropical South Western Indian Ocean (TSWIO) from 6°S -23.5°S, Sub Tropical South Western Indian Ocean (STSWIO) from 23.5°S -45°S Lat. and Sub Tropical Northern Arabian Sea (STNAS), the area north of 23.5°N (Figure 2.1, Study Area, Table 3.2) for revali dating myctophid species diversity in the present study area (Table 3.1).

Taxonomic revalidation of myctophids are based on data collected in the present study from NEAS (15stns), SEAS (37 stns.), WEIO (10 stns.) and TSWIO (4 stns) supplemented with secondary data from published literature. For the TWAS, STNAS, WEIO and STSWIO only the data/ information gathered from secondary sources are utilized. Species description and systematics are based on primary data collected during the present study period (2013 to 2016).

Table 3.2 : Details of Study area

Abbreviations	Region	Latitude	Longitude
STNAS	SUB TROPICAL NORTHERN ARABIAN SEA	>23.5°N	30°-73°E
NEAS	NORTH EASTERN ARABIAB SEA	16-23.5° N	63°-73°E
SEAS	SOUTH EASTERN ARABIAN SEA	6-16°N	63°-78°E
TWAS	TROPICAL WESTERN ARABIAN SEA	6-23.5°	49°-63°E
WEIO	WESTERN EQUTORIAL INDIAN OCEAN	6°N-6°S	39°-80°E
TSWIO	TROPICAL SOUTH WESTERN INDIAN OCEAN	6°S- 23.5°S	30°-80°E
STSWIO	SUB TROPICAL SOUTH WESTERN INDIAN OCEAN	23.5°S- 45°S	30°-80°E
Species reported in fish Base from WIO (Froese and Pauly 2017)	WESTERN INDIAN OCEAN	23.5°S- 45°S	30°-80°E
Species reported in FAO identification sheets Area 51 WIO- Nafpakitis(1982)	WESTERN INDIAN OCEAN	32°N-45°S	30°-80°E
NEAS	NORTH EASTERN ARABIAB SEA	22°N- 16°N	65°-70°E
SEAS	SOUTH EASTERN ARABIAN SEA	16°N-6°N	67°-76°E
WEIO	EASTERN PART OF WESTERN EQUTORIAL INDIAN OCEAN	6°N-6°S	60°-70°E
TSWIO	TROPICAL SOUTH WESTERN INDIAN OCEAN	6°S-16°S	56°-60°E

3.3 Results and discussion.

3.3.1 Sampling sufficiency.

To test the sufficiency of sampling, species accumulation curves (PRIMER) were plotted for the sectors NEAS, SEAS, WEIO from where primary data were collected during the course of the present study using which species estimators are calculated to determine the number of species likely to be encountered in the study area with unlimited sampling (principles detailed in Chapter 2).

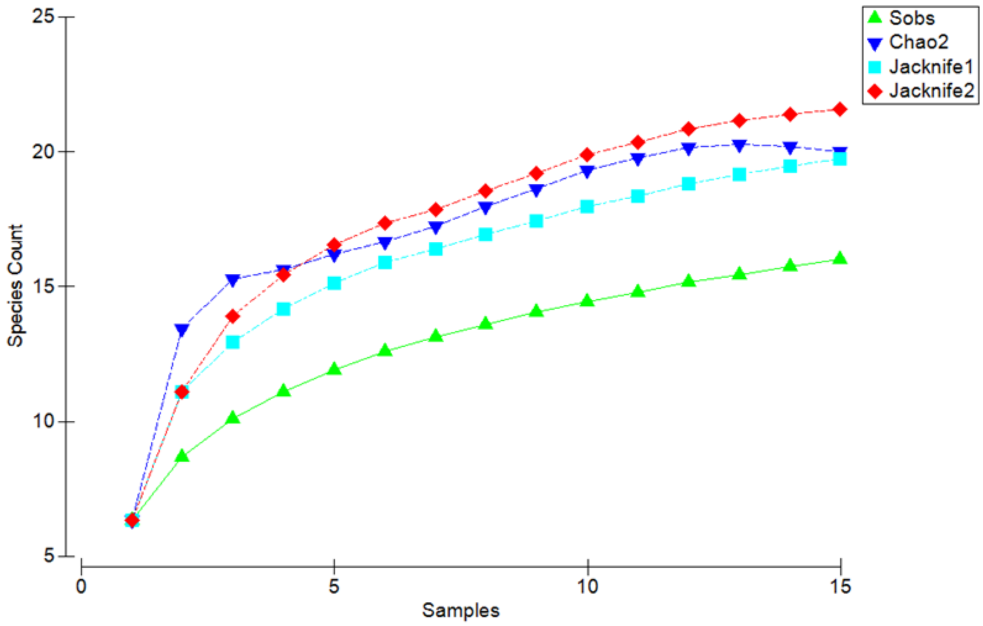


Figure 3.2 : Species accumulation curves for Myctophids in NEAS

The species accumulation curve for NEAS (Figure 3.2) did not reach the upper asymptote, as estimators predicted the occurrence of up to 21 species in this region (Chao's 2 estimator: 20 ± 5.29, Jacknife 1 estimator: 19 and Jacknife 2 estimator: 21 species). The present study (sobs) was able to collect only 16 species from 15 stations representing

76.2 – 84.2% of the highest estimated diversity. From the secondary data species such as *Bolinichthys indicus, Diaphus aliciae, Diaphus fulgens, Diaphus hudsoni, Diogenichthys panurgus and Myctophum aurolaternatum reported* from NEAS and not obtained in the present study, are added to the list of species from NEAS taking the tally of species to 22, one species higher than the highest predicted value of 21 species.

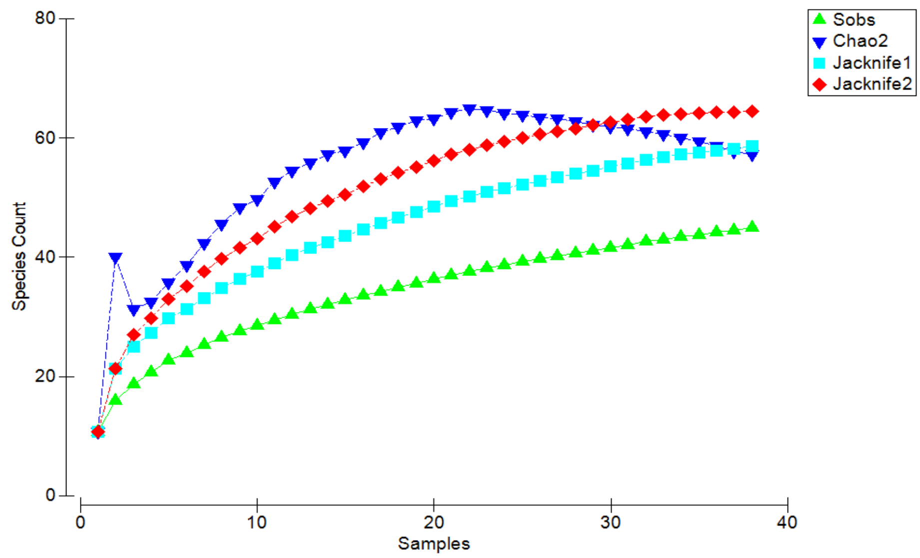


Figure 3.3 : Species accumulation curves for Myctophids in SEAS

The species accumulation curve for the SEAS (Figure 3.3) did not reach the upper asymptote. Estimators predicted the occurrence of up to 64 species in this region (Chao's 2 estimator: 57 ± 8.59, Jacknife 1 estimator: 58 and Jacknife 2 estimator: 64 species). However in the present study only 45 Species from 37 sites were obtained (sobs) representing 70.3% of the highest estimated diversity. With the inclusion of species reported from SEAS by others (*Bolinichthys indicus, Diaphus dumerilii, Diaphus hudsoni, Diaphus luetkeni, Diaphus malayanus, Diaphus phillipsi, Diogenichthys panurgus, Hygophum reinhardtii, Lampanyctus pusillus, Myctophum fissunovi* and *Myctophum selenops)* the total number of myctophid species in SEAS reached 56 numbers, which is very close (87.5%) to the value predicted by the estimators.

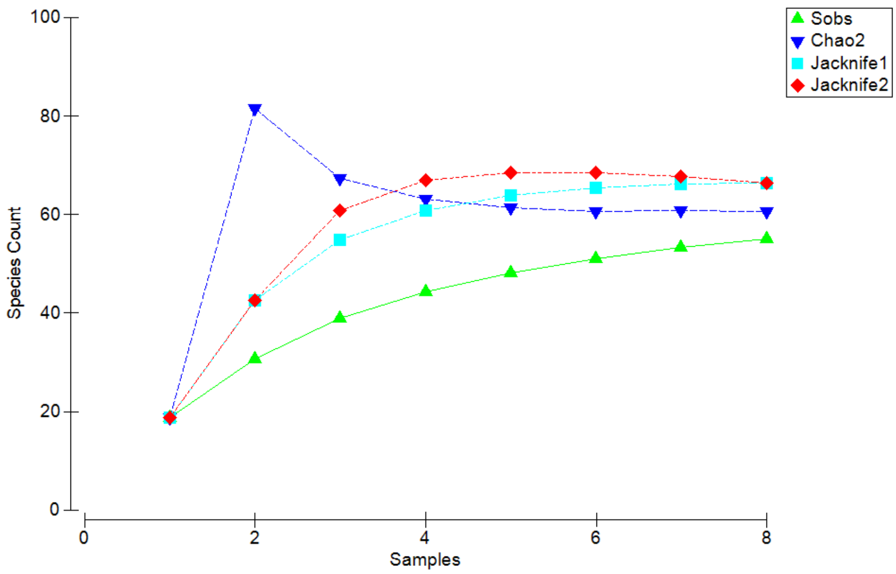


Figure 3.4: Species accumulation curves for Myctophids in WEIO

The species accumulation curve for the WEIO (Figure 3.4) did not reach the upper asymptote, as estimators predicted the occurrence of up to 66 species in this region (Chao's 2 estimator: 60 ± 4.1, Jacknife 1 estimator: 63 and Jacknife 2 estimator: 66 species). In the present study 55 species were obtained from 10 stations representing 86.4% of the highest estimated diversity. Though the WEIO extends from 6°S to 6°N and 40°E to 80°E, in the present study the 10 stations represent only 25% of the total area of WEIO (60°E to70°E) and therefore the species accumulation curve represent the maximum possible species numbers within the study area. Previous workers had reported a total of 85 species from WEIO (Tsarin 1983; Smith and Heemstra 1986; Nafpakitis 1984; Balachandran and Nazar 1990; Bolin 1946, 1959; Bradbury *et al.,* 1971; Kawaguchi and Aioi 1972; Paxton 1972; Gjosaeter 1977;

Nafpaktitis 1984; Gjosaeter and Kawaguchi 1980; Zahuranec 2000; Jayaprakash 1996; Catul *et al.*, 2010; Vipin *et al.,* 2011) of which 50 species (55 species – 5 new records) are common with the present observations. The remaining 335 species are reported from outside the survey area covered in the present study. On adding the 35 species from outside the present study area, the total number of species within the WEIO will be 85 which are consistent with the observations of the previous workers. Further an additional 5 new records of species *Bolinichthys nikolayi, Diaphus theta, Lampadena urophaos, Lampanyctus crocodilus* and *Lampanyctus macdonaldi* were obtained during the course of the present study. Accordingly the species diversity of WEIO is revalidated as 90 species including the 5 new records reported in the present study.

Species accumulation curves for TSWIO could not be attempted as this area is represented only by 4 stations in the present study. However, 39 numbers of species were identified from this area in the present study. Earlier workers had reported 113 species (Bolin 1946, 1959; Bradbury *et al.,* 1971; Kawaguchi and Aioi 1972; Paxton 1972; Gjosaeter and Kawaguchi 1980; Nafpaktitis 1984; Hulley 1984a,b, 1986a, b, c; McGinnis 1982; Kawaguchi and 1972; Gjoaster and Kawaguchi and Aioi 1980; Aglen *et al.,* 1982; Zahuranec 2000; Catual *et al.,* 2010; Hulley and Lutjeharms 1995; Vipin *et al.,* 2012) from this area, which include all species recorded in the course of the present survey. Therefore the total number of myctophid species in TSWIO is retained as 113.

3.3.2 Check-list of myctophids from WIO.

On the basis of the present study an updated check-list of myctophid species in the Western Indian Ocean is given in Table 3.1. As per this check list the myctophids in the WIO are represented by 158 species belonging to 28 genera.

Nafpaktitis (1982) reported 97 species of myctophids under 23 genera from Western Indian Ocean (present study area). The number of genera in Nafpaktitis (1982) study is in fact 24 since the species *Lampanyctus achirus* which he included under genus *Lampanyctus* is actually coming under genera *Nannobrachium* (short-pectoral-finned group) which was divided from genus *Lampanyctus*, defined and recog nized as a monophyletic assemblage, the genus *Nannobrachium* by Zahuranec (2000).

In an updated check-list of myctophid species from Indian Ocean (Eastern and Western IO combined), Vipin *et al.,* (2012) recorded 137 species of myctophids falling under 27 genera. Of the 158 myctophid species reported in the present study from the WIO, 59 species including 6 new record of species viz, (*Bolinichthys nikolayi*, *Diaphus theta*, *Lampanyctus crocodilus*, *Lampanyctus macdonaldi*, *Lampadena urophaos* from WEIO and *Diaphus similis* from SEAS) were collected in the course of the present study and the remaining 99 species are added to this list based on information and data gathered from secondary sources (published literature). Sector wise, the WEIO represented 55 species out of the 59 species recorded in the present study (Table-3.1, 3.1.1) and together with the species added to this list from secondary data, the total number of species in this sector was 90. Bradbury *et al.,* (1971) had reported the occurrence of 36 species and Jayaprakash *et al.,* (2006) reported the occurrence of 12 species of myctophids in the EIO. In the Eastern Arabian Sea (SEAS and NEAS), the SEAS had 45 myctophid species out of the 59 species obtained in the present study, whereas the NEAS had only 16 species (Table-3.1). By pooling the data gathered through the present study with secondary data retrieved from published literature, the number of myctophid species in SEAS is revalidated to 56 and for NEAS to 21 species. Karuppasamy *et al.,* (2006) reported the occurrence of 28 species of myctophids under 10 genera from EAS, which appears to be a gross underestimate of the species abundance in Eastern Arabian Sea. The myctophid species list for TWAS compiled from secondary sources is given in Table 3.1.This sector represented 48 species out of the 158 species recorded for the entire WIO. In the present study 39 Species were recorded from TSWIO (Table 3.1). In the pooled data set (primary and secondary data) TSWIO accounted for 124 number of species amongst the total of 158 species recorded in the WIO. Total myctophid species from STSWIO as per the present study is 90 (Table1) which consist of 32 species obtained in the present study and 58 number of myctophid species reported by earlier workers. South of 30º S, McGinnis (1982) recorded 84 species of myctophids. However, the present study is restricted to the area up to 45ºS only. The STNAS appears to have 9 species of myctophids, as per available published literature.

3.3.3 Systematic Description

Characteristics of Family Myctophidae

The most distinctive external characters of the lantern fishes are their large eyes (situated close to the tip of the blunt snout), wide mouth gape extending back beyond the eye, compressed head and body. Teeth small. Rudimentary spine at base of dorsal, anal and pectoral and ventral ray. Adipose fin present. Anal fin origin under or close behind base of dorsal fin. Photophores arranged in distinct group on head and trunk. Taxonomic key and terminology as given by Smith and Heemstra (1986) is followed (Figure 3.5).

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

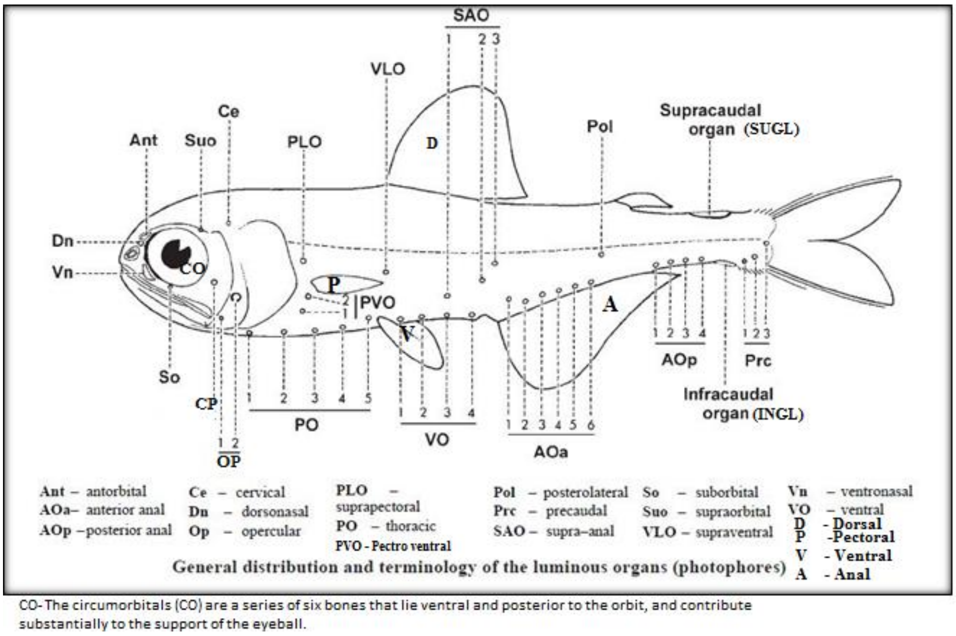


Fig 3.5: Diagram of a myctophid fish showing the location and terminology of photophores

KEY TO GENERA OF MYCTOPHIDS OBTAINED FROM PRESENT STUDY AREA:

1A. No secondary photophores, one or two Prc, neither far above lateral line, dorsal and ventral extra scapulars separate or only ventral element present, no postero- medial shelf on cleithrum Jaws short or moderate in length, extending one-half eye diameter or less behind posterior margin of orbit. Preopercular flag absent or free from dorsal tip of preopercle- ***(SUBFAMILY MYCTOPHINAE***……………………..………2

1B. Secondary photophores present or absent, primary photophores indistinct from secondary photophores or two to nine Prc, if two Prc, one far above lateral line, ventral extrascapulars fused into one element. Jaws usually long, extending one or more eye diameters behind posterior margin of orbit, rarely short or moderate. Preopercular flag absent or fused to dorsal tip of preopercle ***(SUBFAMILY LAMPANYCTINAE)*** ……………………………….……………………….5

2A. PLO ventral to or distinctly dorsal to pectoral base, jaws short, extending less than one-half eye diameter behind orbit, mouth terminal, snout not projecting, antorbital not reduced, pro-current caudal rays not fused ***(TRIBE MYCTOPHINI)***…………………. ……3

3A. Dn present, Vn and Suo absent. PVO arranged horizontally, with PVO1 not more than its diameter below level of PVO2, PVO2 below level of upper end of base of pectoral fin. SAO series angulate, One Pol, Prc2, much higher than Prc1, lying twice its own diameter or less below lateral line, small, simple teeth on premaxillaries and dentaries... ……………………………………….…….………***Benthosema***

3B. Both Dn and Vn present. Suo present, often indistinct PVO on an inclined line, with PV01 more than its own diameter below level of PVO2, all VO at same level, SAO series angulate. Two Pol…… ***Hygophum***

3C. Both Dn and Vn. present. Suo absent PVO1 well below level of PVO2. VO series level. One Pol. SAO on a straight or slightly angular line, SAO1 behind VO3, 1 Pol, 2 Prc. No broad based hooked teeth on jaws..***Myctophum***

2B. PLO opposite or just dorsal to upper edge of pectoral base, jaws moderate, extending one-half eye diameter behind orbit, mouth subterminal, snout projecting, antorbital reduced, procurrent caudal rays weakly fused at tips (***TRIBE GONICHTHYINI***)………………….…….4

4A. Dn small, Vn larger. Five PO, with POs somewhat dorsolaterally displaced. Four VO, level. SAO strongly angulate, with SAO1 in advance of VO3. AO series divided AOa and AOp. One Pol. Two Prc, with Prc2 elevated and immediately, behind Prc1. Supra-caudal (males) and infra-caudal (females) luminous glands present or males and females both with supra and infracaudal glands………… ……………………..***Symbolophorus***

2C. No distinct Pol. AO series relatively unbroken, but sometimes not forming a straight line.PLO before and near PVO1, both below but close to PVO2. No marked development of lateral-line pores. (***TRIBE ELECTRONINI***)…...4B

4B. Lateral line pores readily visible but the line incomplete in some genera. AO series undivided but often undulating near end of anal base, no distinct Pol. VO2 not, or but slightly, elevated, VG series curved. PLO above PVO, about level with PVO, the three forming a right-angled triangle……………………………………….………..***Electrona***

5A. No Dn, posterior portion of dentary with row of moderately or strongly hooked teeth. (***TRIBE LAMPANYCTINI***)……….…….……7

5B. No secondary photophores, PO elevated, PVO inclined, First PO and 2 PVO on a straight ascending line, caudal glands absent. No supramaxillary, one to seven ossified distal pectoral radials, ventral procurrent rays five to seven. Dn present, teeth on posterior portion of dentary small and conical, enlarged, or slightly hooked……………..……6

6. No secondary photophores, PO elevated, PVO inclined, First PO and 2 PVO on a straight ascendind line, caudal glands absent. No supramaxillary, one to seven ossified distal pectoral radials, ventral procurrent rays five to seven (***TRIBE DIAPHINI***)………………………14

7A. Supra and infracaudal luminous glands large, single organs bordered by heavy black pigment 8

7B. Supra and infracaudal luminous glands of narrow, overlapping plates with no pigment 9

8A. Luminous tissue on posterior half of iris, Origin of dorsal fin behind base of pelvic fin. Photophores present. One SAO, Lateral line poorly developed. CO3 lateral shelf solid, without keel, CO5 straight, jaws moderate, extending one-half eye diameter behind posterior margin of orbit, posterior portion of dentary without dorsal expansion, basibranchial plate not extending behind third hypobranchial, procurrent caudal rays not fused at tips …………….……***Taaningichthys***

8B. Origin of dorsal fin somewhat in front of base of pelvic fin. Photophores well developed, SAO in steep, slightly angulate line in series with last VO. No luminous tissue on posterior half of iris (but rarely on dorsal portion), posterior portion of dentary with small dorsal expansion, No luminous gland in front of adipose fin. No Prc above lateral line. No secondary photophores on body procurrent caudal rays strongly fused……….…………………………………….………***Lampadena***

9A. Primary photophores indistinct from secondary photophores or three to nine Prc, no primary photophores far above lateral line, supracaudal gland present or absent, if present as large, single organ bordered by heavy black pigment, a simi-lar infracaudal gland also present eight pelvic rays, 12 to 26 dorsal rays, 31 to 45 vertebrae. Luminous tissue over base of anal fin and on other portions of body in addition to caudal luminous glands, posterior teeth of den-tary moderately or strongly hooked, Postpalatine process and dorsal wing of palatine ossified ……………..…………………….………………………10

9B. Luminous tissue restricted to caudal luminous glands and occasionally at base of adipose fin, hyomandibular nerve foramen between first two hyomandibular heads, posterodorsal expansion of maxillary short …………………………….……………….…………...12

10A. Three Prc, luminous tissue on posterior half of iris, SAO weakly angulated, a line through SAO1 and SAO2 intersecting VO series, Patches of luminous tissue at bases of median and often paired fins, anterior of trunk and on top of head.no keel on CO3, orbital shelf of CO4 extensive, enlarged dentigerous area on anterior portion of premaxillary, anterior tip of urohyal with one head, no posterior spines on procurrent caudal rays…………………………………….***Bolinichthys***

10B. Four Prc, no luminous tissue on iris, CO3 with keel, orbital shelf of CO4 moderate, no enlarged dentigerous area on anterior portion of premaxillary, anterior tip of urohyal slightly split or with two distinct heads, ventral series of procurrent caudal rays with posterior spines …………………………….………………………………11

11. PO level, VO slightly arched, luminous scale like structure midventrally between base of pelvic fins and anus. Jaws moderate,

extending half of eye diameter behind posterior margin of orbit, no dorsal process on opercular head of hyomandibula, first pharyngobranchial with one tooth plate, no ossified distal pectoral radials, hypural flange well developed, both dorsal and ventral series of procurrent caudal rays with posterior spines, PO4 not elevated. …………………….……………………….……………………***Ceratoscopelus***

12. Two Pol, CO3 lateral shelf solid with keel, posterior portion of dentary with small dorsal expansion, urohyal wing behind anterior margin of second hypobranchial 13

13A. Pectoral fin long and broad based. Three to six level VO or four VO with VO2 elevated, opercular head of hyomandibula with small dorsal process …………………………………………………***Lampanyctus***

13B Short rudimentary or no pectoral fin, narrow base always equal to or shorter than distance between lower orbital margin and toothed margin of upper jaw in the adult………………..***Nannobrachium***

14. No caudal luminous glands, More than one pair of luminous organs on head. Luminous scale at PLO ..………………………..***Diaphus***

SPECIES DESCRIPTION OF MYCTOPHIDS OBTAINED FROM PRESENT STUDY:

***GENUS Benthosema* Goode and Bean, 1896**

Mouth moderately large, extending beyond posterior margin of orbit. Maxilla expanded posteriorly. Dn and Vn minute. PVO almost horizontal, not in line with PO1. Five PO, with PO5 somewhat dorsally displaced. Four VO, with VO2 raised to elevated. SAO weakly to strongly angulate. AO divided into AOa and AOp, One Pol. Two Prc, with Prc2 elevated. Supra-caudal (males) and infracaudal (females) glands present. High-oceanic mesopelagic in warm waters of all three oceans, except *B. glaciale*.

Remarks: Five species of Myctophids under this genera have been reported from world oceans of which 3species are from the western Indian Ocean. Among this, 2 species are represented in the present study area.

Benthosema fibulatum (Gilbert and Cramer, 1897)

Common Name: Spinycheek lanternfish

Synonym: *Myctophum fibulatum* Gilbert and Cramer 1897, *Benthosema fibulata* Gilbert and Cramer 1897, *Myctophum hollandi* Jordan and Jordan 1922*, Myctophum renschi, Benthosema pinchoti* Fowler 1932.

Collection Locations: 21°04.195'N, 68°03.879'E, 393m, 22.02.13 night (Cr. 313, St.9), CT,20°57.735'N, 66°14.478'E, 281m, 21.02.13 night (Cr. 313, St.8), CT,20°56.044'N, 65°56.529'E, 372m, 21.02.13 day (Cr. 313, St.7), CT,19°17.840'N, 65°55.013'E, 377m, 20.02.13 night (Cr. 313, St.6), CT,19°12.833'N, 67°58.297'E, 391m, 19.02.13 day (Cr. 313, St.3), CT,19°10.740'N, 67°56.671'E, 282m, 19.02.13 night (Cr. 313, St.4), CT,19°06.722'N, 68°31.402'E, 355m, 18.02.13 night (Cr. 313, St.2), CT,19°00.511'N, 66°06.791'E, 349m, 20.02.13 day (Cr. 313, St.5), CT,18°37.619'N, 69°03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT, 12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr.

320, St.16), CT,11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT,11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT,11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT,11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT,11˚06.39'N, 74˚52.394'E, 350m, .10.13 day (Cr. 320, St.17), 45mMT,11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT,10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT,10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT,10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT,10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320,St.13),CT,09˚03.195'N,75˚53.172'E,270m,08.10.13night,(Cr.320,St.6),45mMT,08˚ 59.820'N, 75˚51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45Mmt ,08˚35.131'N, 76˚00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08˚29.411'N, 76˚06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT,08˚08.933'N, 76˚15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT,08˚01.563'N, 76˚25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 11°08.141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39),CT,21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT,20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT,19°31.129'N, 65°26.695'E, 110m, 08.02.16 night (Cr. 347II, St.2), CT,18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT,17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT,15°58.481'N, 65°29.986'E, 100m, 10.02.16 night (Cr. 347II, St.9), CT,14°41.855'N, 73°00.985'E, 100m, 13.01.16 night (Cr. 347I, St.5), CT,13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT, 12°17.255'N, 65°27.965'E, 100m, 14.02.16 night (Cr. 347II, St.26), CT,11°08.141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39), CT,10°58.142'N, 67°30.071'E, 95m, 16.02.16 night (Cr. 347II, St.32), CT,10°57.446'N, 70°31.136'E, 120m, 18.02.16 night (Cr. 347II, St.36), CT,10°11.997'N, 74°04.2800'E, 100m, 30.07.15 night (Cr. 342, St.71), 09°42.984'N, 75°31.255'E, 50-200m, 01.08.15 night (Cr. 342, St.79), CT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT,08˚06.857'N, 71˚55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT,08˚06.354 'N, 73˚22.682'E, 55m, 14.10.15 night (Cr.344II, St.11), 28.4mMT, 07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT,06˚58.058 'N, 72˚00.045'E, 101m, 13.10.15 night (Cr. 344II, St.10), 28.4mMT,05˚34.670'N,70˚47.179'E,180m,12.10.15 night (Cr. 344II, St.9), 28.4mMT, 05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT,03˚53.184'S, 66˚22.248'E, 400m,15.09.15day(Cr. 344I, St.10), 45mMT,03˚48.460'N, 69˚19.753'E, 150m, 11.10.15 night (Cr. 344II, St.8), 28.4mMT,02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 00˚44.022'S, 68˚03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT,15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT,14˚24.68'S, 57˚15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT,09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT,21°04.195'N, 68°03.879'E, 393m, 22.02.13 night (Cr. 313, St.9), CT,20°57.735'N, 66°14.478'E, 281m, 21.02.13 night (Cr. 313, St.8), CT,19°12.833'N, 67°58.297'E, 391m, 19.02.13 day (Cr. 313, St.3), CT,19°10.740'N, 67°56.671'E, 282m, 19.02.13 night (Cr. 313, St.4), CT,19°06.722'N, 68°31.402'E, 355m, 18.02.13 night (Cr. 313, St.2), CT,18°37.619'N, 69°03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT,12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT,11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT,11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT,11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT,11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT,11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT,10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT,10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT,10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT,10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT,09˚03.195'N, 75˚53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08˚59.820'N, 75˚51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08˚35.131'N, 76˚00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08˚29.411'N, 76˚06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT,08˚08.933'N, 76˚15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT, 08˚01.563'N, 76˚25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 10°02.194 'N, 71°27.066 'E, 100m, 15.03.14 day (Cr. 325, St.6), 45mMT, 21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT,20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT, 18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT,08˚06.857'N, 71˚55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT,07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT,06˚27.834'N, 70˚02.688'E, 62-120m, 11.09.15 day (Cr. 344I, St.6), CT,06˚26.486'N, 70˚00.489'E, 30-50m, 10.09.15 day (Cr. 344I, St.5), CT,05˚27.666'S, 65°52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT,05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT,03°53.184'S, 66°22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT,02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT,00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 06°58.058 'N, 72°00.045'E, 101m, 13.10.15 night (Cr. 344II, St.10), 28.4 mMT.

Voucher Specimen No: IO/SS/FIS/00455

Diagnosis: Standard length of the specimen ranged from 30mm- 70mm. Mouth terminal, So absent, Opercular margin sharply angular posterodorsally, abruptly produced into a tapering projection posteriorly. Dn and Vn poorly developed. Origin of dorsal fin behind vertical through base of outermost ray of ventral fin. Origin of anal fin under base of dorsal fin. Base of adipose fin well in advance of vertical through end of base of anal fin. OP2 on level of ventral margin of orbit, PLO markedly nearer LL than upper base. A base larger than D base. SAO series widely angular, SAO1 slightly behind vertical through centre of VO3, well below line connecting VLO with SAO2 and very slightly above line connecting VO2 with SAO2, second SAO about over origin of anal fin, SAO3 over AOa1-AOa2 interspace, in contact with lateral line. Prc widely separated, Prc2 about its own diameter below level of lateral line. Vertebrae: 31 – 32. Mature males have large 3 to 5 translucent supracaudal glands and smaller infracaudal glands, mature females have small supracaudal gland and much smaller infracaudal patches.

D12, A17, P14, GR 6+1+14, AO 5+5

Habitat: Benthopelagic and mesopelagic in slope and oceanic waters, but usually not high-oceanic. Occurs in the upper 200 m at night. Epipelagic in near shore areas at 0-856 m. occasionally seen during dark nights on slopes that are near very deep water.

Distribution: Indian Ocean, Area of Pakistan, Gulf of Aden and Somali coast. Gulf of Oman, Western Indian Ocean, Indian Ocean (18°N-20ºS) to 42°S in Agulhas current, Sri Lankan waters (07°06'N- 08° 26'N and 79°29'E-81°59'E), North- Eastern Arabian Sea, Indian EEZ of Arabian Sea (6-21ºN and 66º -77ºE).

Reference: Bolin 1946 ; Gjosaeter 1977; Nafpaktitis 1984 ; Hulley 1986a,b,c; Dalpadado and Gjosaeter 1993; Kinzer *et al.,* 1993; Menon 2002 ; Valinassab 2005 ; Karuppasamy *et al.,* 2006, 2010; Kinzer *et al.,* 1993 ; Nair *et al.,* 1999; Globec 1993; Sebastine *et al.,* 2013 ; Tsarin 1983; Bradbury *et al.,* 1971 ;Dalpadado and Gjosaeter 1993; Alwis and Gjosaeter 1988; Valinassab 2005; Boopendranath *et al.,* 2009.

Benthosema pterotum (Alcock, 1890)

Common Name: Skinnycheek lanternfish

Synonym: *Scopelus pterotus* Alcock, 1890, *Myctophum pterotum* Alcock, 1890, *Benthosema pterota* Alcock, *1890, Benthosema ptertum* Alcock, 1890, *Scopelus pterotum* Alcock, 1890, *Myctophum gilberti* Evermann and Seale, 1907.

Collection Locations: 21°04.195'N, 68°03.879'E, 393m, 22.02.13 night (Cr. 313, St.9), CT,20°57.735'N, 66°14.478'E, 281m, 21.02.13 night (Cr. 313, St.8), CT,20°56.044'N, 65°56.529'E, 372m, 21.02.13 day (Cr. 313, St.7), CT,19°17.840'N, 65°55.013'E, 377m, 20.02.13 night (Cr. 313, St.6), CT,19°12.833'N, 67°58.297'E, 391m, 19.02.13 day (Cr. 313, St.3), CT,19°10.740'N, 67°56.671'E, 282m, 19.02.13 night (Cr. 313, St.4), CT,19°06.722'N, 68°31.402'E, 355m, 18.02.13 night (Cr. 313, St.2), CT,19°00.511'N, 66°06.791'E, 349m, 20.02.13 day (Cr. 313, St.5), CT,18°37.619'N, 69°03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT,12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT, 11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT,11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT,11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT,11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT,11˚06.39'N, 74˚52.394'E, 350m, .10.13 day (Cr. 320, St.17), 45mMT,11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT,10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT,10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT,10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT,10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT,09˚03.195'N, 75˚53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08˚59.820'N, 75˚51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08˚35.131'N, 76˚00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08˚29.411'N, 76˚06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT, 08˚08.933'N, 76˚15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 5mMT,08˚01.563'N, 76˚25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT,21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT,20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT,18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT,10°02.194 'N, 71°27.066 'E, 100m, 15.03.14 day (Cr. 325, St.6), 45mMT,06˚58.058 'N, 72˚00.045'E, 101m, 13.10.15 night (Cr. 344II, St.10), 28.4mMT,09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT,08˚06.857'N, 71˚55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT,07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT,06˚27.834'N, 70˚02.688'E, 62-120m, 11.09.15 day (Cr. 344I, St.6), CT,05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT,03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT,02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 06˚58.058 'N, 72˚00.045'E, 101m, 13.10.15 night (Cr. 344II, St.10), 28.4mMT.

Voucher Specimen No: IO/SS/FIS/00456

Diagnosis: Standard length of the specimen ranged from 20mm- 60mm Mouth terminal, So absent, Posteriodorsal opercular margin broadly rounded abruptly produced into a tapering projection posteriorly. Maxillae expanded posteriorly, Dn and Vn small and poorly developed. Posterio dorsal margin broadly rounded. Origin of dorsal fin behind vertical through base of outermost ray of ventral fin. Origin of anal fin under base of penultimate ray of dorsal fin. Base of adipose fin well in advance of vertical through end of base of anal fin. Pectoral fin long, extending to about second AOa, with upper end of its base about on level of ventral margin of orbit. Ventral fin short, not reaching anus. PLO mid-way between LL and p base, SAO on line connecting VLO and SAO. PO1 through PO4 gently arched, PO5 abruptly displaced dorsa laterally to a position in front of base of outermost ray of ventral fin. VLO distinctly nearer to lateral line than to base of ventral fin, its distance from latter 2-2.5 times as great as that between it and lateral line. SAO series widely angular, SAO1 slightly behind vertical through centre of VO3 on line connecting VLO with SAO2, second SAO about over origin of anal fin, SAO3 over AOa1-AOa2 interspace, in contact with lateral line. AOa1 slightly depressed, space between it and AOa2 usually a little wider than spaces between rests of organs of same series. AOp level and equidistant, AOp1 over or somewhat in advance of end of base of anal fin. Pol in contact with lateral line. Prc widely separated, Prc2 about its own diameter below level of lateral line. Mature males have a large supracaudal gland and a smaller infracaudal gland. Each luminous scale is completely surrounded by black pigment. Infracaudal gland is located between the last AOp and the first Prc.

D 13-14, A 18-19, P 14, GR 6 +1+ 15, AO 6+ 5

Habitat: Benthopelagic and mesopelagic in slope and near continental and island waters. Found in 130-300 m depths during the day and in 10-200 m at night. Feeds in the evening. Feed mainly on copepods, euphasids, ostracods and various other crustacean.

Distribution: Deep-water, Indian DSL: West coast- 7°-21°N, East coast 10°N-20°N.Indian Ocean from Arabian Sea to about 25°S off Mozambique Western North Pacific.

Reference: Gjosaeter 1977; Nafpaktitis 1984; Gjosaeter 1984; Kinzer *et al.,* 1993; Valinassab 2005; Valinassab *et al.,* 2007; Fao 1997 ;Karuppasamy *et al.,* 2006, 2010; Kinzer *et al.,* 1993 ; Nair *et al.,* 1999; Menon 2002; Hulley 1986a,b,c; Globec 1993; Alwis and Gjosaeter 1988; Tsarin 1983; Dalpadado and Gjosaeter 1993; Valinassab 2005.

***GENUS Hygophum* Bolin, 1939**

Mouth moderately large, jaws extending to posterior margin of orbit. Maxillae broadly expanded posteriorly. Dn small, Vn larger. Suo present. Five PO, level or with PO5 elevated. Four VO, level. SAO angular. AO series divided into AOa and AOp. Two Pol. Two Prc, with Prc2 elevated to lateral line or midway between lateral line and ventral contour. Supra-caudal and infracaudal glands present.

Remarks: 9 species under this genera are reported from World Ocean which include 4 species reported from western Indian Ocean. Out of the 4 species, 2 species have been obtained from the present study area.

Hygophum hanseni (Taning, 1932)

Common Name: Hansen's lanternfish

Synonym: Myctophum hanseni Tåning 1932, *Serpa peccatus* Whitley and Phillipps 1939

Collection Locations: 07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 01˚41. 188'S, 63˚38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT.

Voucher Specimen No: IO/SS/FIS/00489

Diagnosis: Standard length of the specimen ranged from 30mm- 40mm. Maxilla broadly expanded posteriorly, extending to or a little behind vertical through rear margin of orbit, A base longer than D base, P base equidistant from dorsal and ventral margins of trunk. Dn smaller than Vn, PLO one photophore below LL.VLO midway between LL and PO.5 PO, 4 VO, SAO series angulate, AO series divided into AOa and AOp, PO5 elevated above level of rest of series, well above level of outer base of V, AOa series arched, with AOa1 and AOa4 elevated. Mature males with single, supracaudal luminous gland only, mature females with 1-3 partially- coalesced luminous patches infracaudally.

D 13-14, A 19, P 14-16, GR 3 +1 + 13-14, AO 6 +6.

Habitat: Oceanic and mesopelagic, occurs at depths between 608-728 m during the day and between 57-110 m at night. (*H. hanseni*) with restricted convergence distribution in southern hemisphere.

Distribution: Convergence species (30º-43°S) in all 3 oceans.

Reference: Nafpaktitis 1984; Hulley1986 a,b,c; Koubbi *et al.,* 2011; Mc Ginnis 1982; Froese and Pauly 2017.

Hygophum proximum Becker, 1965

Common Name: Firefly lanternfish

Synonym: NIL

Collection Locations: 17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT, 15°58.481'N, 65°29.986'E, 100m, 10.02.16 night (Cr. 347II, St.9), CT,13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT.

Voucher specimen No: IO/SS/FIS/00490

Diagnosis: Standard length of the specimen ranged from 30mm- 50mm. Maxilla broadly expanded posteriorly, extending a little behind vertical through rear margin of orbit, Pectoral fin extending to about anal origin. Ventral fin reaching anal origin. Origin of dorsal fin on vertical through outer ventral base, origin of anal fin on or slightly behind vertical through base of last dorsal ray. Origin of adipose fin well in advance of vertical through base of last anal ray. Pectoral fin extending to about anal origin, ventral fin reaching anal origin. Dn and Vn present, small, luminous organ at posterior end of supraorbital ridge, slightly in advance of posterior margin of orbit. PLO midway between upper pectoral base and LL. 4 VO, SAO series obtusely angulate with SAO1 on a slightly in advance of vertical through VO3. VLO about midway between LL and outer base of V. A base longer than D base, 5 PO, 4 VO, SAO series angulate, AO series divided into AOa and AOp. Distance between Prc2 and rear end of D base less than distance from tip of snout to V base. Mature males with single, black-edged, Supracaudal luminous gland, mature females with single, Infracaudal luminous gland.

D 13, A 19, P 13-14, GR 4 +1+ 14, AO 6 + 5.

Habitat: Oceanic and mesopelagic. Nyctoepipelagic at the surface. Neustonic at 0-150 m at night, 500-700 m during day. Range Deep-water. Oviparous, with planktonic eggs and larvae.

Distribution: Northern Arabian Sea, Western Indian Ocean, South of 37 ºS in Agulhascurrent, Indian Ocean (25°N-10ºS), Indian EEZ of Arabian Sea (06º00'- 21º00'N, 67º00' – 77º00'E, 07°08'N, 79°29'E), Sri Lankan waters (07°06'N- 08° 26'N and 79°29'E-81°59'E), North-Eastern Arabian Sea, Area of Pakistan, Gulf of Aden and Somali coast, Eastern Indian Ocean.

Reference: Nafpaktitis 1984; Hulley 1986a,b,c; Kinzer *et al.,* 1993; Karuppasamy *et al.,* 2006, 2010; Muhlinga *et al.,* 2007; Menon 2002; Gjosaeter 1977; Tsarin 1983; Dalpadado and Gjosaeter 1993.

GENUS Myctophum **Rafinesque, 1810**

Mouth moderately large, jaws extending beyond posterior margin of orbit. Maxillae from slightly to markedly expanded posteri orly. Dn small, Vn larger. Five PO, level. Four VO, level. SAO in a straight or slightly angulate line, with SAO1 always posterior to V03. AO series divided into AOa and AOp. One Pol, Two Prc, with Prc2 either elevated and just posterior to Prcl or highly elevated to lateral line. Supra-caudal (males) and infra-caudal (females) luminous glands pre sent. High Oceanic, mesopelagic in warm waters of all three oceans, one species (*M.punctatum*)in boreal North Atlantic andin Mediterranean.

Remarks: 17 species have been reported from world oceans which include 14 species from western Indian Ocean. Five species from study area.

Myctophum asperum Richardson, 1845

Common Name: Prickly lanternfish

Synonym: *Dasyscopelus asper*, Richardson 1845, *Scopelus asper* Richard son1845, *Dasyscopelus naufragus* Waite 1904.

Collection Locations: 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 07°45.322'N, 70°55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT,03°53.184'S, 66°22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT,02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT,00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 02°23.269'S, 63°04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT.

Voucher specimen No: IO/SS/FIS/00504

Diagnosis: Standard length of the specimen ranged from 50mm- 70mm. 5-PO, elevated, 2-PVO, PVO1, PVO2 and PO1 forms an inclined line. 4 VO, SAO3, Pol and PLO one photophore diameter below LL.SAO1,2,3 forming a distinct angle, a line through SAO1,2 passing through VO2, SAO1 over the interspace between VO3 and VO4, closer to VO2, a line through SAO2, 3 passing slightly in advance of VO4. SAO3 over anal fin origin. Interspace between Prc1 and Prc2 slightly wider than that between AOp photophores, Prc2 closer to lateral line than to ventral margin. No serration at the posterodorsal margin of opercle. Scales strongly ctenoid. Infra luminous gland present. 2-Prc, Prc2 one photophore below LL.

D 12, A 17-18, P 15, G R 5 +1+ 9, AO 7+ 5

Habitat: High- Oceanic, mesopelagic, occupy 425-750m depths during day and from surface to 125m during night.

Distribution: Off east coast and in Agulhas water pockets off west coast. Atlantic (20°N-8°NS) and in Indian and Pacific Oceans (North and South Equatorial Currents and Equatorial Counter currents, with northern and Southern extensions in Western boundary currents.

Reference: Bradbury *et al.,* 1971; Kawaguchi *et al.,*1972; Tsarin 1983; Hulley 1986a,b,c; Nafpaktitis 1984; Menon 2002; Karuppasamy et al. 2006; Muhlinga *et al.,* 2007; Jayaprakash *et al.,* 2006.

Myctophum aurolaternatum Garman, 1899

Common Name: Golden lanternfish

Synonym: *Myctophum aurolaternatum gracilior* Fowler 1944

Collection Locations: 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher specimen No: IO/SS/FIS/00505

Diagnosis: The Standard length of the specimen ranged from 40mm-60mm. SAO forming a straight line passing slightly in advance of VO4, SAO1 slightly behind the centre of VO4, SAO3 slightly anterior to anal origin. Pol well before base of adipose fin. Interspace between Prc1 and Prc2 not more than a half diameter of a Prc photophore, and much less than the interspace between AOp photophores. Prc2 only slightly elevated. The posterodorsal margin of the operculum serrated. Scales cycloid.

D 13-14, A 23-24, P 14, G R 4+1 +12, AO 10 + 6

Habitat: High Oceanic, mesopelagic from surface to 300m (night)

Distribution: In Aghulas current south to about Sofala bank to gulf of Aden and in eastern Indian Ocean (5ºS- 18ºS), South eastern Asian Seas and equatorial pacific.

Reference: Kawaguchi and Aioi 1972; Nafpaktitis 1982; Kinzer *et al.,* 1993; Muhlinga *et al.,* 2007;Karuppasamy *et al.,* 2006; Menon 2002; Kawaguchi *et al.,* 1972; Tsarin 1983; Hulley 1986a,b,c.

Myctophum spinosum (Steindachner, 1867)

Common Name: Spiny lantern fish

Synonym: *Scopelus spinosus* Steindachner 1867*, Myctophum spinosus* Steindachner, 1867

Collection Locations: 12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT,11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT,11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT,11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT,11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT,11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT,10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT,10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT,10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT,10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT,09˚03.195'N, 75˚53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT,08°59.820'N, 75°51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08°35.131'N, 76°00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT,08°29.411'N, 76°06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT,08°08.933'N, 76°15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT,08°01.563'N, 76°25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 11°18.907'N, 67°00.273'E, 270m, 11.03.14 night (Cr. 325, St.3), 45mMT, 10°35.875'N, 67°00.170'E, 100m, 12.03.14 day (Cr. 325, St.4), 45mMT, 10°67.894'N, 66°58.797'E, 110m, 13.03.14 day (Cr. 325, St.5), 45mMT, 10°11.997'N, 74°04.2800'E, 100m, 30.07.15 night (Cr. 342, St.71), CT, 09°42.984'N, 75°31.255'E, 50-200m, 01.08.15 night (Cr. 342, St.79), CT, 21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT, 11°08.141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39), CT,10°58.142'N, 67°30.071'E, 95m, 16.02.16 night (Cr. 347II, St.32), CT,10°57.446'N, 70°31.136'E, 120m, 18.02.16 night (Cr. 347II, St.36), CT, 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08°21.533'N, 72°06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 07°45.322'N, 70°55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05°27.666'S, 65°52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT,05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 08°06.354 'N, 73°22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT.

Voucher specimen No: IO/SS/FIS/00508

Diagnosis: The Standard length of the specimen ranged from 20mm-90mm. Ctenoid scales along A base with 1-3 strong, posteriorly directed spines, Pol well in advance of vertical at origin of adipose fin, posterodorsal margin of operculum serrate .SAO series straight, PLO, SAO3 and Pol one photophore below LL. VLO mid-way between ventral base and LL. SAO3 form inclined line with VO3. Body scales ctenoid. Prc2 more than 1 photophore diameter below LL. Prc1-Prc2 interspace about half the AOp-Prc1 interspace. Body elongate, BD about 4 times in SL.

D 13-14, A 18-19, P 14-15, GR 6 +1+ 14, AO 7+7.

Habitat: High- Oceanic, mesopelagic, nycto- epipelagic at surface.

Distribution: Atlantic, Indian and Pacific: in tropical and subtropical waters. South China Sea.

Reference: Bradbury *et al.,* 1971; Kawaguchi and Aioi 1972; Kawaguchi *et al.,* 1972; Tsarin 1983; Nafpaktitis 1984; Hulley 1986 a,b,c; Jayaprakash 1996; Balachandran and Nizar 1990; Dalpadado and Gjosaeter 1993; Karuppasamy *et al.,* 2006; Muhlinga *et al.,* 2007; Menon 2002; Pillai *et al.,* 2009; Sebastine *et al.,* 2013; Boopendranath *et al.,* 2009.

Myctophum obtusirostre Taning, 1928

Common Name: Golden lanternfish

Synonym: Myctophum pristilepis obtusirostre Tåning, 1928, *Myctophum obtusirostrum* Tåning, 1928

Collection Locations: 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT,09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 08°41.330 'N, 74°09.677'E, 220m, 15.10.15 day (Cr. 344II, St.12), 28.4mMT,08°06.354 'N, 73°22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT.

Voucher specimen No: IO/SS/FIS/00507

Diagnosis : The Standard length of the specimen ranged from 40mm-60mm. Body elongate, BD about 4 times in SL. Poster dorsal margin of operculum rounded, scales on anterolateral part of body weakly crenulate, all others with smooth margins. SAO curved. SAO1, 2 a forming a slight angle when a line through SAO1 and SAO2 passing through VO3, SAO1 slightly in advance of VO4, SAO3 over anal origin. Interspace between Prcl and Prc2 slightly less than interspace of AOp photophores. A line through SAO1, 2 passes through VO3.Pol on or slightly behind vertical at origin of adipose fin, Prc2 more than 1 photophore-diameter below LL, Prc1-Prc2 interspace about half AOp-Prc1 interspace. Body scales cycloid.

D 13, A 18-19, P 17, GR 6+1+ 17, AO 6-7+ 2-3.

Habitat: High- Oceanic, mesopelagic, 325-70m in day and from surface to 125 n during night

Distribution: In Agulhas current and off west coast in pockets of Agulhas water, Recorded from Tropical waters of all oceans.

Reference: Kawaguchi *et al.,* 1972; Tsarin 1983; Nafpaktitis 1984; Alwis and Gjosaeter 1988; Hulley1986a,b,c; Dalpadado and Gjosaeter 1993; Menon 2002; Karuppasamy *et al.,* 2006; Muhlinga *et al.,* 2007; Dalpadado and Gjosaeter 1993; Boopendranath *et al.,* 2009; Froese and Pauly 2017

Myctophum nitidulum Garman, 1899

Common Name: Pearly lanternfish

Synonym: *Myctophum margaritatum* Gilbert 1905

Collection Locations: 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 03°53.184'S, 66°22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher specimen No: IO/SS/FIS/00506

Diagnosis: The Standard length of the specimen ranged from 30mm-50mm. SAO forming a straight line passing through the interspace between the centres of VO3 and VO4, SAO1 slightly in advance of VO4, SAO2 usually equidistant between SAO1 and SAO3. SAO1,2,3 forming a straight the centres of VO3 and VO4, SAO1 directly over or slightly in advance of VO4, SAO2 usually equidistant between SAO1and SAO3, sometimes slightly closer to SAO1, SAO3 over anal origin or AOal. Interspace between Prc1and Prc2 equal to interspace between AOp photophores. Serration along posterodorsal opercular margin absent. A line passing through the Interspace between Prc1 and Prc2 equal to interspace between AOp photophores. Serration along posterodorsal opercular margin absent. Shape of posterodorsal opercular margin sharply angulated, Scales cycloid, but exposed margin sometimes rough. D 13, A 19, P 14, AO 8 +5, GR 6+1+15, LL 37-39

Habitat: High-oceanic, mesopelagic: day at 475-850 m, nyctoepipelagic, surface and down to 200 m with occasional specimens up to 950 m.

Distribution: All three oceans and related to the development of a steep thermocline. Atlantic: broadly tropical pattern (thermophilic eurytropical subpattern), between about 42° N and 31° S (western sector) and between 35° N and 20° S (eastern sector) and as expatriates in Agulhas pockets in eastern South Atlantic. Elsewhere: Indian Ocean (between 7 N and 24° S) and Pacific (between 32° N and 31° S, but with northern extension to 40° N in Kuroshivo Current).

Reference: Kawaguchi *et al.,* 1972; Tsarin 1983; McGinnis 1982; Bradbury *et al.,* 1971; Gjosaeter 1977; Nafpaktitis 1984; Hulley 1986 a,b,c; Dalpadado and Gjosaeter 1993; Menon 2002; Karuppasamy *et al.,* 2006.

***GENUS Symbolophorus* Bolin and Wisner, 1959**

Mouth large, jaws extending beyond posterior margin of orbit. Maxillae moderately expanded posteriorly. Eyes large. Dn small, Vn larger. Five PO, with POs somewhat dorsolaterally displaced. Four VO, level. SAO strongly angulate, with SAO1 in advance of VO3. AO series divided AOa and AOp. One Pol. Two Prc, with Prc2 elevated and immediately, behind Prc1. Supra-caudal (males) and infra-caudal (females) luminous glands present in males and females both with supra and infra-caudal glands. High-oce anic mesopel agic, in high and low latitudes of all three oceans nycto epipelagic at surface.

Remarks: 8 species have been recorded from world oceans of which 4 species are found in western Indian Ocean. 2 species from study area.

Symbolophorus evermanni Gilbert, 1905

Common Name: Evermann's lantern fish

Synonyms: Myctophum evermanni

Collection Locations: 13°24.864'N, 67°00.781'E, 260m, 10.03.14 night (Cr. 325, St.2), 45mMT, 21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT,20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT,18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT,17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT, 13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT,12°17.255'N, 65°27.965'E, 100m, 14.02.16 night (Cr. 347II, St.26), CT,11°08.141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39), CT,10°58.142'N, 67°30.071'E, 95m, 16.02.16 night (Cr. 347II, St.32), CT,10°57.446'N, 70°31.136'E, 120m, 18.02.16 night (Cr. 347II, St.36), CT, 03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT, 05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT.

Voucher specimen No: IO/SS/FIS/00509

Diagnosis: Standard length of the specimen ranged from 35mm-110mm. PLO nearer LL than to upper base of Pectoral fin. Palatine and dentaries with numerous rows of minute sub equal teeth, Gill rakers slender and lath like. Cheek photophore and brancheostegal photophore present. PO1, PVO1 and PVO2 form a line. PVO1 below the pectoral fin base. PO5 slightly elevated. SAO1 over VO2 equi distant from VLO and SAO1. VLO slightly in advance of vertical at outer base of ventral and slightly above line connecting PLO and SAO1. SAO1-2 interspace greater than that of SAO 2-3. Pol on LL and behind vertical at origin of adipose fin. Prc2 one-two photophore below LL.

D 13, A 19, P 14, V 9, GR (5) +1+ (14-15), AO (8) + (5).

Habitat: High oceanic and mesopelagic, nyctoepipelagic at the surface. Neustonic occupy 1-125 m at night, 600-1150 m during day.

Distribution: Western Indian Ocean, In Agulhas Current south to about 33°S, tropical waters of Indo-Pacific, Area of Pakistan, Gulf of Aden and Somali coast, Sri Lankan waters (07°06'N-08° 26'N and 79°29'E 81°59'E), Indian Ocean,(0 ºN-03 ºS and 76 ºE- 86 ºE), Indian EEZ of Arabian Sea (06º00'N-21º00'N and 66º00'E-77º00'E), Eastern Indian Ocean.

References: Gjosaeter 1977; Tsarin 1983; Bradbury *et al*. 1971; Dalpadado and Gjosaeter 1993; Alwis and Gjosaeter 1988; Hulley 1986 a,b,c; Nafpaktitis 1984; Dalpadado and Gjosaeter 1993; Jayaprakash 1996; Muhlinga *et al.,* 2000; Balachandran and Nizar 1990; Menon 2002; Karuppasamy *et al.,* 2006.

Symbolophorus rufinus Tåning, 1982

Common Name: Rufous lanternfish

Synonyms: *Myctophum rufinum* Tåning 1928

Collection Locations: 10°67.894'N, 66°58.797'E, 110m, 13.03.14 day (Cr. 325, St.5), 45mMT, 18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05˚07.190'N, 69˚04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT,03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT, 15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 01˚41.188'S, 63˚38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 08˚06.354 'N, 73˚22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT, 08˚41.330 'N, 74˚09.677'E, 220m, 15.10.15 day (Cr. 344II, St.12), 28.4mMT.

Voucher specimen No: IO/SS/FIS/00509

Diagnosis: Standard length of the specimen ranged from 40mm- 90mm. Pol behind vertical at origin of adipose fin, PLO nearer LL than to upper base of Pectoral .SAO1 in advance of vertical through VO3 and nearer to SAO2 than to VLO. VLO mid-way between LL and Ventral fin.4VO, PLO and SAO3 just below LL and Pol one photophore below LL. SAO1 after VO2. Pectoral fin extending little beyond VLO, VLO about outer base of Ventral and below line connecting PLO and SAO1.Mature males with supracaudal luminous gland of 5-6 non-overlapping, scale-like structures, mature females with infracaudal luminous gland of 3-4 non-overlapping patches.

D 14, A 17, P 11, GR 4 +1+ 14, AO 7+5

Habitat: High-oceanic species found between 425-850 m during the day and nycto epipelagic at the surface and down to 125 m.

Distribution: Western Atlantic: tropical and subtropical waters, but extensions to 40°N and 28°S in western boundary currents. Eastern Atlantic: between about 28°N to 16°S, but seasonally less abundant in the Mauritanian Upwelling Region. Indian Ocean: in the equatorial region, including Reunion. Western Central Pacific: Papua New Guinea Range Deep-water.

Reference: Tsarin 1983; Nafpaktitis 1984; Hulley 1986 a,b,c; Jayaprakash 1996; Menon 2002; Karuppasamy *et al.,* 2006; Froese and Pauly 2017.

***GENUS Electrona* Goode and Bean, 1896**

Mouth moderately large, extending to or slightly beyond poster ior margin of orbit. Maxillae greatly expanded posteriorly. Lateral line well developed. Dn and Vn small. PLO below level of upper base of pectoral fin, forming a triangle with PVO1 and PV02. Five PO, level, sometimes PO5 raised above base of ventral fin. Four VO, level. Three SAO, weakly to strongly angulate. AO series continuous, sometimes with depressed photophores behind end of base of anal fin. Pol absent. Two Prc, Supracaudal (males) and infra-caudal (females) luminous glands present, or both sexes with supra- and infra-caudal glands.

Remarks: Of the 5 species recoded from world oceans, 5 species are found in WIO and 1 species is recorded from study area.

Electrona risso (Cocco, 1829)

Common Name Chubby flashlightfish

Synonym: *Scopelus risso* Cocco 1829*, Myctophum risso* Cocco 1829*, Sco pelus rissoi Cocco, 1829, Electrona risso salubris* Whitley 1933*, Myctophum risso salubris,* Whitley 1933.

Collection Locations: 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT,03°53.184'S, 66°22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT,02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 04°30.286'S, 60°45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT

Voucher Specimen No: IO/SS/FIS/00488.

Diagnosis: Standard length of the specimen ranged from 40mm- 80mm. Body short and deep. Body depth greater than one third of SL. Mouth oblique, terminal, maxillary expanded posteriorly. Eye very large. Origin of dorsal fin behind base of ventral fin. Origin of anal fin about under middle base of dorsal fin. Pectoral fins extending to almost SAO1. Ventral fins reaching anus. Base of adipose fin in advance of end of base of anal fin. Small Dn and Vn. PLO over PVO1, in front of ventral half of base of pectoral fin. PVO1 slightly in advance of a line between PVO2 and PO2, PVO2 in contact with lower end of base of pectoral fin. Five

PO, level. VLO about over VO1 and on a line between SAO1 and PVO2. Four VO, level. SAO forming a very obtuse angle, SAO1 over VO4, Pol absent, 11 AO, less than one organ diameter apart from each other, in line except for last three organs which behind end of base of anal fin. Prc nearly on same level and less than one organ diameter apart from each other. Males and females with supracaudal or infracaudal luminous gland or both.

D 13, A 19(18), P 14, AO 18-19, GR 8 + 1 + 17

Habitat: Oceanic, found between 225-750 m during the day and between 90-375 m and 450-550 m (adults) at night. Epipelagic to mesopelagic. (*E. rissoi*) only in warmer waters of all three oceans.

Distribution : Widespread species in Atlantic (55°N-400S), Mediterranean, Indian Ocean (0°-40°S) Tasman Sea and Cook Strait and eastern Pacific (42°N-20°S).

Reference: Nafpaktitis 1984; Hulley 1986a,b,c; Muhlinga *et al.,* 2007; Koubbi *et al.,* 2011.

GENUS *DIAPHUS* Eigenmann and Eigenmann, 1890

Diagnosis: 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 (OP1) small, placed just behind posterior tip of mouth, sometimes covered with whitish tissue and invisible, OP2 large, its size approximately equal to that of the largest body photophore . PO directly above OP1, PO1, PVO1, PVO2 forming a straight line or straight angle, five PO, first three PO above level, PO4 elevated to the level of PVO2, 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), AOa1 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).

Remarks: Diaphus is the largest of the myctophid genera, with 79 known species from world Ocean, 43 from WIO, 26 from our study area. The members of this genus can be assigned to one of 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 premaxillary.

Diaphus aliciae Fowler, 1934

Common Name: Chubby flashlightfish

Synonym: *Diaphus layi* Fowler, 1934

Collection Locations: 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08˚06.857'N, 71˚55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT, 05˚07.190'N, 69˚04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 00˚44.022'S, 68˚03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 14˚24.68'S, 57˚15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT, 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT.

Voucher Specimen No: IO/SS/FIS/00463.

Diagnosis: Standard length of the specimen ranged from 20mm-50mm. Head Organ consist of Dn, Vn and So, Dn round, directly forward ,slightly smaller than nasal rosette, Vn small ,anterior end of Vn behind vertical through anterior margin of orbit. So round, enclosed by blackish tissue slightly behind vertical through center of eye lens. Size of So is equal to PLO photophore. PLO closer to upper base of pectoral fin than to lateral line. Luminous scale at PLO and its diameter twice the size of PLO. VLO closer to ventral fin ray than to lateral line. VLO, VO3 and VO5 on a straight line, angular SAO, SAO3 2.5-3 times its own diameter below LL. Aoa1 elevated, Aoa continuous with Pol, Pol 2.5- 3times diameter below LL. Prc4 twice its own diameter below LL.

D 13-14, A 12-13, P 10-11, GR 5+1+ 12, AO 6+5.

Habitat: High- Oceanic and mesopelagic.

Distribution: Tropical waters of the Indian Ocean and South East Asian Sea between approximately 10°N and 10°S extending its distribution as far north as 30°N in Kuroshio region. Indian DSL: West coast- 7°-21°N, East coast 10°N-20°N.

Reference: Nafpaktitis 1978; Hulley 1986a,b,c; Nafpaktitis 1984; Menon 2002; Karuppasamy *et al.,* 2006, 2010; Froese and Pauly 2017.

Diaphus antonbruuni Nafpaktitis, 1978

Common Name: NIL

Synonym: NIL

Collection Locations: 05˚07.190'N, 69˚04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 00˚44.022'S, 68˚03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 04˚30.286'S, 60˚45.869'E, 10018°37.619'N, 69˚03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT m, 08.10.15 night (Cr. 344II, St.5), CT.

Voucher Specimen No: IO/SS/FIS/00464.

Diagnosis: Standard length of the specimen ranged from 30mm- 50mm. PLO closer to lateral line than to base of uppermost pectoral ray, VLO closer to lateral line than to ventral fin. VO2 and VO3 elevated. SAO series angulate, SAO3 about its own diameter below LL .AOa abruptly elevated, last AOa about level with SAO2. AOp series forming as straight line, Pol about its own diameter below LL. Prc4 its own diameter below LL. Luminous scale at PLO, roughly rectangular and is twice larger than PLO. Prc forms a straight line.

D 14, A 15, P 11-12, GR 6+1+14, AO 6+ 5

Habitat: Oceanic and mesopelagic, found in the upper 500 m at night

Distribution: Western Indian Ocean: 04°-12°S, 40°-65°E. Eastern Indian Ocean: 17°02'S, 94°50'E.

Reference: Nafpaktitis 1984; Hulley 1986a,b,c.

Diaphus arabicus Nafpaktitis, 1978

Common Name: NIL

Synonym: NIL

Collection Locations: 18°37.619'N, 69°03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT, 19°12.833'N, 67°58.297'E, 391m, 19.02.13 day (Cr. 313, St.3), CT, 19°00.511'N, 66°06.791'E, 349m, 20.02.13 day (Cr. 313, St.5), CT, 21°04.195'N, 68°03.879'E, 393m, 22.02.13 night (Cr. 313, St.9), CT,20°57.735'N, 66°14.478'E, 281m, 21.02.13 night (Cr. 313, St.8), CT, 20°56.044'N, 65°56.529'E, 372m, 21.02.13 day (Cr. 313, St.7), CT,19°17.840'N, 65°55.013'E, 377m, 20.02.13 night (Cr. 313, St.6), CT, 14°41.855'N, 73°00.985'E, 100m, 13.01.16 night (Cr. 347I, St.5), CT, 17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT, 18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT, 21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT,20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT, 19°31.129'N, 65°26.695'E, 110m, 08.02.16 night (Cr. 347II, St.2), CT,15°58.481'N, 65°29.986'E, 100m, 10.02.16 night (Cr. 347II, St.9), CT,13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT,12°17.255'N, 65°27.965'E, 100m, 14.02.16 night (Cr. 347II, St.26), CT,11°08.141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39), CT,10°58.142'N, 67°30.071'E, 95m, 16.02.16 night (Cr. 347II, St.32), CT,10°57.446'N, 70°31.136'E, 120m, 18.02.16 night (Cr. 347II, St.36), CT.

Voucher Specimen No: IO/SS/FIS/00465.

Diagnosis: Standard length of the specimen ranged from 20mm- 50mm. Pectoral fin reaching ventral fin base. Pelvic fin reaching anal fin base. Origin of D fin before V fin. Origin of A after D. PLO 2-2.5 times nearer to base of pectoral fin than to lateral line. VLO nearer to the base of ventral fin than to LL. SAO slightly angular, SAO3 twice its diameter below LL, AOa1 elevated. Pol behind adipose fin and 1.5-2 times its own diameter below LL. Prc forms a gentle curve with Prc4 2-2.5 times diameter below LL. Luminous scale at PLO present and is greater than body photophore.

D 11-12, A 11-12, P 11-12, V 7, AO 5+4, GR 6+1+18

Habitat: Bathypelagic, marine, depth range 0 – 468 m

Distribution: Western Indian Ocean: Arabian Sea,

Reference: Tsarin 1983; Nafpaktitis 1984, 1978; Kinzer *et al.,* 1993; Nair *et al.,* 1999; Globec 1993; Froese and Pauly 2017.

Diaphus brachycephalus Taning, 1928

Common Name: Short-headed lantern fish

Synonym: NIL

Collection Locations: 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT,02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT,14˚24.68'S, 57˚15. 592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT,09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07˚43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr.

344II, St.4), CT,09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08°21.533'N, 72°06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT.

Voucher Specimen No: IO/SS/FIS/00466

Diagnosis: Standard length of the specimen ranged from 40mm-50mm.Dn, Vn and So Present. Dn deeply recessed into cup shaped structure above nasal rosette. Vn expanded and occupying the area surrounded by anteroventral margin of orbit, So behind Vn and its size half of OP2. Dorsal margin of Vn and So framed with blackish tissue. Body photophores very large. PLO nearer to Pectoral base than to LL.VLO 2-3.5 photophore diameter above base of Ventral fin. Vo3 almost at the level of VLO. SAO series forms a slight angle SAO1 behind and above VO5. SAO3 3.5 times its diameter below LL. Pol more than 2 photophore below LL. Prc4 about twice its own diameter below LL.

D 13, A 13, P 11, GR 6+1+9, AO 6+4**.**

Habitat: Mesopelagic. Found between 175-550 m during the day and near the surface to about 225 m at night. Large males partially migratory or non-migratory.

Distribution: In Agulhas Current and off west coast in Agulhas Water pockets, broadly tropical distribution in Atlantic and Indo-Pacific range Deep-water, 42°N - 33°S.

Reference: Hulley 1984 a,b, 1986 a,b,c; Tsarin 1983; Nafpaktitis 1978, 1982, 1984; Froese and Pauly 2017.

Diaphus coeruleus (Klunzinger, 1871)

Common name: Blue lantern fish

Synonym: Diaphus coeruleus: Scopelus (Lampanyctus) coeruleus Klunzinger 1871, *Diaphus (Lamprossa) coeruleus*, Fraser-Brunner 1949.

Collection Locations:12°54.04'N, 73°46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT,11°42.04'N, 73°45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT,11°18.68'N, 73°35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT,11°10.93'N, 73°01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT,11°09.97'N, 72°58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT,11°06.39'N, 74°52.394'E, 350m,10.13 day (Cr. 320, St.17), 45mMT, 11°00.04'N, 73°05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT,10°55.30'N, 73°13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT,10°32.17'N, 73°12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT,10°20.18'N, 73°21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT,10°08.80'N, 73°32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT, 09°03.195'N, 75°53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08°59.820'N, 75°51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT,08°35.131'N, 76°00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08°29.411'N, 76°06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT,08°08.933'N, 76°15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT,08°01.563'N, 76°25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT.

Voucher Specimen No: IO/SS/FIS/00444

Diagnosis: Standard length of the specimen ranged from 60mm-140mm .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 PO5. Ventral fins reaching anus. Base of adipose fin over end of base of anal fin. Dn immediately posterio-dorsal to nasal apparatus, lentil-shaped and smaller than body photophore. Vn massive, roughly crescent-shaped, along anterior and antero-ventral 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 nearly straight line, SAO3 on or slightly in front of vertical through origin of anal fin and about 2.5 times its own diameter below lateral line. AOa1 about 1.5

times its diameter anterio-dorsal to AOa2, 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 Prc3 - Prc4 interspace often distinctly enlarged, Prc4 about twice its diameter below lateral line. A luminous scale at PLO, its size 3-4 times that of a body photophore.

D.15 (14), A.15 (14), P. 10-11, GR 6+ 1 + 12-13, AO 6 +5, LL 37.

Habitat: Marine; bathypelagic, depth range 457 - 549 m

Distribution: Indo-West Pacific: Red Sea and the Andaman Sea, Papua New Guinea, Indonesia, Taiwan, Chesterfield Islands and Australia. South China Sea.

Reference: Gunther 1887; Nafpaktitis 1984; Gjosaeter 1977; Kailola, 1987; Paxton *et al.,* 1989; Wang and Chen 2001; Kulbicki *et al.,*1994; Yang *et al.,* 1996.

Diaphus diadematus Taning, 1932

Common Name: Crown lanternfish

Synonyms: *Diaphus diademetus* Tåning 1932*, Diaphus diademeus* Tåning 1932

Collection Locations: 08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT,08˚06.857'N, 71˚55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT,05˚07.190'N, 69˚04.122'E,400-506m, 12.09.15 day (Cr. 344I, St.7), CT,00˚44.022'S, 68˚03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT.15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT.

Voucher Specimen No: IO/SS/FIS/00467

Diagnosis: Standard length of the specimen ranged from 30mm- 40mm. Dn is smaller, Vn large, occupying entire space of eye and the upper jaw. PLO 2.5 times its diameter above pectoral fin. VLO almost midway between base of ventral fin and LL. SAO1 slightly higher than VO5, SAO3 over anal fin and 2 times its own diameter below lateral line. AOa forms an arc. Pol and Prc4 more than 1 photophore diameter below LL. Prc3-Prc4 interspace enlarged. Luminous scale at PLO present.

D 13, A 14, P 11-12, GR 4+1+11, AO 6+ 4-5.

Habitat: High-oceanic and mesopelagic species occurring in the upper 100 m at night, High-oceanic.

Distribution: In Agulhas Current and off west coast in Agulhas Water pockets and warmed, upwelled Central Water northwards to 18°S. Indian Ocean (02°N-38°S and Mozambique Channel, but absent in central sector). Deep-water, Indian DSL: West coast- 7°-21°N, East coast 10°N-20°N.

Reference: Taning 1928; Nafpaktitis 1978, 1984; Hulley 1986a,b,c; Menon 2002; Froese and Pauly 2017

Diaphus diademophilus (Nafpaktitis, 1978)

Common Name: NIL

Synonym: NIL

Voucher Specimen No: IO/SS/FIS/00468

Collection Locations: 07°45.322'N, 70°55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05°27.666'S, 65°52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT.

Diagnosis: Standard length of the specimen ranged from 40mm- 50mm. Dn smaller than body photophore, round directed forward and set in shallow recess. Vn round and larger than Dn. PLO 3 times diameter above the level of pectoral fin. VLO midway between base of ventral fin and lateral line. SAO1 higher than VO5. SAO3 over anal fin and 2-3 times its own diameter below LL. AOa forms a wide arc. Pol one photophore diameter below LL. AOp1 behind the end of base of anal fin. Prc3-Prc4 interspace usually somewhat enlarged. Prc4 about twice its diameter below lateral line. Luminous scale at PLO present.

D 14, A 14, P 11-12, GR 7+1+12, AO 6+ 4

Habitat: Deep-water, Benthopelagic, depth range 275-1500m

Distribution: Indo-West Pacific, common in the tropical Indian Ocean 10°N - 20°S and Southeast Asian seas. South China Sea.

Reference: Gjosaeter 1977; Nafpaktitis 1978, 1984; Froese and Pauly 2017.

Diaphus effulgens (Goode and Bean, 1896)

Common Name: Headlight Lantern fish

Synonym: *Aethoprora effulgens* Goode and Bean 1896, *Myctophum effulgens* Goode and Bean 1896, *Myctophum aeolochrus* Barnard 1927, *Diaphus macrophus* Parr 1928, *Diaphus antelucens* Kulikova 1961.

Collection Locations: 08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 00˚44.022'S, 68˚03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 01˚41.188'S, 63˚38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 14˚24.68'S, 57˚15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT.

Voucher Specimen No: IO/SS/FIS/00469

Diagnosis: Standard length of the specimen ranged from 50mm- 80mm. Dn very large, extending dorsal margin of orbit. Vn occupying entire lower half of snout, spreading behind olfactory organ. Dn and Vn in contact with each other. Ant well developed in contact with Dn. PLO nearer to base of pectoral fin. PLO mid-way between LL and Pectoral fin. 5 VO, elevated, VLO mid-way between base of Ventral fin and Lateral line. SAO more than 2 photophore below LL. Pol more than one photophore below LL, continuous with AOa. Prc form a gentle curve, Prc4 1-2 times diameter below LL. A roundish luminous scale at PLO.

D 15, A 15, P 13, GR (5-6) + (12-14), AO 6+1+12.

Habitat: High-oceanic, mesopelagic, 325 - 600 m (day), 40 - 175 m (night), adults probably non- migratory. Exhibiting size stratification with depth.

Distribution: In Atlantic (50º-17°N and 19º S to Subtropical Convergence) and Indo-Pacific, 50°N - 49°S, 82°W - 180°W.

Reference: Nafpaktitis 1978,1984; Hulley 1986a,b,c; Jayaprakash 1996; Karuppasamy *et al.,* 2006; Menon 2002; Balachandran and Nizar 1990; Koubbi *et al.,* 2011; McGinnis 1982; Boopendranath *et al.,* 2009; Froese and Pauly 2017.

Diaphus fulgens (Brauer, 1904)

Common name: Nil

Synonym: *Myctophum fulgens* Brauer, 1904*, Diaphus nanus* Gilbert, 1908.

Collection Locations: 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08°21.533'N, 72°06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 04°30.286'S, 60°45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 01°41.188'S, 63°38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 14°24.68'S, 57°15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT.

Voucher Specimen No: IO/SS/FIS/00470

Diagnosis: Standard length of the specimen ranged from 40mm- 70mm. Vn about equal in length to distance between it and So. So small less than one half the size of a body photophore. PLO about 1.5 times nearer to base of pectoral fin than to lateral line. VLO midway between base of ventral fin and lateral line. SAO angular with VO5, SAO1 and SAO2 in a straight line passing well behind SAO3, SAO3 and Pol one photophore diameter below LL. AOa1 elevated, Pol less than its own diameter below LL. Prc forming a gentle curve. Prc4 less than 1.5 diameter below LL. Large luminous scale at PLO.

D 13-14, A 12-13, P 9-10, GR 5+1+14, AO 6+5

Habitat: High-oceanic, mesopelagic.

Distribution: Indian Ocean (08°N-l0ºS) and Mozambique Channel (southwards to 18°S), Southeast Asian seas and tropical Pacific.

Reference: Nafpaktitis 1984; Hulley 1986 a,b,c; Karuppasamy *et al.,* 2010; Froese and Pauly 2017.

Diaphus fragilis Taning, 1928

Common Name: Fragile lantern fish

Snonym: Nil

Collection Locations: 21°04.195'N, 68°03.879'E, 393m, 22.02.13 night (Cr. 313, St.9), CT, 19°17.840'N, 65°55.013'E, 377m, 20.02.13 night (Cr. 313, St.6), CT, 19°12.833'N, 67°58.297'E, 391m, 19.02.13 day (Cr. 313, St.3), CT, 19°00.511'N, 66°06.791'E, 349m, 20.02.13 day (Cr. 313, St.5), CT, 18°37.619'N, 69°03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT, 13°24.864'N, 67°00.781'E, 260m, 10.03.14 night (Cr. 325, St.2), 45mMT, 11°18.907'N, 67°00.273'E, 270m, 11.03.14 night (Cr. 325, St.3), 45mMT, 11°00.450 'N, 73°08.403 'E, 345m, 16.03.14 day (Cr. 325, St.7), 45mMT, 10°35.875'N, 67°00.170'E, 100m, 12.03.14 day (Cr. 325, St.4), 45mMT, 10°02.194 'N, 71°27.066 'E, 100m, 15.03.14 day (Cr. 325, St.6), 45mMT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 08˚06.857'N, 71˚55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT, 05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 05˚07.190'N, 69˚04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT, 02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 08˚41.330 'N, 74˚09.677'E, 220m, 15.10.15 day (Cr. 344II, St.12), 28.4mMT, 06˚58.058 'N, 72˚00.045'E, 101m, 13.10.15 night (Cr. 344II, St.10), 28.4mMT, 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 01˚41.188'S, 63˚38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 14˚24.68'S, 57˚15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT, 09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00471

Diagnosis: Standard length of the specimen ranged from 40mm- 70mm. Dn round almost equal in size to nasal rosette. Dn and Vn continuous, Vn extending dorsally along anterior border of orbit. Ant well developed. SO absent. PLO midway between LL and Pectoral fin. 5 PO, PO 3and 5 elevated. VLO mid-way between LL and base of ventral fin. 5 VO, VO 2, 3 elevated. SAO straight line. AOa1 abruptly elevated. Pol immediately below LL. Prc forms a gentle arc. Prc 4 2-2.5times its diameter below LL. Luminous scale at PLO.

D 17, A 17, P 11-12, GR 5+1+11, AO 6+ 5

Habitat: Mesopelagic, high-oceanic, mesopelagic, 520 - 600 m (day),15 - 125 m (night).

Distribution: Atlantic (39°N-26°S, but absent in Benguela Upwelling Region) and tropical Indo-Pacific (with extensions to 35ºN in Kuroshio Current and to 34ºS in East Australian Current).

Reference: Bradbury *et al.,* 1971; Nafpaktitis 1978,1984;Tsarin 1983; Hulley 1986a,b,c; Karuppasamy *et al.,* 2006, 2010; Menon 2002; Froese and Pauly 2017.

Diaphus garmani Gilbert, 1906

Common Name: Garman’s Lanternfish

Synonyms: *Diaphus latus* Gilbert 1913*, Diaphus ashmeadi* Fowler 1934

Collection Locations: 21°04.195'N, 68°03.879'E, 393m, 22.02.13 night (Cr. 313, St.9), CT, 19°17.840'N, 65°55.013'E, 377m, 20.02.13 night (Cr. 313, St.6), CT, 19°12.833'N, 67°58.297'E, 391m, 19.02.13 day (Cr. 313, St.3), CT, 19°00.511'N, 66°06.791'E, 349m, 20.02.13 day (Cr. 313, St.5), CT, 18°37.619'N, 69°03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT, 12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT, 11°42.04'N, 73°45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT, 11°18.68'N, 73°35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT, 11°10.93'N, 73°01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT, 11°09.97'N, 72°58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT, 11°06.39'N, 74°52.394'E, 350m, .10.13 day (Cr. 320, St.17), 45mMT, 11°00.04' N, 73°05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT, 10°55.30'N, 73°13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT, 10°32.17'N, 73°12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT, 10°20.18'N, 73°21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT, 10°08.80'N, 73°32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT, 09°03.195'N, 75°53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08°59.820'N, 75°51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08°35.131'N, 76°00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08°29.411'N, 76°06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT, 08°08.933'N, 76°15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT, 08°01.563'N, 76°25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 11°00.450 'N, 73°08.403 'E, 345m, 16.03.14 day (Cr. 325, St.7), 45mMT, 10°67.894'N, 66°58.797'E, 110m, 13.03.14 day (Cr. 325, St.5), 45mMT, 20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT, 18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT, 17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT, 14°41.855'N, 73°00.985'E, 100m, 13.01.16 night (Cr. 347I, St.5), CT, 19°31.129'N, 65°26.695'E, 110m, 08.02.16 night (Cr. 347II, St.2), CT, 15°58.481'N, 65°29.986'E, 100m, 10.02.16 night (Cr. 347II, St.9), CT, 13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT, 12°17.255'N, 65°27.965'E, 100m, 14.02.16 night (Cr. 347II, St.26), CT, 11°08.141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39), CT, 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08°21.533'N, 72°06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 08°06.857'N, 71°55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT, 07°45.322'N, 70°55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05°27.666'S, 65°52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 08°41.330 'N, 74°09.677'E, 220m, 15.10.15 day (Cr. 344II, St.12), 28.4mMT, 06°58.058 'N, 72°00.045'E, 101m, 13.10.15 night (Cr. 344II, St.10), 28.4mMT, 04°30.286'S, 60°45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 01°41.188'S, 63°38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 14°24.68'S, 57°15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00472

Diagnosis: Standard length of the specimen ranged from 30mm-70mm.Origin of dorsal fin over base of ventral fin. Origin of anal fin behind end base ofdorsal 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 meetsand often overlaps with dorsal, attenuated extension of Vn. Main bulk of Vn atanteroventral aspect of orbit. PLO distinctly near to lateral line than to base of pectoralfin. PO4 elevated. VLO midway between lateral line and base of ventral fin or a little higher. SAO on astraight line, sometimes SAO2 slightly in front of or behind line through centres of SAO1and SAO3, SAO3 at lateral line. Pol on LL. AOa1 abruptly elevated, sometime directly above AOa2, last AO also elevated. Pol in contact with lateral line. AOp1 sometimes over end of base of anal fin. First three Prc evenly spaced, forming a gentle arc, Prc3-Prc4 inter spaceenlarged, with Prc4 about 1.5 times its diameter below mid lateral line. A verticallyelongated, roughly rectangular luminous scale at PLO.

D 14, A. 14, P. 12 (11), GR 7 + 1 + 13, AO 5 + 5

Habitat: Pseudoceanic, Pelagic 325-750m day, from surface to 125m at night.

Distribution: Northern Arabian Sea, Western Indian Ocean, Indian Ocean, Sri Lankan waters (07°06'N- 08°26 N and 79°29'E- 81°59'E), Coast of Africa (0°- 15°N)

Reference: Gjosaeter 1977; Nafpaktitis 1984; Hulley 1986a,b,c; Hulley and Lutjeharma 1995; Dalpadado and Gjosaeter 1993; Pillai *et al.,* 2009; Bineesh *et al.,* 2010; Sebastine *et al.,* 2013.

Diaphus jenseni Taning, 1932

Common Name: Jensen's lanternfish

Synonym: *Diaphus kylei* Tåning, 1932*, Diaphus carlsoni* Fowler, 1934*, Diaphus gudgeri* Fowler, 1934

Collection Locations: 17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT. 08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT.08˚06.857'N, 71˚55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT.05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT.05˚07.190'N, 69˚04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT.03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45m MT.02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT.08˚06.354 'N, 73˚22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT.15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT

Voucher Specimen No: IO/SS/FIS/00473

Diagnosis: Standard length of the specimen ranged from 30mm- 50mm. Maxilla not or only slightly expanded posteriorly, extending from slightly behind to well behind orbit. Pterotic spine sometimes well developed. At least 1 pair of sexually dimorphic, luminous glands on head, 5 PO, 5 VO, SAO series curved to strongly angulate, AO series divided into AOa and AOp, AOa1 usually elevated, sometimes level, 1 Pol, sometimes continuous with AOa, 4 Prc. Supracaudal and Infracaudal luminous glands absent, usually a luminous scale at PLO. PLO midway between LL and base of Pectoral fin. VLO midway between base of ventral fin and LL. SAO on a straight line.SAO1 higher than VO5. SAO3 one photophore below LL. AOa1 highly elevated. AOa2and AOa3 interspace distinctly enlarged. Pol 1-1.5 times its own diameter below LL. Prc forms an arc with Prc3-Prc4 interspace markedly enlarged. Prc 4 1.5-2 times its diameter below LL. Luminous scale at PLO present.

D 14-15, A 14-15, P 9-10, GR 6+15, AO 5+6

Habitat: High-oceanic and mesopelagic. Found in the upper 85 m at night

Distribution: Indo-Pacific. Southeast Atlantic. South China Sea.

Reference: Nafpaktitis 1978, 1984, 1995; Alwis and Gjosaeter 1988; Hulley 1984 a,b; 1986 a,b,c; Froese and Pauly 2017.

Diaphus lobatus Nafpaktitis, 1978

Common Name: NIL

Synonym: NIL

Collection Locations: 12°54.04'N, 73°46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT, 11°42.04'N, 73°45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT, 11°18.68'N, 73°35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT, 11°10.93'N, 73°01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT, 11°09.97'N, 72°58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT, 11°06.39'N, 74°52.394'E, 350m, .10.13 day (Cr. 320, St.17), 45mMT, 11°00.04'N, 73°05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT, 10°55.30'N, 73°13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT, 10°32.17'N, 73°12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT, 10°20.18'N, 73°21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT, 10°08.80'N, 73°32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT, 09°03.195'N, 75°53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08°59.820'N, 75°51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08°35.131'N, 76°00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08°29.411'N, 76°06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT, 08°08.933'N, 76°15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT, 08°01.563'N, 76°25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 04°30.286'S, 60°45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 02°23.269'S, 63°04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT, 01°41.188'S, 63°38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT.

Voucher Specimen No: IO/SS/FIS/00474

Diagnosis: Standard length of the specimen ranged from 30mm-60mm. Snout overhanging mouth. Pectoral fin reaching base of ventral fin.

Ventral fin long and reach up to AOa2. Vn short shorter than distance between it and SO. PLO nearer to pectoral fin than to LL. VLO nearer to base of Ventral fin than to LL. SAO slightly angular. SAO3 twice its own diameter below LL. First AOa elevated Pol twice its own diameter below LL. Prc evenly spaced and forms an arc, Prc4 twice its diameter below lateral line. Luminous scale at PLO.

Habitat: Bathypelagic, Deep water

Distribution: Western Indian Ocean, known from the type locality, 6°52'N, 79°30'E.

Reference: Nafpaktitis 1984; Dalpadado and Gjosaeter 1993; Kinzer *et al.,* 1993; Froese and Pauly 2017.

Diaphus lucidus (Goode and Bean, 1896)

Common name: Spotlight lantern fish

Synonyms: *Aethoprora licida* Goode and Bean 1896**,** *Diaphus monodi* Fowler 1934**,** *Diaphus reidi* Fowler 1934**,** *Diaphus altifrons* Kulikova 1961.

Collection Locations: 12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT, 11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT, 11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT, 11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT, 11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT, 11˚06.39'N, 74˚52.394'E, 350m, .10.13 day (Cr. 320, St.17), 45mMT, 11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT, 10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT, 10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT, 10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT, 10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT, 09˚03.195'N, 75˚53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08˚59.820'N, 75˚51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08˚35.131'N, 76˚00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08˚29.411'N, 76˚06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT, 08˚08.933'N, 76˚15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT, 08˚01.563'N, 76˚25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 10°23.170 'N, 73°10.984 'E, 250m, 16.03.14 night (Cr. 325, St.8), 45mMT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT, 02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 08˚41.330 'N, 74˚09.677'E, 220m, 15.10.15 day (Cr. 344II, St.12), 28.4mMT, 08˚06.354 'N, 73˚22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT, 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 02˚23.269'S, 63˚04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT, 01˚41.188'S, 63˚38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00475

Diagnosis: Standard length of the specimen ranged from 30mm-100mm.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 antero ventral 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. SAO3 over base of anal fin and its diameter or less below lateral line. AOa1 elevated well above and in front of AOa2. Pol its diameter or less below lateral line. AOp1 often over base of anal fin and distinctly raised. A vertically elongated luminous scale at PLO.

D.17 (18), A.17-18, P. 11-12, GR 5-6 + 1 + 11-12, AO 7 (8) + 4-5.

Habitat: High Oceanic mesopelagic, 425-750m during day, 40-550m during night

Distribution: Western Indian Ocean, EEZ of Arabian Sea, Equatorial region of Arabian Sea.

Reference: Nafpaktitiss 1984; Hulley 1986a,b,c; Karuppasamy *et al.,* 2006, 2010; Tsarin and Boltachev 2006; Nafpaktitis 1978; Gjosaeter 1977; Dalpadado and Gjosaeter 1993.

Diaphus luetkeni (Brauer, 1904)

Common Name: Luetken's lanternfish

Synonyms: *Myctophum luetkeni* Brauer 1904*, Diaphus leutkeni* Brauer 1904*, Diaphus lutkani* Brauer 1904*, Diaphus lutkeni* Brauer 1904*, Diaphus lütkeni* Brauer 1904.

Collection Locations: 05°27.666'S, 65°52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 02°28. 622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 01°41.188'S, 63°38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT.

Voucher Specimen No: IO/SS/FIS/00476

Diagnosis: Standard length of the specimen ranged from 40mm- 60mm. A small round forwardly directed Dn above nasal organ. Vn long extending to anterior border of eye, terminating behind vertical through posterior margin of pupil, its dorsal border with 3-5 small round projections protruding into iris. PLO nearer to pectoral fin than to LL. VLO midway between base of ventral fin and LL. SAO1 slightly higher than VO5.SAO3 less than its diameter below LL. AOa form an Arc with AOa1 abruptly elevated and also last AOa raised. Pol less than its diameter below LL. A luminous scale at PLO present.

D 15, A 15-16, P 11-12, GR 6+1+18, AO 6+5.

Habitat: High- Oceanic mesopelagic 375-750m during day and 40-325 during night.

Distribution: Atlantic, Indian and Pacific: in tropical waters with extensions into higher latitudes in western boundary currents. Atlantic: 42°N-11°S. In the eastern Atlantic known from about 20°N to about 11°S. South China Sea. In Agulhas Current to 37°S., 42°N - 11°S, 180°W - 180°E.

Reference: Gjosaeter 1977; Nafpaktitis 1984; Hulley 1986a,b,c; Menon 2002; Tsarin 1983; Bradbury *et al.,* 1971; Nafpaktitis 1978; Boopendranath *et al.,* 2009.

Diaphus mollis Taning, 1928

Common Name: Soft lanternfish

Synonym: *Diaphus mellis* Tåning 1928*, Diaphus molli* Tåning 1928

Collection Locations: 14°10.167'N, 69°49.409'E, 330m, 08.03.14 night (Cr. 325, St.1), 45mMT, 13°24.864'N, 67°00.781'E, 260m, 10.03.14 night (Cr. 325, St.2), 45mMT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 14˚24.68'S, 57˚15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT, 11°00.450 'N, 73°08.403 'E, 345m, 16.03.14 day (Cr. 325, St.7), 45mMT, 10°02.194 'N, 71°27.066 'E, 100m, 15.03.14 day (Cr. 325, St.6), 45mMT.

Voucher Specimen No: IO/SS/FIS/00477

Diagnosis: Standard length of the specimen ranged from 40mm- 60mm. Body photophores rather small, often indistinct against the very dark integument normally found on freshly preserved and undamaged specimens. Vn narrow and longer than distance between it and SO. PLO nearer to base of pectoral fin than to LL. VLO midway between base of ventral fin and LL. PLO on or very slightly behind a vertical from origin of pectoral fin .VLO over bases of inner pelvic rays than to lateral line. VO2-3 is half the space between VLO and VO2. SAO3, Pol, and Prc4 lie about three of their respective diameters below lateral line. SAO series broadly angulate, a line through SAO1-2 passing before VO5, and well behind SAO3. SAO2-3 interspace 2.0 to 2.5 times that of SAO1-2. First AOa elevated nearly to level of SAO2 and from 1.5 to 2.0 times its diameter above second AOa. Last AOa seldom elevated by more than its diameter above next to last AOa. Pol about over base of last anal ray. Prc interspaces progressively wider. SAO3 more than one photophore diameter below LL. AOa1 elevated. Pol more than one photophore below LL. Luminous scale at PLO present.

D 12-14, A 12-14, P 10-11, GR 5+ 11, AO 5+ 4.

Habitat: Mesopelagic Oceanic, found between 300-600 m during the day and between 50-300 m at night, exhibiting size stratification with depth.

Distribution: Eastern Atlantic, Morocco to Namibia. Western Atlantic: Canada to Argentina. Indian Ocean: 0°-34°S west of 70°E and 80°E, at 38°S, 100°E. Western Pacific: south of 20°S, west of 170°W and in Tasman Sea, centrally between 30°N and 7°S. Eastern Pacific: between 25°N and 15°S. South China Sea. 50°N - 58°S, 78°W - 153°W.

Reference: Nafpaktitis 1978, 1984; Hulley 1986a,b,c; Menon 2002; Froese and Pauly 2017.

Diaphus parri Taning, 1932

Common Name: Parr’s lanternfish

Synonym: *Diaphus longleyi* Fowler 1934*, Diaphus kendalli* Fowler 1934*, Diaphus rassi* Kulikova 1961.

Collection locations: 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08°06.857'N, 71°55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT, 08°06.354 'N, 73°22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT, 07°45.322'N, 70°55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05°27.666'S, 65°52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 01°41.188'S, 63°38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT.

Voucher Specimen No: IO/SS/FIS/00478

Diagnosis: Standard length of the specimen ranged from 40mm-60mm.Vn short, So large vertically elongate and protruding in to iris. PLO 2.5 times nearer to base of pectoral fin as to LL. VLO about 1.5 times near to base of ventral fin as to LL. VO5, SAO1 and SAO2 evenly spaced, in a straight line passing behind SAO3. SAO3 more than 2.5 times its own diameter below LL. Pol 2.5 times its own diameter below LL. Prc in a slightly curved line, Prc 4 more than 2.5times its own diameter below LL. Luminous scale at PLO.

D 12-14, A 12-13, P 10-11, GR 6+1+12, AO 5+4

Habitat: Oceanic and mesopelagic. Found in the upper 150 m at night.

Distribution: Southeast Atlantic: off the west coast of South Africa, in Agulhas water pockets. Indian Ocean: 10°N-12°S, with an extension to 25°S in the Mozambique Channel. Western Pacific: off southern Japan and the South China Sea to Australia and New Zealand. Also known from the eastern Pacific. South China Sea.

Reference: Nafpaktitis 1978, 1984; Gjosaeter 1977; McGinnis 1982; Hulley 1986a, b, c; Menon 2002

Diaphus perspicillatus (Ogilby, 1898)

Common Name: Transparent lantern fish

Synonym: *Aethoprora perspicillata* Ogilby 1898*, Collettia perspicillata* Ogilby 1898, *Diaphus perspicullata* Ogilby 1898, *Myctophum elucens* Brauer 1904*, Diaphus elucens* Brauer 1904.

Collection Locations:12°54.04'N, 73°46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT, 11°42.04'N, 73°45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT, 11°18.68'N, 73°35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT, 11°10.93'N, 73°01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT, 11°09.97'N, 72°58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT, 11°06.39'N, 74°52.394'E, 350m, .10.13 day (Cr. 320, St.17), 45mMT, 11°00.04'N, 73°05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT, 10°55.30'N, 73°13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT, 10°32.17'N, 73°12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT, 10°20.18'N, 73°21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT, 10°08.80'N, 73°32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT, 09°03.195'N, 75°53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08°59.820'N, 75°51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08°35.131'N, 76°00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08°29.411'N, 76°06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT, 08°08.933'N, 76°15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT, 08°01.563'N, 76°25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 04°30.286'S, 60°45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 01°41.188'S, 63°38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 14°24.68'S, 57°15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT.

Voucher Specimen No: IO/SS/FIS/00479

Diagnosis: Standard length of the specimen ranged from 40mm- 60mm. Dn large thick, directed forward and roughly rectangular in shape. Vn equally large and massive extending behind olfactory organ to ethmoid crest in contact with Dn and continuing along antero ventral border of orbit, terminating in advance of vertical through anterior margin of pupil. PLO midway between base of pectoral fin and LL. 5 PO, PO 4 elevated.5 VO, VO 2-3 elevated. VLO nearer to base of ventral fin than to LL. SAO3 in contact with LL. Pol less than its diameter below LL.AOa1 and last Aoa elevated. Luminous scale at PLO present.

D 14-15, A 14-15, P 11, GR 9+1+18, AO 6+5.

Habitat: Oceanic, found between 375-750 m during the day and nyctoepipelagic at surface down to 125 m. Mesopelagic at 0-240 m at night, 315-1500 m during day.

Distribution: In Agulhas Current and off west coast in Agulhas Water pockets. Broadly tropical species in Atlantic (45°N- 36°S, but absent in southeastern sector), Indo-Pacific. 50°N - 58°S, 78°W - 153°W.

Reference: Hulley 1986a,b,c; Karuppasamy *et al.,* 2006; Menon 2002; Nafpak titis 1978, 1984; Jayaprakash 1996; Tsarin 1983; Balachandran and Nizar 1990; Alwis and Gjosaeter 1988; Froese and Pauly 2017.

Diaphus problematicus Parr, 1928

Common Name: Problematic lanternfish

Synonym: *Diaphus weberi* Tåning 1932

Collection Locations: 08°21.533'N, 72°06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 01°41.188'S, 63°38.006'E, 330m, 10.10.15 day (Cr. 344II, St.7), CT, 14°24.68'S, 57°15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT, 04°30.286'S, 60°45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00479

Diagnosis: Standard length of the specimen ranged from 30mm- 60mm. Dn smaller than body photophore. Vn three times larger than Dn. PLO nearer to base of pectoral fin than to LL. VLO nearer to LL than to base of ventral fin. SAO in a straight ascending line. SAO3 more than one photophore diameter below LL. AOa1 elevated and last AOa elevated.

Pol 1-1.5 times its own diameter below LL. Prc forms an arc and Prc3-Prc4 interspace enlarged, Prc 4 one to two times its diameter below LL. Luminous scale at PLO.

D 15, A 15, P 11-12, GR 4+1+8 AO 5+ 4.

Habitat: Oceanic species occurring between 375-750 m during the day and between 40-225 m at night.

Distribution: Tropical waters of all three oceans with extensions into higher latitudes in western boundary currents: in the Atlantic to 38°N and 39°S, in the western Pacific to 26°N. Eastern Atlantic: from about 4°N to about 13°S, with some records at about 20°N, but absent over the Mauritanian Upwelling Region. Deep-water, 40°N - 39°S, 78°W - 156°E (East and West of Indian Ocean).

Reference: Nafpaktitis 1978, 1984; Karuppasamy *et al.* 2006; Menon 2002; Tsarin 1983; Bradbury *et al.,* 1971; Hulley 1986a,b,c; Froese and Pauly 2017.

Diaphus regani Tåning, 1932

Common Name: Regan's lanternfish

Synonym: NIL

Collection Locations: 14°24.68'S, 57°15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT.

Voucher Specimen No: IO/SS/FIS/0048

Diagnosis: Standard length of the specimen ranged from 40mm-60mm. Ant, Dn and Vn present. SO absent. Dn directed anterolaterally, Vn continuous with Dn terminating posteriorly in front of vertical through anterior margin of pupil. PLO nearer to LL than to the base of

Pectoral fin. PO, VO, Prc widely spaced. VLO midway between ventral fin and LL. SAO3 at vertical through the origin of anal fin and in contact with LL. AOa arrangement variable highly elevated with AOa3 higher than AO1. Pol immediately below LL. Penultimate AOp elevated. Prc3- Prc4 interspace greatly enlarged with Prc4 lying at LL. Luminose scale present below PLO more than 2 photophore diameter. Pol on lateral line.

D 15, A15, P 11-12, GR 6+1+12, AO 6+6.

Habitat: Marine, pelagic-oceanic, depth range 0 - 750 m.

Distribution: *D. regani* has been taken across the Northen Indian Ocean, Andaman and Arabian Sea to ~ 15°N. Also occurring in South East Asian Seas and western Tropical Ocean.

Reference: Gjosaeter 1977; Nafpaktitis 1984, 1978; Bradbury *et al.,* 1971; Dalpadado and Gjosaeter 1993; Hulley 1986a,b,c; Dalpadado and Gjosaeter 1993; Froese and Pauly 2017

Diaphus similis Wisner, 1974

Common Name: Nil

Synonym: Nil

Collection Locations: 12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT, 11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT, 11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT, 11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT, 11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT, 11˚06.39'N, 74˚52.394'E, 350m, .10.13 day (Cr. 320, St.17), 45mMT, 11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT, 10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT, 10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT, 10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT, 10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT, 09˚03.195'N, 75˚53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08˚59.820'N, 75°51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08°35.131'N, 76°00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, 08°29.411'N, 76°06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT, 08°08.933'N, 76°15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT, 08°01.563'N, 76°25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT.

Voucher Specimen No: IO/SS/FIS/00483

Diagnosis: Standard length of the specimen ranged from 50mm- 60mm. Vn is more rounded and the streak of pigmented tissue around the Vn. Dn and Vn widely separated. Dn and Vn small but conspicuous, Vn somewhat the larger, more or less rounded, occasionally protruding into orbital rim, a little before vertical from hind margin of orbit. Vn triangular. PLO slightly below midway between lateral line and pelvic origin. First AOa elevated to about level of SAO2 No small mounds of pigmented tissue anterior to Vn. Luminous tissue present at PLO. Has very few gill rakers. AOa1 is seldom elevated to the level of SAO2. Last AOa less elevated.

D 14, A- 15, P 12-13, AO 6+5. GR: 7+1+14.

Habitat: Marine, bathypelagic, depth range 0 - 631 m.

Distribution: *D. similis* known only from small areas of eastern tropical pacific ocean bounded by about 4 -1° N, 87-119° W.

Reference: Wisner 1974

Remarks: *D. similis* is new record from SEAS as well as WIO. *D. similis* is very similar to *D. trachops*. It differ from *D. subtilis* is that Vn is more rounded and the streak of pigmented tissue around the Vn.

Diaphus signatus Gilbert, 1908

Common Name: NIL

Synonyms: NIL

Collection Locations: 21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT. 20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT. 10°57.446'N, 70°31.136'E, 120m, 18.02.16 night (Cr. 347II, St.36), CT.

Voucher Specimen No: IO/SS/FIS/00483

Diagnosis: Standard length of the specimen ranged from 40mm- 60mm. A roughly heart shaped anterolaterally directed Dn. Vn apparently continuous with Dn. So absent. PLO almost midway between LL and pectoral fin. Distance between VLO and base of ventral fin is 1.5-2 times larger than that between it and LL. SAO slightly angular, SAO3 in advance of origin of anal fin and in contact with LL. AOa1 highly elevated, last AOa elevated. Pol immediately below LL and is continuous with Aoa. Last AOp distinctly raised. Prc4 about its own diameter below LL. A roughly triangular luminous scale at PLO.

D 14, A 14, P 11-12, GR 5+1+ 13, AO 6+5.

Habitat: Pelagic-oceanic, depth range

Distribution: Indo-Pacific to 18°S in Mozambique Channel, South China Sea.

Reference: Nafpaktitis 1978, 1984; Hulley 1986 a,b,c; Dalpadado and Gjosaeter 1993; Karuppasamy *et al.,* 2006, 2010; Menon 2002,

Diaphus splendidus (Brauer, 1904)

Common Name: Horned lanternfish

Synonym: *Myctophum splendidum* Brauer 1904, *Diaphus steadi* Fowler 1934, *Diaphus scapula* fulgens Fowler 1934, *Diaphus vitiazi* Kulikova 1986.

Collection Locations: 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08°21.533'N, 72°06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I,St.9), 45mMT, 00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 04°30.286'S, 60°45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT.

Voucher Specimen No: IO/SS/FIS/00484

Diagnosis: standard length of the specimen ranged from 40mm- 60mm. Dn and Vn present. Dn round directed forward , smaller than nasal rosette, Vn located anteroventral margin of orbit, extending upwards as a narrow band along anteroventral margin of orbit and reaching Dn. PLO twice as close to pectoral fin base as to the LL, SAO slightly angulate , SAO3 its own diameter below LL. AOa1elevated but lower than SAO3. Last AOa elevated and slightly higher than SAO2.Pol its own diameter below LL. Prc forms an arc and Prc4 about its own diameter below LL .Luminous scale at PLO.

D 15, A 16-, P 12, GR 5+1+12, AO 6+6

Habitat: High Oceanic, mesopelagic 375-750 m in day and 40-225 m during night,

Distribution: In Agulhas current southwards to 31°S.Atlantic (40ºN-28°S, Indo pacific sector)

Reference: Bradbury *et al.,* 1971; Hulley 1986a,b,c; Nafpaktitis 1978, 1984; Jayaprakash 1996; Tsarin 1983; Balachandran and Nizar 1990.

Diaphus taaningi (Norman, 1930)

Common Name: Slopewater lanternfish

Synonym: NIL

Collection Locations: 10°02.194 'N, 71°27.066 'E, 100m, 15.03.14 day (Cr. 325, St.6), 45mMT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 02°23.269'S, 63°04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00483

Diagnosis: Standard length of the specimen ranged from 40mm- 50mm. So absent, Vn along anterioventral margin of orbit. Vn widely separated from Dn, confined to antero ventral aspect of orbit, connected by a thin strand of dark tissue along the front margin of orbit. Vn widely separated from Dn, confined to anteroventral aspect of orbit but connected to Dn by a strand of dark tissue along front margin of orbit.SAO1 well above VO5, maxilla extends less than an eye diameter past orbit.

D 14, A 14, P- 10-11, GR 6+ 1+ 12, AO 6-5 + 5- 4

Habitat: Pseudoceanic, Pelagic (325-475) during day and 40-250 during night.

Distribution: Eastern Atlantic: Mauritanian Upwelling region and Gulf of Guinea south to 23°S. Western Atlantic: USA (Gulf Stream) to Gulf of Mexico and the Caribbean Sea. Northwest Atlantic: Canada. Reported off the Guianas, East coast of Africa

Reference: Hulley 1986 a,b,c; Froese and Pauly 2017

Diaphus theta Eigenmann and Eigenmann, 1890

Common name: California headlightfish

Synonym: *Myctophum protoculus* Gilbert 1890, *Diaphus protoculus* (Gilbert 1890)

Collection Locations: 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 02°23.269'S, 63°04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00486

Diagnosis: Standard length of the specimen ranged from 60mm- 70mm. PLO and VLO much nearer pectoral and pelvic bases than to lateral line. SAO, Pol, and upper Prc, two to three diameters below lateral line. SAO series usually equally spaced and in line with VO5. SAO slightly angular, SAO3 three times its own diameter below LL, SAO2 often a little behind a line through SAO1-3, SAO2-3 interspace slightly greater than that of SAO1-2. First AOa usually on level of adjacent ones but occasionally slightly elevated, though seldom by a full diameter, last 1 or 2 AOa elevated to form a curve with Pol. Pol and last AOa interspace usually a little larger than those between the other AOa. AOa slightly elevated, Pol 2-2.5 times its own diameter below LL. Prc forms a curve with Prc4 2-3 times its own diameter below LL. A luminous scale at PLO present.

D. 13, A. 13, P. 10 (11), AO 5-6 + 5, GR 6+ 1+14, LL 35 -36.

Habitat: Bathypelagic; depth range 10 - 3400 m, usually 10 - 400 m. Deep-water; 66°N - 20°S.

Distribution: Eastern Pacific: common in California Current region to 20°S, including Hawaii. Northwest Pacific: throughout subarctic-transitional waters to northern Japan.

Reference: Moser and Ahlstrom, (1970, 1974), Clemens and Willby (1934).

Remarks: First record from WEIO and TSWIO. New record from WIO.

Diaphus thiollierei Fowler, 1934

Common name: Thiolliere's lantern fish

Synonym: *Diaphus jouani* Fowler 1934

Collection location:12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT, 11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT, 11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT, 11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT, 11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT, 11˚06.39'N, 74˚52.394'E, 350m, .10.13 day (Cr. 320, St.17), 45mMT, .11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT.10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT.10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT.10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT.10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT.09˚03.195'N, 75˚53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, .08˚59.820'N, 75˚51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, .08˚35.131'N, 76˚00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT, .08˚29.411'N, 76˚06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT, .08˚08.933'N, 76˚15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT, .08˚01.563'N, 76˚25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, . 13°24.864'N, 67°00.781'E, 260m, 10.03.14 night (Cr. 325, St.2), 45mMT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT.08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT.02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 08˚06.354 'N, 73˚22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT, .02˚23.269'S, 63˚04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT, 09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT, 20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT, 18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT, 17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT, 14°41.855'N, 73°00.985'E, 100m, 13.01.16 night (Cr. 347I, St.5), CT, 19°31.129'N, 65°26.695'E, 110m, 08.02.16 night (Cr. 347II, St.2), CT, 15°58.481'N, 65°29.986'E, 100m, 10.02.16 night (Cr. 347II, St.9), CT, 13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT.

Diagnosis: Standard length of the specimen ranged from 30mm- 90mm 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 medianethmoid 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, SAO3 in front of origin of anal fin and less than its diameter below lateral line. AOa1 1.5 - 2.5 times its diameter anterodorsal to AOa2. Pol directly under or slightly in advance of base of adipose fin and its diameter or less below lateral line, AOp1 behind base of anal fin, Prc evenly spaced, Prc4 2 - 2.5 times its diameter below lateral line. A luminous scale at POL.

D.15, A.15, P. 12), GR 7 + 1 + 14 , total 22, AO 6 + 5, LL 36 - 37.

Habitat: Bathypelagic; oceanodromous

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

Reference: Gjosaeter 1977, Nafpaktitis 1978, 1984; Alwis and Gjosaeter 1988; Hulley 1986 a,b,c; Kinzer *et al.,* 1993; Dalpadado and Gjosaeter 1993; Pillai *et al.,* 2009; Froese and Pauly 2017.

Diaphus watasei Jordan and Starks, 1904

Common Name (English) Chubby flashlightfish

Synonyms: NIL

Collection Locations: 10°67.894'N, 66°58.797'E, 110m, 13.03.14 day (Cr. 325, St.5), 45mMT.

Voucher Specimen No: IO/SS/FIS/00488

Diagnosis: The size range of males and females were 12-16.5 cm TL and 10-15.6 cm TL, respectively. PLO nearer upper base of P than LL, SAO3 and Pol three photophore-diameters or more below LL. Dn smaller than nasal rosette. Ant present. Vn extending dorsally to make contact with Dn. AOa1 elevated. So absent. Luminous scale at PLO smaller. SAO series almost in a straight line. 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 PO5. 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.

D. 15 (14), A. 15 (14), P. 11, GR 5 (4-6) + 1 + 12-13, AO 6 (7) + 5 (6)

Habitat: This is a common species seen off south west coast of India, captured in trawls that fish on or very near the bottom and at depths ranging from 100 to 500 m.

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.

Reference: Nafpaktitis 1978, 1984; Hulley 1986 a,b,c; Alwis and Gjosaeter 1988; Karuppasamy *et al.,* 2006; Menon 2002; Pillai *et al.,* 2009; Boopendranath *et al.,* 2009; Sebastine *et al.,* 2013.

Remarks: *D. watasei* is an occasional species seen in Indian waters. *D. coeruleus* is very similar to *D. watase*i. *D. watasei* can be distinguished by the larger, deeper body with the luminous organs on the head, the shape of the operculum and the Vn.

GENUS Bolinichthys **Paxton, 1972**

Mouth moderate, jaws extending half an eye diameter or less behind posterior margin of orbit. Posterodorsal marg in of operculum sharply angulate, posterior margin deeply anteriorly concave. Crescent of whitish tissue on posterior half of iris. Dn absent, Vn small. Five PO, with P04 elevated. Five VO, with VO2 elevated. AO divided into AOa and AOp. Two Pol. 2 + 1 Prc. Supra- and infra-caudal luminous patches present. Luminous tissue at bases of dorsal, anal and ventral fins and often on thorax and dorsal surface of head. Highoceanic, mesopelagic in tropical and subtropical waters.

Remarks: Of the 7 species reported from world oceans, 4 are reported previously from WIO and from our present study 5 species are represented in the study area. Further, a new record of species is reported in the present study which increases the number of species in WIO to 5.

Bolinichthys indicus (Nafpaktitis and Nafpaktitis, 1969)

Common Name: Chubby flashlightfish

Synonym: *Lepidophanes indicus* Nafpaktitis and Nafpaktitis 1969

Collection Locations: 12°54.04'N, 73°46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT,11°42.04'N, 73°45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT,11°18.68'N, 73°35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT,11°10.93'N, 73°01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT,11°09.97'N, 72°58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT,11°00.04'N, 73°05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT,10°55.30'N, 73°13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT,10°32.17'N, 73°12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT,10°20.18'N, 73°21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT,10°08.80'N, 73°32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT,09°03. 195'N, 75°53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08°59.820'N, 75°51.3 10'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08°35.131'N, 76°00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT,08°29.411'N, 76°06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT,08°08.933'N, 76°15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT,08°01.563'N, 76°25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 13°24.864'N, 67°00.781'E, 260m, 10.03.14 night (Cr. 325, St.2), 45mMT,11°18.907'N, 67°00.273'E, 270m, 11.03.14 night (Cr. 325, St.3), 45mMT, 10°35.875'N, 67°00.170'E, 100m, 12.03.14 day (Cr. 325, St.4), 45mMT, 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT, 02°23.269'S, 63°04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT.

Voucher Specimen No: IO/SS/FIS/00458

Diagnosis: Standard length of the specimen ranged from 40mm- 60mm. Eye large, aphakic space present, crescent of white tissue on posterior half of iris. Large re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave. Origin of dorsal fin about slightly behind vertical through outer base of pelvic fin, origin of anal fin behind vertical through posterior end of base of dorsal fin, pectoral fins long, reaching to SAO3, pelvic fins reaching to anus, adipose origin in advance of end of base of anal fin. Vn at anterior border of eye, between nasal rosette and anterior margin of pupil. PLO immediately above, lateral line. PVO1 slightly in advance, PVO2, which is in front of middle of base of pectoral fin. 5 PO, with PO3 raised above line through centres of PO1-PO2, with PO4 dorsal to level of PVO1, and nearer to PO5 than PO3, and with PO5 in front of outer pelvic base. VLO less than 1 photophore diameter below lateral line, well posterior to vertical through outer pelvic base. 5 VO, with VO2 highly and abruptly elevated, above line connecting PO4-SAO1, and VO3-VO5 on a straight descending line. SAO1 slightly posterior to vertical through VO5, below level of PO4, SAO2 slightly behind vertical through origin of anal fin, and nearer to SAO1 than SAO3, and with SAO3 at, lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp with AOa1 and last AOa level, 4 AOp, evenly spaced and all posterior to end of anal fin. 2 Pol with Pol1 elevated above AOa series, about on vertical through middle of adipose fin, and with Pol2 at lateral line, Prc2 about 1-1.5 photophore diameters posterodorsad to Prc1, and with Prc3 well behind Prc2 and above level of lateral line. Minute secondary photophores on trunk. Supracaudal organ consisting of 1-2 luminous, scale-like patches, infracaudal organ consisting of 2-4 luminous, scale-like patches, extending anteriorly from procurrent caudal rays to behind, at, or anterior to level of last AOp 2-3 pairs of patches of luminous tissue on top of head. A patch of luminous tissue present between upper base of pectoral fin and PLO, a single, scale-like patch of luminous tissue at base of pelvic fin. 0-2 luminous patches along base of dorsal fin, 2-3 elongate, luminous patches along base of anal fin.

D 13 , A 13, P 12-13, AO 6 + 4, GR 4 + 1 + 11-12

Habitat: High-oceanic, mesopelagic.

Distribution: Atlantic (20º-50ºN and 20º- 40ºS), Eastern Atlantic: Spain to Mauritania, and also from Namibia to South Africa. Western Atlantic: USA to about 20°N, and from Uruguay to Subtropical Convergence. Indian Ocean: between20°S and 45°S. Also recorded from Papua New Guinea.

Reference: Nafpaktitis 1984; Hulley 1986a,b,c; Menon 2002; Koubbi *et al.,* 2011; Hulley and Duhamel 2009; Froese and Pauly 2017

Bolinichthys longipes (Brauer, 1906)

Common Name (English): Chubby flashlightfish

Synonym: *Myctophum longipes* Brauer 1906, *Lampanyctus fraser brunneri* Bolin 1946

Collection Locations: 21°04.195'N, 68°03.879'E, 393m, 22.02.13 night (Cr. 313, St.9), CT,20°57.735'N, 66°14.478'E, 281m, 21.02.13 night (Cr. 313, St.8), CT,20°56.044'N, 65°56.529'E, 372m, 21.02.13 day (Cr. 313, St.7), CT,19°17.840'N, 65°55.013'E, 377m, 20.02.13 night (Cr. 313, St.6), CT,19°12.833'N, 67°58.297'E, 391m, 19.02.13 day (Cr. 313, St.3), CT,19°10.740'N, 67°56.671'E, 282m, 19.02.13 night (Cr. 313, St.4), CT,19°06.722'N, 68°31.402'E, 355m, 18.02.13 night (Cr. 313, St.2), CT,19°00.511'N, 66°06.791'E, 349m, 20.02.13 day (Cr. 313, St.5), CT,18°37.619'N, 69°03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT,19°31.129'N, 65°26.695'E, 110m, 08.02.16 night (Cr. 347II, St.2), CT,18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT,17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT, 21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT,20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT 15°58.481'N, 65°29.986'E, 100m, 10.02.16 night (Cr. 347II, St.9), CT, 13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT, 12°17.255'N, 65°27.965'E, 100m, 14.02.16 night (Cr. 347II, St.26), CT,11°08.141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39), CT,10°58.142'N, 67°30.071'E, 95m, 16.02.16 night (Cr. 347II, St.32), CT,10°57.446'N, 70°31.136'E, 120m, 18.02.16 night (Cr. 347II, St.36), CT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT,08°21.533'N, 72°06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT,07°45.322'N, 70°55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT,05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 05°27.666'S, 65°52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 06°58.058 'N, 72°00.045'E, 101m, 13.10.15 night (Cr. 344II, St.10), 28.4mMT, 08°41.330 'N, 74°09.677'E, 220m, 15.10.15 day (Cr. 344II, St.12), 28.4mMT.

Voucher Specimen No: IO/SS/FIS/00457

Diagnosis: Standard length of the specimen ranged from 30mm- 50mm. Eye large, aphakic space present, crescent of white tissue on posterior half of iris. Large re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between posterior cusps about twice length of base of pectoral fin, subopercle serrate, interopercle smooth .Origin of dorsal fin slightly behind vertical through outer base of pelvic fin, origin of anal fin behind vertical through posterior end of base of dorsal fin, pectoral fins long, reaching to below adipose fin, pelvic fins reaching to anus, adipose origin in advance of end of base of anal fin. Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. PLO in contact with lateral line. PVO1 slightly in advance of PVO2, which is in front of middle of base of pectoral fin. 5 PO, with PO3 raised above line through centres of PO1-PO2, with PO4 dorsal to level of PVO1, and nearer to PO5 than PO3, and with PO5 in front of outer pelvic base. VLO less than 1 photophore diameter below lateral line, posterior to vertical through outer pelvic base. 5VO, with VO2 abruptly elevated, at line connecting PO4-SAO1, and with VO3-VO5 in a straight descending line. SAO1 slightly posterior to vertical through VO5, about level of PO4, with

SAO2 slightly behind vertical through origin of anal fin, closer to SAO1 than SAO3, and with SAO3 above lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp, with AOa1 and last AOa level, AOp evenly spaced and all posterior to end of anal fin. 2 Pol, with Pol elevated above AOa series, about on vertical through middle of adipose fin, and with Pol2 at, lateral line, little behind vertical through base of adipose fin. Prc2 about 1 photophore diameter posterodorsad to Prc1, and with Prc3 well behind Prc2 and above level of lateral line. Supracaudal luminous tissue and infracaudal present. A patch of luminous tissue between upper base of pectoral fin and PLO absent, a single, scale-like patch of luminous tissue at base of pelvic fin. 2-3 luminous patches along base of dorsal fin, a single elongate, luminous patch at base of anal fin.

D 12, A 13, P 12 (13), AO 4 + 3, GR 6 + 1 + 12, total 19

Habitat: High-oceanic and mesopelagic, found at 500-900 m during day and at 25-300 m by night.

Distribution: Area of Gulf of Pakistan and Gulf of Aden, Western Indian Ocean, Indian

Ocean (20º N -18°S), Sri Lankan waters (08°26'N-81°33'E), North–Eastern Arabian Sea, Indian EEZ of Arabian Sea (06º00'N- 21º00'N and 66º00'E -77º00'E).

Reference: Bolin 1946; Tsarin 1983; Gjosaeter 1977; Nafpaktitis 1984; Hulley 1986a,b,c; Dalpadado and Gjosaeter 1993; Karuppasamy *et al.,* 2006, 2010; Kinzer *et al.,* 1993; Menon 2002; Hulley and Duhamel, 2009.

Bolinichthys nikolayi Becker, 1978

Common Name: Chubby flashlightfish

Synonym: *Bolinichthys nikolai* Becker 1978

Collection Locations: 18°37.619'N, 69°03.492'E, 327m, 17.02.13 night (Cr. 313, St.1), CT, 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 05°27.666'S, 65°52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT,09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 02°23.269'S, 63°04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT.

Voucher Specimen No: IO/SS/FIS/00459

Diagnosis: Standard length of the specimen ranged from 40mm- 60mm. Eye large, aphakic space present, crescent of white tissue on posterior half of iris. Large, re-curved, preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between posterior cusps about equal to length of base of pectoral fin in small specimens much longer than pectoral base in larger specimens .Origin of dorsal fin about on vertical through outer base of pelvic fin, origin of anal fin behind vertical through posterior end of base of dorsal fin, pectoral fins long, probably reaching to SAO3, pelvic fins reaching to anus, adipose origin in advance of end of base of anal fin. Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. PLO in contact with lateral line. PVO1 in advance of PVO2, which is in front of ventral base of pectoral fin. 5 PO, with PO3 raised above line through centres of PO1-PO2, with PO4 dorsal to level of PVO1, and nearer to PO5 than PO3, and with PO5 in front of outer pelvic base. VLO 2-3 photophore diameters below lateral line, 5 VO, with VO2 abruptly elevated, slightly above line connecting VO3-VO5, VO2-VO5 distinctly angulate, with VO2-VO4 in a straight descending line. SAO1 posterior to vertical through VO5, level of PO4, with SAO2 slightly in front of vertical through origin of anal fin, usually closer to SAO1 than SAO3, and with SAO3 just above lateral line, on posterior to vertical through origin of anal fin. AO series divided into AOa and AOp, with AOa1 and last AOa level, AOp evenly spaced and all posterior to end of anal fin. 2 Pol with Pol1 slightly elevated above AOa series, about on vertical through middle of adipose fin and with Pol2 just above lateral line, well behind vertical through base of adipose fin. 2+1 Prc, with Prc2 about 1 photophore diameter posterodorsal to Prc1, and with Prc3 well behind Prc2 and above level of lateral line. Supracaudal luminous organ consisting of 1-2 luminous, scale-like patches, infracaudal organ consisting of 4-6 luminous, scale-like patches, extending anteriorly from procurrent caudal rays to, or slightly anterior to, vertical through AOp1. Luminous tissue on top of head and on sides of body absent. Scale-like patch of luminous tissue at base of pelvic fin absent. No luminous patches along base of dorsal fin, 6-7 elongate, luminous scale-like patches along base of anal fin, commencing about at origin of anal fin, with second patch at AOa1, and extending posteriorly to about last AOa.

Distribution: *Bolinichthys nikolayi* is an oceanic, mesopelagic species, confined to the western South Pacific Ocean between about 10° and 39°S, and is known from the continental slope of the Australian East Coast to 140°W.

Reference: Hulley and Duhamel 2009.

Remarks: New report of *B.nikolayi* from WIO. Specimens were obtained from WEIO and TSWIO. The restricted geographic distribution in the Pacific suggests a relationship of the species to more saline and better oxygenated water masses.

Bolinichthys pyrsobolus (Alcock, 1890)

Common Name (English): Chubby flashlightfish

Synonyms: *Scopelus pyrsobolus* Alcock, 1890*, Serpa blacki* Fowler 1934, *Lampanyctus blacki* Fowler 1934, *Bolinichthys nanshanensis* Yang and Huang 1992.

Collection Locations: 07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT,05˚07.190'N, 69˚04.122'E, 400-506m, 12.09.15 day(Cr. 344I, St.7), CT,03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT,02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT.

Voucher Specimen No: IO/SS/FIS/00460.

Diagnosis: Standard length of the specimen ranged from 50mm-70mm.Eye large, aphakic space present, crescent of white tissue on posterior half of iris. Large re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, distance between cusps about twice length of base of pectoral fin, posterior margin of subopercle serrate, margin of interopercle smooth. Origin of dorsal fin slightly behind vertical through outer base of pelvic fin, origin of anal fin behind vertical through posterior end of base of dorsal fin, pectoral fins long, reaching at least to SAO3, pelvic fins reaching to about anus, adipose origin in advance of end of base of anal fin. Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. PLO above lateral line. PVO1 slightly in advance of PVO2, which is in front of middle of base of pectoral fin. 5 PO, with PO3 raised above line through centres of PO1-PO2, with PO4 dorsal to level of PVO1, and nearer to PO5 than PO3, and with PO5 in front of outer pelvic base. VLO about midway between lateral line and outer pelvic base, well posterior to vertical through outer pelvic base. 4 VO, withVO2 abruptly elevated, VO2 to lastVO4 angulate, and with VO3-VO4 in line parallel to ventral contour. SAO1 posterior to vertical through VO4, at about level of PO4, with SAO2 posterior to vertical through origin of anal fin, usually closer to SAO1 than SAO3, and with SAO3 at lateral line, posterior to vertical through origin of anal fin. AO series divided into AOa and AOp, with AOa1 and last AOa level, AOp evenly spaced and all posterior to end of anal fin. 2 Pol with Pol elevated above AOa series, about on vertical through base of adipose fin, and with Pol 2 at lateral line, well behind vertical through base of adipose fin. Prc2 about 1.5-2 photophore diameters posterodorsad to Prc1, and with Prc3well behind Prc2 and above level of lateral line. Supracaudal luminous tissue and infracaudal luminous tissue consisting of 3-4 scale-like patches, extending anteriorly from procurrent caudal rays to in front of level of last AOp. Luminous tissue on dorsalfin, pelvic fin, top of head and on sides of body absent. Luminous patches along base of anal fin present.

D 12-13, A 12-13), P 9-11, AO 5) + 3), GR 7 + 1 + 12

Habitat: There is some size stratification with depth, small specimens (less than 23 mm SL) were taken in nets operated as shallow as 60 m, while specimens greater than 40 mm SL were obtained only in trawls operated above 490 m depths. Catch data suggest that during the day, *B. pyrsobolus* is not found in the upper 500 m of the water column (very low catches), but that at night small specimens (less than about 25 mm SL) may migrate to the upper 120 m of the water column.

Distribution: Indo-West Pacific. South China Sea .South China Sea.

Reference: Bradbury *et. al.* 1971; Froese and Pauly 2017; Hulley and Duhamel 2009.

Bolinichthys supralateralis (Parr, 1928)

Common Name (English): Chubby flashlightfish

Synonym: *Lepidophanes supralateralis* Parr 1928, *Lampanyctus superlateralis* Parr 1928.

Collection Locations: 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT.

Voucher Specimen No: IO/SS/FIS/00461

Diagnosis: Standard length of the specimen ranged from 30mm- 70mm. Eye large, aphakic space present, crescent of white tissue on posterior half of iris. Large, re-curved preopercular spine absent. Posterodorsal margin of operculum anteriorly concave, posterior margin of subopercle serrate, ventral margin of interopercle serrate .Origin of dorsal fin about on vertical through outer base of pelvic fin, origin of anal fin behind vertical through posterior end of base of dorsal fin, pectoral fins long, reaching at least to AOa3, pelvic fins reaching to origin of anal fin, adipose origin in advance of end of base of anal fin. Vn at anterior border of eye, between nasal rosette and anterior edge of pupil. PLO just above lateral line. PVO1 at, slightly behind PVO2, which is in front of middle of base of pectoral fin. 5 PO, with PO3 raised above line through centres of PO1-PO2, with PO4 dorsal to level of PVO1, and somewhat nearer to PO5 than PO3, and with PO5 in front of outer pelvic base. VLO 3-5 photophore diameters below lateral line, posterior to vertical through outer pelvic base. 5 VO, with VO2 elevated, but distinctly below line connecting PO4-SAO1 and with VO2-VO5 in a straight, oblique, descending line. SAO1 posterior to vertical through VO4 at about level of PO4 with SAO2 about on vertical through origin of anal fin, usually closer to SAO1 than SAO3, and with SAO3 just above lateral line, posterior to vertical through origin of anal fin. AO series divided into

AOa and AOp, with AOa1 and last AOa elevated, AOp evenly spaced and all posterior to end of anal fin. 2 Pol with Pol elevated above AOa series, about on vertical through middle of base of adipose fin, and with Pol2 at lateral line, behind vertical through base of adipose fin. Prc2 one photophore diameter posterodorsad to Prc1, and with Prc3 well behind Prc2 and above level of lateral line. Supracaudal luminous organ consisting of 2-3 luminous, scale-like patches, infracaudal organ consisting of 3-6 luminous, scale-like patches. Luminous tissue on top of head and on sides of body absent. Scale-like patch of luminous tissue at base of pelvic fin absent. No luminous patches along base of dorsal fin, luminous patches along base of anal fin, commencing in front of AOa1 and extending posteriorly to about AOa3-AOa4.

D 13, A 14, P 13, AO 5-6+ 4, GR 6 + 1 + 12-13.

Habitat: High-oceanic, mesopelagic, day at 375-750 m (maximum abundance at 450-500 m), night at 40-650 m (maximum abundance at 100 m). Large specimens non-migratory.

Distribution: Pacific, near Hawaii. Recorded in South China Sea near the Tungsha Islands, Off Cape Peninsula and in Agulhas Current. Atlantic (40ºN-02°S and 32°-40ºS), Indian Ocean (21°-30ºS), west coast of Australia, and near Hawaii.

Reference: Hulley and Duhamel 2009; Hulley 1986a,b,c.

Genus Ceratoscopelus Gunther, 1864

Mouth moderately large, jaws extending half to one eye diameter behind posterior margin of orbit. Palatine teeth in a single series, anterior teeth enlarged and medially depressible. Dn absent, Vn present. Five PO, with PO5 elevated. Five VO, with V02, V03, V5 raised or elevated. AO divided into AOa and AOp. Two Pol, Four Prc. Supra-caudal and infra caudal glands consisting of scale-like luminous structures. Luminous patches and scale-like structures at bases of median fins, on trunk and in some species on head. High-oceanic, mesopelagic in tropical, subtropical and temperate waters in all three oceans.

Remarks: 3 species has been reported from World Ocean. Only single species in WIO and study area.

Ceratoscopelus warmingii (Lutken, 1892)

Common Name: Warming's lantern fish

Synonym: *Scopelus warmingii* Lütken 1892, *Lampanyctus warmingii* Lütken 1892, *Myctophum warmingii* Lütken 1892

Collection locations: 12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT,11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT,11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT,11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT,11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT,11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT,10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT,10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT,10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT,10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT,09˚03.195'N, 75˚53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08˚59.820'N, 75˚51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08˚35.131'N, 76˚00.058'E, 99m, 06.10.13 day (Cr. 320, St.1), 45mMT,08˚29.411'N, 76˚06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT,08˚08.933'N, 76˚15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT,08˚01.563'N, 76˚25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45Mmt ,13°24.86 4'N, 67°00.781'E, 260m, 10.03.14 night (Cr. 325, St.2), 45mMT,10°67.894'N, 66°58.797'E, 110m, 13.03.14 day (Cr. 325, St.5), 45mMT, 10°35.875'N, 67°00.170'E, 100m, 12.03.14 day (Cr. 325, St.4), 45mMT, 21°45.447'N, 66°29.867'E, 100m, 25.01.16 night (Cr. 347I, St.16), CT,20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT,18°20.880'N, 69°25.550'E, 110m, 22.01.16 night (Cr. 347I, St.10), CT,17°34.067'N, 70°39.903'E, 200m, 21.01.16 night (Cr. 347I, St.8), CT, 19°31.129'N, 65°26.695'E, 110m, 08.02.16 night (Cr. 347II, St.2), CT,15°58.481'N, 65°29.986'E, 100m, 10.02.16 night (Cr. 347II, St.9), CT,13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT,12°17.255'N, 65°27.965'E, 100m, 14.02.16 night (Cr. 347II, St.26), CT,11°08. 141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39), CT,10°58.142'N, 67°30.071'E, 95m, 16.02.16 night (Cr. 347II, St.32), CT,10°57.446'N, 70°31.136'E, 120m, 18.02.16 night (Cr. 347II, St.36), CT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08˚06.857'N, 71˚55.829'E, 200-400m, 08.09.15 day (Cr. 344I, St.3), CT,07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT, 14˚24.68'S, 57˚15.592'E, 403m, 05.10.15 day (Cr. 344II, St.2), CT.

Voucher Specimen No: IO/SS/FIS/00462

Diagnosis: Standard length of the specimen ranged from 30mm- 80mm Maxilla extending well behind orbit, P large, extending beyond origin of A. Vn present, POL nearer toll. PVO1 on the mid base of Pectoral Fin. 5 PO, PO 5 elevated, 5 VO, VO2, 3, 5 elevated. VO4, SAO1,2 and SAO3 form a straight line. AO series divided into AOa and AOp, Pol just below LL, patches and scale-like structures of luminous tissue on trunk.Prc4 on LL. Luminescence patches over Pectoral, Pelvic,Anal and Dorsal fin. AO series before adipose and infra and supra caudal glands.

D 13, A 13, P 15, GR 4 + 1 + 9, AO 6+ 4

Habitat: Oceanic species found between 700 and 1,500 m during the day, between 20 and 200 m at night with maximum abundance between 50 and 100 m. Size stratification with depth during both day and night. Small juveniles (1.5-1.9 cm) are apparently non-migratory. Known to feed on zooplankton but appears to be adapted for occasional herbivory.

Distribution: Atlantic (42°N- 40°S), Indian Ocean (20ºN-45°S) and tropical/subtropical Pacific.

Reference: Bradbur*y et al.,* 1971; McGinnis 1982; Hulley 1986a,b,c; Nafpaktitis 1984; Tsarin 1983; Dalpadado and Gjosaeter 1993;

Jayaprakash 1996; Karuppasamy et. al. 2006, 2010; Menon 2002; Balachandran and Nizar 1990; Muhlinga *et al.,* 2007; Froese and Pauly 2017.

Genus Lampadena **Goode and Bean, 1896**

Mouth moderately large, jaws extending one-half eye diameter or morebehind posterior margin of orbit. Maxillae not or only slightly expanded posteriorly. Origin of dorsal fin directly above or in advance of base of ventral fin. Lateral line well developed. Dn absent Vn small. PVO1 about under PV02. Five to six PO, level or with P04 highly elevated. Three to six VO, sometimes arched. Three SAO, weakly angulate. AO series divided into AOa and AOp. One Pol. 2 + 1 Prc, with Prc3 at level of lateral line. Both sexes with large undivided supra-caudal and infra-caudal glands, bordered by black tissue. High- anic, mesopelagic and bathypelagic in tropical, subtropic and temperate waters or pseudo ceanic, pelagic in tropical waters.

Remarks: 10 species have been reported from world oceans of which 8 species are found in WIO. From the study area 3 species were recorded. One species from study area is new record from WIO and that makes 9 species from WIO.

Lampadena anomala Parr, 1928

Common Name: Anomalous lantern fish

Synonym: Nil

Collection location: 08°21.533'N, 72°06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT.

Voucher Specimen No: IO/SS/FIS/00500

Diagonsis: Standard length of the specimen ranged from 90mm-110mm. Photophores smaller than in other species of the genus. VLO nearer lateral line than to pelvic base. Three VO, 3 SAO, 3 AOa, widely separated, 2 AOp, the last over anterior margin of infracaudal luminous gland. Three Prc, the first 2 very close together, the third far distant at end of lateral line. SAO3 and Pol about their diameters below lateral line. Supracaudal luminous gland slightly shorter than infracaudal, its length about equal to distance between end of anal base and anterior margin of infracaudal gland.

D. 16, A. 13-14, P. 16-17, AO 3 + 2, GR 5+1+11.

Habitat: Oceanic, found between 800-2,000 m during the day and mainly below 1,000 m at night, but juveniles migrate to 380 m(night). Meso- and bathypelagic.

Distribution: Eastern Atlantic: Morocco to Angola. Western Indian Ocean:a single specimen at 6°1'N, 64°59'E. Eastern Pacific: near Hawaii. Newly recorded from Asia in waters southwest of Tungsha Island.

Reference: Nafpaktitis 1984; Hulley 1986a,b,c.

Lampadena luminosa (Garman, 1899)

Common name: Luminous lantern fish

Synonym: *Myctophum luminosum* Garman 1899, *Lampadena luminosa nitida* Tåning 1928, *Lampadena nitida* Tåning 1928.

Sampling Locations: 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT, 02˚23.269'S, 63˚04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT.

Voucher Specimen No: IO/SS/FIS/00502

Diagnosis: Standard length of the specimen ranged from 60mm- 70mm. Body elongate, compressed, mouth large, nearly horizontal, eye moderately small, PVO2 below upper end of pectoral fin base, PO4 distinctly higher than other PO photophores , PLO, SAO3 and Pol on lateral line, PO and VO elevated, SAO1 above VO4. SUGL and INGL present as a single large, black-margined organ, Prc3on lateral, adipose fin present.

D15, A 14, P 14-15, V 8, GR 4+1+8, AOa 6+2

Habitat: Benthopelagic, depth range 0 – 1808 m

Distribution: Indo-West Pacific: common in the tropical Indian Ocean and Southeast Asian seas. South China Sea.

Reference: Nafpaktitis 1984; Tsarin 1983; Froese and Pauly 2017.

Lampadena urophaos Paxton, 1963

Common Name: Sunbeam lamp fish

Synonym: *Lampadena urophaos urophaos* Paxton 1963

Voucher Specimen No: IO/SS/FIS/00503

Collection locations: 09°00.953'N, 73°06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 03°53.184'S, 66°22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT,09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT,07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Diagnosis: Standard length of the specimen ranged from 90mm-100mm. Body elongate, compressed, mouth large, nearly horizontal, eye moderately small, Pterotic spine strong, directed posteriorly and slightly ventrally. None of the PO abruptly or highly elevated. Prc 1-2 interspace much shorter than three times the diameter of a photophore of this series. Caudal luminous glands strongly developed and set deeply into vertical surfaces of caudal peduncle. PVO2 below upper end of pectoral fin base, PO4 and PO5 slightly higher than other PO photophores, SUGL and INGL present as a single large, black-margined organ, Prc3 on lateral line, adipose fin present.

D-14, A 14, P 14-15, AO 5 + 2 (3), GR 4 + 1+ 8.

Habitat: Pelagic-oceanic, depth range 50 - 1000 m.

Distribution: *L. urophaos* occurs between about 25° and 42° N in the eastern Pacific andWest ward to Hawaii, A possible subspecies occurs in the North Atlantic Ocean.

Reference: Wisner 1974

Remarks: New record from WIO. Specimens obtained from WEIO and TSWIO.

Genus *Lampanyctus* Bonaparte, 1840

Mouth large, jaws extending beyond posterior margin of orbit. Maxilla only slightly expanded posteriorly. Dn absent, Vn small. PVO1 almost directly below or below and slightly in front of PV02. Five PO, with P elevated. Four VO (rarely five) level, arched or with V02 elevated a anteriorly displaced to about above VO1. SAO usually angulate. AO series divided into AOa and AOp. Two Pol, obliquely arranged. Four Prc, continuous with or separate from AOp. Both males and female with supra-caudal and infra-caudal glands, consisting of numerous over lapping scale-like luminescent structures. Luminous scale(s) at adipose origin or slightly in front of adipose origin present or absent. Cheek photophores and secondary photophores present in some species. High-oceanic mesopelagic/bathypelagic in warm, temperate and cool waters of all three oceans.

Remarks: The genus Lampanyctus is the most widespread and second in the number of species (Backus *et al.,*, 1977). 22 species reported from world oceans including 17 from WIO. 8 species from Study area, one is new record from our area so it makes 18 species from WIO.

Lampanyctus crocodilus (Risso, 1810)

Common Name: Jewel lantern fish

Synonym: *Gasteropelecus crocodilus* Risso 1810, *Myctophum crocodilum* Risso 1810, *Lampanictus crocodilus* Risso 1810, *Macrostoma crocodilus* Risso 1810, *Nyctophus bonapartii* Cocco 1838, *Scopelus bonapartii* Cocco 1838, *Nyctophus bonaparte* Cocco 1838, *Lampanyctus peculiaris* Borodin 1929, *Lampanyctus iselini* Parr 1934.

Voucher Specimen No: IO/SS/FIS/00501

Collection Locations 00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT.

Diagnosis: Standard length of the specimen ranged from 130mm to 135mm Distinguished from other species of Lampanyctus by the pattern of its photophores and by its short pectoral fins located just behind gill opening. Presence of Phtophore on the cheek. Photophores along ventral post-anal region .PLO Just half a diameter photophore below LL. SAO3and Pol on LL. PO elevated, VO almost a straight line. SAO forms an arc. SAO1 after and above VO2 and SAO2 above VO4. VLO nearer to LL. Prc4 on LL.

D 14, A17, P 14, GR 5 + 1 + 11, AO 7 + 8

Habitat: high-oceanic, mesopelagic. Mediterranean: day at 100-200 m and 700-1,000 m (maximum abundance at 700-800 m), night at 45-150 m.

Distribution: Eastern Atlantic: strays as far north as Dohrn Bank (off East Greenland) and off northwest Iceland, from British Isles to Mauritanian Upwelling Region including the Mediterranean .Western Atlantic: as shallow as 46 m in Ungava Bay, Canada, in slope water region.

Reference: Hulley 1990; Scott and Scott 1988.

Remarks: New record from WIO and is obtained from WEIO and TSWIO.

Lampanyctus festivus Tåning, 1928

Common Name: Festive lantern fish.

Synonym: Macrostoma festivum Tåning 1928, *Lampanyctus septilucis* Beebe1932.

Collection locations: 15°26.54'S, 56°48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT.

Voucher Specimen No: IO/SS/FIS/00493

Diagnosis: Standard length of the specimen ranged from 50mm-110mm. VO2 elevated but not anteriorly displaced to above VO1. Brachiostegal membrance without serial photophores.No photophore on cheek. Pectoral fin extending to at least A origin. PLO nearer to LL. PVO1, PVO2 and PO2 form a straight line. VLO more than 3 photophore diameter below LL. SAO3 and Pol on LL. Prc2-Prc4forming an arc with concavity directed anteriorly and dorsally. VO series arched, Infracaudal gland extending from procurrent C rays to A base, Prc3 above level of Prc1.

D 14, A 18-19, P 14-15, GR 4+9-11, AO 5+1+10

Habitat: High Oceanic, mesopelagic 700-950m during day and 100-350m during night.

Distribution: Atlantic (53ºN- 18°N) and 28º- 40°S,12ºS in Benguela current and Indo West Pacific.

Reference: McGinnis 1982; Hulley 1986a,b,c; Koubbi *et al.,* 2011; Froese and Pauly 2017

Remarks: Obtained only from TSWIO from the study area.

Lampanyctus intricarius Tåning, 1928

Common Name: Diamond cheek lantern fish

Synonym: *Serpa conspicua* Whitley, 1936

Collection Locations: 07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 00˚44.022'S, 68˚03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT.

Voucher Specimen No: IO/SS/FIS/00494

Diagnosis: Standard length of the specimen ranged from 40mm- 70mm. PLO below lateral line, about one-third the distance from there to pectoral origin. PVO2 interspace about half that of PLO-PVO1. PLO and PVO2 form straight, posteriorly slanting line that passes slightly before PO4. PO4 elevated to about level of middle of pectoral base, and to almost directly over PO. VLO slightly behind pelvic origin and slightly above midway between that origin and lateral line. SAO1, 2 interspace nearly one and one-halftimes that of SAO3. A line through SAO1, 2 passes slightly behind VO3, SAO1 about over anus, SAO3 slightly behind vertical from AOa,. The 2 Pol and last AOa form line that passes variously through, before, or slightly behind end of base of adipose fin. AOa-AOp interspace equal to about half least depth of caudal peduncle and considerably greater than space between Prc3. First

3 Prc equally spaced in curve, Prc3 at end of lateral line and separate from Prc3 by space only little less than that between Prc1, and Prc2.

D. 14, A. 18, P. 12-13, AO 8 + 7,GR 4+1+9

Habitat: High-oceanic, mesopelagic, 550 - 750 m (day), 40 - 550 m (night).

Distribution: In southern Benguela Upwelling Region. Atlantic (65°-32°N and in region of Subtropical Convergence) and Indo-Pacific (in region of Subtropical Convergence, but with northern extensions to 18°S in eastern boundary currents).

Reference: McGinnis 1982; Tsarin 1983; Hulley 1986a,b,c; Nafpaktitis 1984; Muhlinga *et al.,* 2007; Koubbi *et al.,* 2011; Froese and Pauly 2017.

Lampanyctus macdonaldi **(**Goode and Bean, 1896)

Common name: Rakery Beacon lamp, MacDonald's Lantern fish, Rakery Lantern fish

Synonym: *Nanobrachium macdonaldi* Goode and Bean 1896, *Lampanyctus iselini* Parr, 1934.

Collection Locations: 05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT.

Voucher Specimen No: IO/SS/FIS/00495

Diagnosis: Standard length of the specimen ranged from 100mm-120mm. PLO below lateral line about one third the distance to pectoral origin, VLO usually slightly nearer lateral line than to pelvic origin and slightly before vertical from that origin. Line through SAO1, 2 and VLO passes somewhat below PLO, SAO1 slightly behind vertical from VO5 and usually slightly above level of SAO3. AOa series evenly spaced and occasionally very slightly curved, or AOa, slightly depressed. No AOp over anal base. Prc and AOp often continuous, upper Prc at end of lateral line and distant from closely spaced first 3. The luminous scale before adipose base is weakly developed and easily lost, 2 to 4 weak luminous scales in supracaudal gland, 7 to 9 in infracaudal, the latter usually extending to near base of last anal ray.

D. 14-15, A. 18, P. 12 (11), AO 7 + 6, GR 6 + 1 + 16.

Habitat: Oceanic, mesopelagic, epipelagic to bathypelagic. Found between 500-1,000 m during the day, between 60-175 m (juveniles) and deeper than 250 m (adults) at night.

Distribution: Probably circum global in southern seas. It is also known from the North Atlantic Ocean, but has not been reported from the South Atlantic. In the South Pacific Ocean, it is known from off Valparaiso, Chile (Craddock and Mead, 19701, to Kermedec Islands and Southeast of South Island, New Zealand.

Remarks: New record from WIO and is obtained from WEIO

Reference: Wisner 1974; Froese and Pauly 2017.

Lampanyctus nobilis Tåning, 1928

Common name: Noble lamp fish

Synonym: *Lampanyctus ater* Tåning, 1928, *Macrostoma atrum* Tåning 1928, *Paralampanyctus ater* Tåning 1928, *Lampanyctus niger* non Günther 1887.

Collection Locations: 02°28.622'S, 67°39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 07°45.322'N, 70°55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 09°51.31'S, 58°36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07°43.35'S, 59°09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00496

Diagnosis: Standard length of the specimen ranged from 70mm-100mm. Body elongate, compressed, mouth large, nearly horizontal, eye moderately small, Pectoral fin long, extending far beyond the posterior end of pelvic fin base. PLO midway between LL and pectoral fin. 5 PO, PO4 elevated. VLO distinctly below lateral line, midway. 4 VO, VO2 moderately elevated but not displaced forward, SAO markedly angulated, SAO1 distinctly below level of SAO2, A line through SAO2 and SAO3passes a little before VO4 and PVO1 and PVO2 are in oblique line with PO2. SUGL and INGL present, last three photophores of Prc arranged linearly. Adipose fin present. Supracaudal gland has 4 to 5, Infracaudal gland 10 to 11, well developed luminous scales, the latter filling the infracaudal space.

D. 14, A. 19, P. 14, AO 6 -7+ 9, GR. 3+ 1+ 10.

Habitat: Between 100 and 200 m at night.

Distribution: Western Indian Ocean, In Agulhas Current and off west coast in Agulhas Water pockets, Indian EEZ of Arabian Sea

Reference: Gjosaeter 1977, Tsarin 1983, Bradbury *et al.,* 1971; Nafpaktitis 1984; Hulley 1986a,b,c; Menon 2002.

Lampanyctus photonotus Parr, 1928

Common name: Dotback Lantern fish

Synonym: *Lampanyctus taaningi* Parr 1929

Collection Locations: 05°07.190'N, 69°04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT, 03°53.184'S, 66°22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT.

Voucher Specimen No: IO/SS/FIS/00497

Diagnosis: Standard length of the specimen ranged from 100mm-120mm. Origin of D after V. Origin of A after D. P reaching almost ventral fin base. PLO nearer to LL than to P base. 5 PO. PO4 elevated. VLO mid-way between Ventral base and LL. VO2 elevated, but not anteriorly displaced to above VO1. SAO3 and Pol on LL.

Branchiostegal membrance without serial photophores. More than one photophore on cheek. Luminous gland at origin of adipose fin absent. PO4 midway between PO3-PO5 and level with VLO.

D 12, A 16, P 14, GR (3-4) + (9-11), AO 4+1+9

Habitat: High Oceanic, mesopelagic, 500-1000m during day, 4-250m night.

Distribution: Indian Ocean (08°N-l0ºS) and Mozambique Channel (southwards to 18°S), Southeast Asian Seas and tropical Pacific.

Reference: Nafpaktitis 1984; Hulley 1986 a,b,c; Menon 2002; Karuppasamy *et al.,* 2010; Froese and Pauly 2017.

Lampanyctus tenuiformis (Brauer, 1906)

Common Name: Slender lantern fish

Synonym: Myctophum tenuiforme Brauer 1906

Collection Locations: 02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT, 05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT, 09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00498

Diagnosis: Standard length of the specimen ranged from 50mm- 80mm. Body elongate, compressed, mouth large, nearly horizontal, eye moderately small, Pectoral fin long extending well beyond posterior end of pelvic fin base. Line joining VO1 and VO2 passing below SAO1, SAO markedly angulated, line through SAO2, SAO1 and VLO passing near PLO, adipose fin present, SUGL and INGL present, last three photophores of Prc angled upward. PLO two to three of its diameters below lateral line, SAO.3, Pol, and Prc3 touching lateral line. VLO about over base of inner pelvic ray and slightly nearer lateral line than to pelvic base.

D. 13, A. 16-17, P. 12-13, AO 6-7 + 8, G R 4+1+9.

Habitat: Mesopelagic. High-oceanic, found between 300-700 m during the day and between 40-325 m. at night with maximum abundance at 100 m.

Distribution: Atlantic (17° N- 10ºS, including Gulf of Mexico), Indian Ocean (07°N-04°S) and tropical Pacific.

Reference: Nafpaktitis 1984; Hulley 1986 a,b,c; Froese and Pauly 2017.

Lampanyctus turneri (Fowler, 1934)

Common name: NIL

Synonym: Serpa turneri Fowler 1934

Collection Locations: 12˚54.04'N, 73˚46.315'E, 275m, 14.10.13 day (Cr. 320, St.16), CT,11˚42.04'N, 73˚45.160'E, 300m, 13.10.13 night (Cr. 320, St.15), CT,11˚18.68'N, 73˚35.362'E, 330m, 13.10.13 day (Cr. 320, St.14), CT,11˚10.93'N, 73˚01.059'E, 320m, 11.10.13 day (Cr. 320, St.9), CT,11˚09.97'N, 72˚58.629'E, 223m, 10.10.13 day (Cr. 320, St.7), CT,11˚00.04'N, 73˚05.653'E, 287m, 10.10.13 day (Cr. 320, St.8), CT,10˚55.30'N, 73˚13.021'E, 290m, 11.10.13 day (Cr. 320, St.10), CT,10˚32.17'N, 73˚12.942'E, 300m, 12.10.13 day (Cr. 320, St.11), CT,10˚20.18'N, 73˚21.971'E, 400m, 12.10.13 day (Cr. 320, St.12), CT,10˚08.80'N, 73˚32.252'E, 350m, 12.10.13 night (Cr. 320, St.13), CT,09˚03.195'N, 75˚53.172'E, 270m, 08.10.13 night (Cr. 320, St.6), 45mMT, 08˚59.820'N, 75˚51.310'E, 260m, 08.10.13 day (Cr. 320, St.5), 45mMT, 08˚29.411'N, 76˚06.184'E, 84m, 06.10.13 night (Cr. 320, St.2), 45mMT,08˚08.933'N, 76˚15.115'E, 370m, 07.10.13 day (Cr. 320, St.3), 45mMT,08˚01.563'N, 76˚25.471'E, 350m, 07.10.13 day (Cr. 320, St.4), 45mMT, 11°18.907'N, 67°00.273'E, 270m, 11.03.14 night (Cr. 325, St.3), 45mMT, 20°08.671'N, 68°24.407'E, 100m, 23.01.16 night (Cr. 347I, St.11), CT, 14°41.855'N, 73°00.985'E, 100m, 13.01.16 night (Cr. 347I, St.5), CT, 19°31.129'N, 65°26.695'E, 110m, 08.02.16 night (Cr. 347II, St.2), CT,15°58.481'N, 65°29.986'E, 100m, 10.02.16 night (Cr. 347II, St.9), CT,13°01.549'N, 65°31.634'E, 120m, 12.02.16 night (Cr. 347II, St.16), CT,12°17.255'N, 65°27.965'E, 100m, 14.02.16 night (Cr. 347II, St.26), CT,11°08.141'N, 73°05.481'E, 120m, 20.02.16 night (Cr. 347II, St.39), CT,10°58.142'N, 67°30.071'E, 95m, 16.02.16 night (Cr. 347II, St.32), CT,10°57.446'N, 70°31.136'E, 120m, 18.02.16 night (Cr. 347II, St.36), CT, 09˚00.953'N, 73˚06.717'E, 300-360m, 07.09.15 day (Cr. 344I, St.1), CT, 08˚21.533'N, 72˚06.529'E, 250-348m, 08.09.15 day (Cr. 344I, St.2), CT,07˚45.322'N, 70˚55.413'E, 304-600m, 09.09.15 day (Cr. 344I, St.4), CT, 05˚27.666'S, 65˚52.820'E, 400m, 16.09.15 day (Cr. 344I, St.11), CT,05˚07.190'N, 69˚04.122'E, 400-506m, 12.09.15 day (Cr. 344I, St.7), CT,03˚53.184'S, 66˚22.248'E, 400m, 15.09.15 day (Cr. 344I, St.10), 45mMT,02˚28.622'S, 67˚39.312'E, 220-400m, 14.09.15 day (Cr. 344I, St.9), 45mMT,00˚44.022'S, 68˚03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT,15˚26.54'S, 56˚48.034'E, 220m, 04.10.15 night (Cr. 344II, St.1), CT, 04˚30.286'S, 60˚45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 02˚23.269'S, 63˚04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT, 05˚34.670'N , 70˚47.179'E, 180m, 12.10.15 night (Cr. 344II, St.9), 28.4mMT, 08˚06.354 'N, 73˚22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT .

Voucher Specimen No: IO/SS/FIS/00499

Diagnosis: Standard length of the specimen ranged from 60mm-110mm.Anal base longer than dorsal base. Dn absent, Vn small, 5 PO,PO4 elevated, 4 VO, VO2 elevated, SAO angulate, PLO on LL,VLO midway between ventral base and LL. AO series divided in to AOa and AOp, 2 PolOblique, 4 Prc.VO2 elevated and anteriorly displaced toile in front of , above and slightly behind VO1.

D 12, A17, P 12-13, GR 3+1+ 9, AO 5 + 7

Habitat: High oceanic, mesopelagic upper 212 m during night.

Distribution: In Agulhas current and off west coast in Agulhas water pockets, also in tropical and subtropical waters between South China Sea and Western Indian Ocean.

Reference: Hulley 1986 a,b,c; Karuppasamy *et al.,*2006, 2010.

Genus *Nannobrachium* Günther, 1887

The species of the tribe Lampanyctini were defined by Paxton (1972) as Nannobrachium having the following features short (never reaching far beyond pelvic-fin base), rudimentary, or no pectoral fins with narrow base always equal to or shorter than distance between lower orbital margin and toothed margin of upper jaw in the adult. Solid, squarish otolith, longest vertically, without prominent notch or rostrum, often somewhat rounded into a kidney-bean shape. Weak musculature resulting in a soft, flaccid body. Body profile appearing pinched because both predorsal and preanal profiles tend to be concave, with body depth a short distance anterior to dorsal fin less than at dorsal-fin origin and less than at nape.

Remarks: 17 species from world oceans,4 species from WIO 2 species from study area.

Nannobrachium atrum (Tåning, 1928)

Common Name: Dusky lantern fish

Synonym Lampanyctus ater Tåning 1928*, Macrostoma atrum* Tåning 192*1, Paralampanyctus ater* Tåning, 1928.

Collection Locations: 00°44.022'S, 68°03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT.

Voucher Specimen No: IO/SS/FIS/00492

Diagnosis: Standard length of the specimen ranged from 70mm-950mm. Origin of anal fin behind vertical from middle of base of dorsal fin. Pectoral fin barely reaching vertical from PO3, its rays weak, flexible. Base of adipose fin above end of anal-fin base, its origin well before end of anal-fin base. PLO 1-3 times its diameter below lateral line. PO4 slightly higher than level of PVO2 and above PO3 or slightly anterior to vertical from PO3. VLO less than one photophore diameter below, frequently nearly touching, lateral line. SAO2 always behind vertical from VO4 but usually closer to VO4 than to AOa1. SAO3 before vertical from AOa1. AOa1 slightly depressed and AOa1-2 interspace enlarged. AOp1 at or behind end of anal-fin base one photophore below LL. Prc well separated from AOp, Prc1-2 on horizontal line, Prc3-4 on or nearly on vertical line, well behind Prc2. Supracaudal and infracaudal luminous scales well developed, often with single separated scale preceding infracaudal gland. No secondary photophores found.

D 15, A 18, P 11-12, GR 4 +1+ 11, AO 6+ 5

Habitat: *N. atrum* to have a daytime maximum abundance in the North Atlantic at 700-800 m and occupy shallower depths (100 m) at night.

Distribution: *Nannobrachium atrum,* the most widely distributed species of *Nannobrachium,* is found in the Western Indian Ocean, Indian Ocean (12°- 44°S)

Reference: Nafpaktitis 1984; Hulley 1986a,b,c; Zahuranec 2000

Remarks: Previously Identified as *Lampanyctus ater.*

Nannobrachium achirus (Andriashev, 1962)

Common name: NIL

Synonym: *Lampanyctus achirus* Andriashev 1962

Collection location: 00˚44.022'S, 68˚03.990'E, 380-600m, 13.09.15 day (Cr. 344I, St.8), 45mMT, 09˚51.31'S, 58˚36.344'E, 150m, 06.10.15 night (Cr. 344II, St.3), CT, 07˚43.35'S, 59˚09.451'E, 300m, 07.10.15 night (Cr. 344II, St.4), CT.

Voucher Specimen No: IO/SS/FIS/00491

Diagnosis: Standard length of the specimen ranged from 80mm-950mm.Origin of anal fin behind vertical from middle of base of dorsal fin. Adults with vestigial rays buried in skin and not externally visible unless skin abraded or otherwise torn. In largest adults, vestigial pectoral-fin elements cannot be found. Adipose fin over end of anal-fin base. PLO about 2 photophore diameters below lateral line. PO4 approximately on level of PVO2 and above PO3. PVO1-2 interspace wide, that distance 2-3 times into PVO2-PLO distance. SAO1 above VO2-3 interspace, frequently closer to VO3. SAO2 midway above interspace between VO4 and AOa1. SAO3 above AOa1 but somewhat variable in position. AOa1 slightly depressed, AOa1- 2 interspace not visibly enlarged. AOp1 above or behind end of anal fin base. Prc separate from AOp, Prc1-2 on horizontal line, Prc3 below Prc4 but slightly in advance of vertical from center of Prc4. Supracaudal and infracaudal luminous glands well developed, commonly having single separate luminous scale preceding solid infracaudal gland. Secondary photophores in single row on either side of back, single photophore on posterior edge of each scale in first full scale row below middle row of scales, best developed and most prominent in region of adipose fin and less well developed further forward but appear to extend forward to nape.

D 14-15, A 18-19, AOa -8,AO 8+8, GR- 4+1+ 12.

Habitat: Usually found below 500 m at night but shallower in upwelling regions.

Distribution: In southern Benguela Upwelling Region and off south and east coasts, north to about 31°S. Circumglobal from about Sub- tropical Convergence to south of Antarctic Polar Front, with northern extensions to 21°S in eastern boundary currents. Usually below 500 m.

Reference: Nafpaktitis 1984; Hulley 1986a,b,c; Muhlinga *et al.,* 2007; Zahuranec 2000.

Remarks: Previously Identified as *Lampanyctus achirus.*

Genus Taaningichthys Bolin, 1959

Lateral line poorly developed or obsolete. Snout short and blunt, less than half the orbital diameter, orbit large, usually less than 3.0 in head. A large, opaque, whitish crescent on posterior half of iris. Photophores weakly developed or entirely absent, often lost with the fragile, easily eroded integument. PO 5-7, VO 3-10. A large, pearly white luminous organ set deeply into upper and lower surfaces of the caudal peduncle of both sexes. Three Prc, the first 2 low and closely spaced, the third at lateral line and widely separated from the others.

Remarks: 3 species has been reported from World oceans, 3 species from WIO and 1 species from study area.

Taaningichthys minimus **(Taning, 1928)**

Common name: Waistcoat lantern fish

Synonym: *Lampadena minima* Tåning 1928

Collection location: 04°30.286'S, 60°45.869'E, 100m, 08.10.15 night (Cr. 344II, St.5), CT, 02°23.269'S, 63°04.470'E, 30-50m, 09.10.15 night (Cr. 344II, St.6), CT, 08°06.354 'N, 73°22.682'E, 55m, 14.10.15 night (Cr. 344II, St.11), 28.4mMT.

Voucher Specimen No: IO/SS/FIS/00511

Diagnosis: Standard length of the specimen ranged from 90mm- 110 mm .Distance from anal origin to end of hypural less than distance from anal origin to upper end of pectoral base. Pectoral fin extending well beyond pelvic base. 5 PO, VO 8-10, only 1SAO, near lateral septum. Supracaudal luminous gland usually less than half the length of infracaudal gland. PVO1 well behind a vertical from PVO2. VLO midway between pelvic base and lateral line. Prc1-2interspace equal to at least two photophore. PVO1 well behind a vertical from PVO2. VLO midway between pelvic base and lateral line, or slightly nearer the latter. Prc1-2 interspace equal to at least two photophore diameters.

D 12, A 13, P 16-17, AO 7 + 4 , PO 5, GR 4+1+9.

Habitat: High-oceanic species found between 1-800 m during the day and between 90-600 m at night (large specimens between 200 and 400 m). Size stratification with depth at night. Epipelagic to mesopelagic.

Distribution: Indian Ocean: between 20°S and 30°S. Western Pacific: New Zealand. Central and northeast Pacific: between 35°N and 12°N. Reference: Nafpaktitis 1984; Hulley 1986 a,b,c.

3.3.4 Diversity of Myctophids in the NEAS, SEAS and WEIO

A total of 59 species of Myctophids were recorded in the present study, which include 53 previously known species and 6 new records. The 6 new records of species from WIO reported in the present study are *Diaphus similis*, *Diaphus theta*, *Bolinichthys nikolayi*, *Lampadena urophaos*, *Lampanyctus crocodilus* and *Lampanyctus macdonaldi*. From the study area (50-500 m), Myctophids were identified (from 6 cruises and 66 stations), and assigned to 59 species under 12 genus. Among the different sectors chosen in the present study, the NEAS represented 16 species under 8 genus, SEAS had 45species under 11genus and WEIO had 55 species representing 12 genus. Only 4 stations which were sampled from SWIO contributed to 39 species under 10 genus. *Lampanyctus festivus* was exclusively obtained from 15°S, 56°E of TSWIO. *Lampanyctus macdonaldi* was new record from WEIO obtained from 5°S and 65°E. *Benthosema fibulatum, Diaphus arabicus, Bolinichthys longipes, Benthosema pterotum, Diaphus garmani, Diaphus thiollierei* were numerically abundant in NEAS while *Benthosema fibulatum , Diaphus thiollierei, Benthosema pterotum, Diaphus garmani, Bolinichthys longipes, Diaphus lucidus, Mycto phum spinosum* were dominant in SEAS and *Lampanyctus turneri, Diaphus lucidus, D. lobatus, D. jenseni* were dominant species in the WEIO.

Diversity Indices

Analysis of the diversity indices are restricted to the sectors NEAS, SEAS and WEIO where reasonably good sampling efforts were undertaken in the course of the present study.

Table 3.3 : Diversity Indices

Area	Species number(n)	Species richness(d^I)	Species evenness(J^I)	Species diversity(H^I)
NEAS	16	1.793	0.665	2.66
SEAS	45	6.006	0.6384	3.506
WEIO	55	9.43	0.75	4.33

An examination of the species diversity and distribution of myctophids in the 3 sectors (methodology detailed in Chapter 2), reveal that the Species richness, species evenness and species diversity of myctophids is exceptionally high in the WEIO, medium in the SEAS and low in NEAS. The high values in diversity indices for WEIO is due to the exceptionally high species diversity in the EIO region. Though the sampling sufficiency in the present study was adequate for all the three regions, the species diversity was high for WEIO since the number of species were high (55 species) and sampling sites were very limited (10 stations). The SEAS stands second in terms of species diversity with 45 species and 37 sampling locations. When compared to the other two areas, the species diversity of NEAS is very low (16 species) despite sampling 15 sites. Both species richness (d^I) and species eveness (J^I) were high for WEIO as compared to the other two areas (Table 3.3, Figure 3.6). The species accumulation curve for the NEAS, SEAS and WEIO did not approach the asymptote (Figure 3.2, 3.3 and 3.4). Species estimators predict the occurrence of 66 species in EIO, 64 in SEAS and 21 in NEAS which may be collected from these regions with more sampling. Sampling sufficiency was found to be 86% for WEIO, 70% for SEAS and 85% for NEAS. The present study, with reports on 16 species from NEAS (from 15 trawl surveys), 45 species from SEAS (from 37 trawl surveys) and 55 species from WEIO (from 10 trawl surveys) has recorded 70-90% of the highest estimator of species diversity.

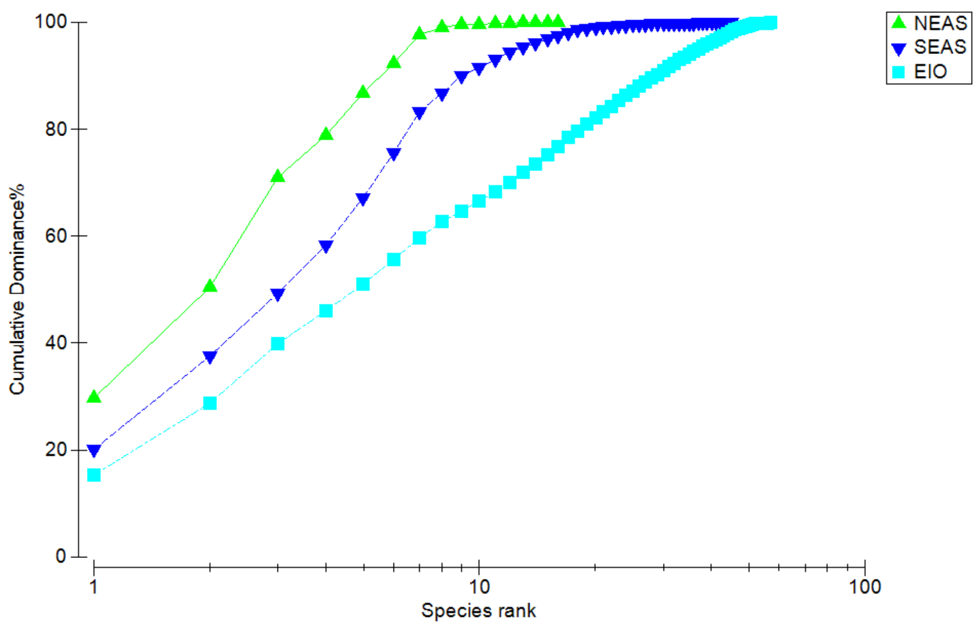


Figure 3.6 : Sector-wise Diversity of myctophids.

To conclude, the present study revalidates the number of myctophid species in the WIO to 158 species which include 6 new records from the study area. The 6 new records from the present study are *Bolinichthys nikolayi, Diaphus theta, Lampanyctus crocodilus, Lampa nyctus macdonaldi Lampadena urophaos* obtained exclusively from WEIO and TSWIO and *Diaphus similis* from SEAS. Based on surveys carried out in the western Indian Ocean, Nafpaktitis 1982 estimated the presence of 97 species of myctophids belonging to 23 genera in the WIO. Previous studies in the Indian Ocean (eastern and western IO, combined) have reported the occurrence of 146 species of myctophids belonging to 29 genera in the Indian Ocean (Bolin 1946; Bradbury *et al.,* 1971; Kawaguchi and Aioi 1972; Gjosaeter 1977; Nafpaktitis 1984; Hulley 1986a,b,c; Raman and James 1990; Dalpadado and Gjosaeter 1993; Kinzer *et al.,* 1993; Jayaprakash 1996; Menon 2002; Valinassab 2005; Karuppasamy *et al.,* 2006; Valinassab *et al.,* 2007; Vipin *et al.,* 2012). Among the sectors of the study area, where sampling sufficiency was reasonably good (WEIO, SEAS and NEAS) species abundance and related diversity indices were high in the WEIO, followed by the SEAS and NEAS.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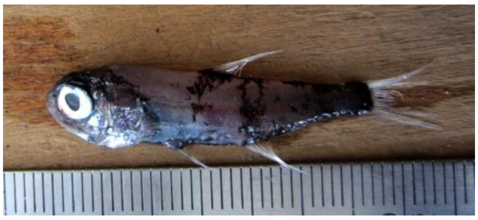
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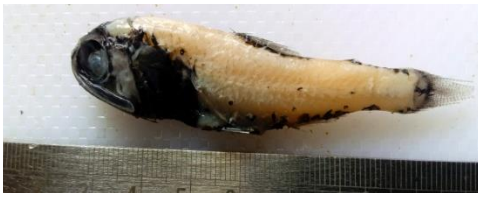
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PLATE I.

1. *Benthosema fibulatum*, 2. *B. pterotum*, 3. *Bolinicthys longipes*, 4. *B. nikolkai*, 5. *B. pyrosobolus*, 6. *B. supralateralis*, 7. *B.indicus*, 8. *Ceraotoscopelus warmingii*

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PLATE II

9. *Diaphus aliciae*, 10. *D. antonbruuni*, 11. *D. arabicus* 12. *D. brachycephalus*, 13.*D. coeruleus*, 14. *D. diadematus*, 15. *D. coeruleus*, 15. *D.diademophilus*, 16. *D. efflugens*

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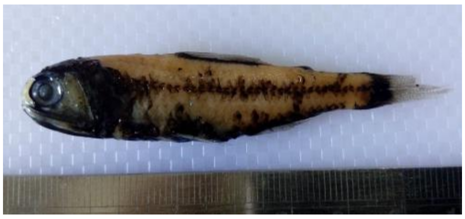

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PLATE III

17. *D. fulgens*, 18. *D. fragilis*, 19. *D. garmani*, 20. *D. jenseni*, 21. *D. lobatus*, 22. *D. lucidus*, 23. *D. luetkeni*, 24. *D. mollis*

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PLATE IV

25. *D. parri*, 26. *D. perspicillatus*, 27. *D. problematicus*, 28. *D. regani*, 29. *D. signatus*, 30. *D. similis*, 31. *D. splendidus*, 32. *D. taaningi*

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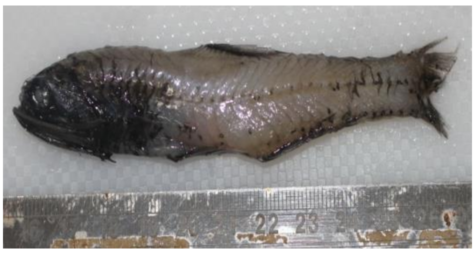

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PLATE V

33. *D. theta*; 34.*D. thiollierei*, 35. *D. watasei*, 36. *Electrona risso*,
37. *Hygophum hanseni*, 38. *H. proximum*, 39. *Lampanyctus festivus*,
40. L. *intricaris*

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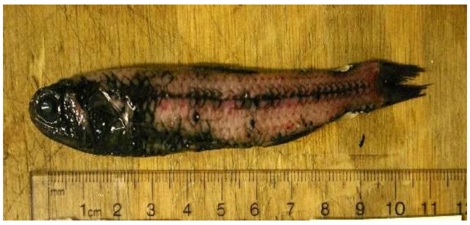

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41. L. macdonaldi, 42. L. nobilis, 43. L. photonotus 44. L. tenuiformis, 45. L. turneri, 46. Lampadena anomala, 47. Lampanyctus crocodiles, 48. Lampadena luminosa, 50. Myctophum asperum

PLATE VI

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49. *Lampadena urophaos,* 51. *Myctophum aurolaternatum,* 52. *M. nitidulum*, 53. *M. obtusirostre*, 54. *M. spinosum,* 55. *Nannobrachium archius,* 56. *N. atrum,* 57. *Symbolophorus evermanni,* 58. *S. rufinus,* 59. *Taaningichthys minimus*

Plate VII

Table 3.1: Revalidated check list of Myctophids from WIO

		Revalidated Check List of Myctophids from WIO									Sampling Area (Present study)				
SL NO	**SPECIES NAME**	**STNAS**	**NEAS**	**SEAS**	**TWAS**	**WEIO**	**TSWIO**	**STSWIO**	**Reported in fishbase from WIO**	**Reported in FAO Area 51 WIO**	**NEAS**	**SEAS**	**WEIO**	**TSWIO**	**REMARKS**
1	***Benthosema fibulatum***	P	P	P	P	P	P	A	P	P	P	P	P	A	Rospa
2	***Benthosema pterotum***	P	P	P	P	P	P	A	P	P	P	P	P	A	Rospa
3	***Benthosema suborbitale***	P	A	A	P	P	P	P	P	P	A	A	A	A	Rospa
4	***Bolinichthys indicus***	P	P	P	P	P	P	P	P	P	A	P	P	P	Rospa
5	***Bolinichthys longipes***	P	P	P	P	P	P	P	P	P	P	P	P	P	
6	***Bolinichthys photothorax***	A	A	A	P	P	P	P	P	P	A	A	A	A	Rospa.
7	***Bolinichthys pyrosobolus***	A	A	A	A	P	A	A	P	A	A	P	P	A	Rospa.
8	***Bolinichthys supralateralis***	A	A	A	P	P	P	P	A	A	A	A	P	A	Rospa.
9	***Bolinicthys nikolkai***	A	A	A	A	A	A	A	A	A	A	A	P	P	New record from WIO
10	***Centrobranchus andreae***	A	A	A	A	P	P	A	P	P	A	A	A	A	Rospa.
11	***Centrobranchus nigroocellatus***	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.
12	***Ceratoscopelus warmingii***	A	A	P	P	P	P	P	P	A	P	P	P	P	
13	***Diaphus aliciae***	A	P	P	A	P	P	P	P	P	A	P	P	P	Rospa.
14	***Diaphus anderseni***	A	A	A	A	A	A	A	P	A	A	A	A	A	Rospa.
15	***Diaphus antonbruuni***	A	A	A	A	P	P	A	P	P	A	A	P	P	Rospa.
16	***Diaphus arabicus***	A	P	P	P	A	A	A	P	P	P	P	P	A	Rospa.
17	***Diaphus basileusi***	A	A	A	A	A	A	A	P	A	A	A	A	A	Rospa.
18	***Diaphus brachycephalus***	A	A	A	A	P	P	A	P	P	A	P	P	P	Rospa.
19	***Diaphus coeruleus***	A	A	P	P	P	A	A	P	P	A	P	P	A	Rospa.
20	***Diaphus danae***	A	A	A	A	P	P	P	A	A	A	A	A	A	Rospa.

21	***Diaphus diadematus***	A	A	A	A	P	P	P	P	P	A	P	P	P	Rospa.
22	***Diaphus diademophilus***	A	A	A	P	P	P	A	P	P	A	P	P	P	Rospa.
23	***Diaphus drachmanni***	A	A	A	A	P	A	A	P	P	A	A	A	A	Rospa.
24	***Diaphus dumerilii***	A	A	P	A	A	A	A	A	A	A	A	A	A	Rospa.
25	***Diaphus effulgens***	A	A	P	P	P	P	P	P	P	A	P	P	P	
26	***Diaphus fragilis***	A	P	P	A	P	A	A	P	P	P	P	P	P	
27	***Diaphus fulgens***	A	P	P	A	P	P	A	P	P	A	P	P	P	
28	***Diaphus garmani***	P	A	P	P	P	P	A	P	P	P	P	P	A	
29	***Diaphus holti***	A	A	A	A	A	P	A	P	P	A	A	A	A	Rospa.
30	***Diaphus hudsoni***	A	P	P	P	A	P	P	P	A	A	A	A	A	Rospa.
31	***Diaphus Impostor***	A	A	A		A	A	P	A	A	A	A	A	A	Rospa.
32	***Diaphus jenseni***	A	A	A	A	P	P	P	P	P	P	P	P	A	Rospa.
33	***Diaphus knappi***	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.
34	***Diaphus lobatus***	A	A	P	P	P	A	A	P	P	A	P	P	A	Rospa.
35	***Diaphus lucidus***	A	A	P	P	P	P	P	P	P	P	P	P	P	
36	***Diaphus luetkeni***	A	A	P	A	P	P	P	P	P	A	A	P	P	
37	***Diaphus malayanus***	A	A	P	P	P	P	A	P	P	A	A	A	A	Rospa.
38	***Diaphus mascarensis***	A	A	A	A	A	A	A	P	A	A	A	A	A	Rospa.
39	***Diaphus meadi***	A	A	A	P	A	A	P	A	P	A	A	A	A	Rospa.
40	***Diaphus megalops***	A	A	A	P	A	A	P	P	P	A	A	A	A	Rospa.
41	***Diaphus metopoclampus***	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.
42	***Diaphus mollis***	A	A	A	A	P	A	P	P	P	A	P	A	P	Rospa.
43	***Diaphus nielseni***	A	A	A	P	P	P	P	P	P	A	A	A	A	Rospa.
44	***Diaphus ostenfeldi***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
45	***Diaphus pallidus***	A	A	A	A	A	A	A	P	A	A	A	A	A	Rospa.
46	***Diaphus parri***	A	A	A	P	P	P	P	P	P	A	P	P	P	
47	***Diaphus perspicillatus***	A	A	P	P	P	P	P	P	P	A	P	P	P	

48	*Diaphus phillipsi*	A	A	P	A	P	P	A	P	P	A	A	A	A	Rospa.
49	*Diaphus problematicus*	A	A	A	A	P	P	A	P	P	A	P	P	P	
50	*Diaphus rafinesquii*	A	A	A	A	A	P	A	A	A	A	A	A	A	Rospa.
51	*Diaphus regani*	A	A	A	A	P	A	A	P	P	A	A	P	P	Rospa.
52	*Diaphus richardsoni*	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.
53	*Diaphus signatus*	A	A	P	A	P	P	A	P	P	P	P	P	P	
54	*Diaphus similis*	A	A	A	A	A	A	A	A	A	A	P	A	A	New record from WIO
55	*Diaphus splendidus*	A	A	A	A	P	A	P	P	P	A	P	P	A	Rospa.
56	*Diaphus suborbitalis*	A	A	A	P	P	A	A	A	P	A	A	A	A	Rospa.
57	*Diaphus subtilis*	A	A	A	A	A	P	A	A	A	A	A	A	A	Rospa.
58	*Diaphus taaningi*	A	A	A	P	P	P	A	A	A	A	P	P	P	
59	*Diaphus thermophilus*	A	A	A	A	P	A	A	A	A	A	A	A	A	Rospa.
60	*Diaphus theta*	A	A	A	A	A	A	A	A	A	A	A	P	P	New record from WIO
61	*Diaphus thiollieri*	P	P	P	P	P	P	A	P	P	P	P	P	P	
62	*Diaphus watasei*	A	A	P	P	A	A	P	P	P	A	P	A	A	Rospa.
63	*Diogenichthys atlanticus*	A	A	A	A	A	P	P	P	A	A	A	A	A	Rospa.
64	*Diogenichthys panurgus*	A	P	P	P	P	P	P	P	P	A	A	A	A	Rospa.
65	*Electrona antarctica*	A	A	A	A	P	P	P	P	A	A	A	A	A	Rospa.
66	*Electrona carlsbergi*	A	A	A	A	A	P	P	A	A	A	A	A	A	Rospa.
67	*Electrona paucirastra*	A	A	A	A	A	P	P	A	P	A	A	A	A	Rospa.
68	*Electrona risso*	A	A	A	A	P	P	P	P	P	A	A	P	P	Rospa.
69	*Electrona subaspera*	A	A	A	A	A	P	P	A	A	A	A	A	A	Rospa.
70	*Gonichthys barnesi*	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
71	*Gymnoscopelus bolini*	A	A	A	A	A	P	P	A	A	A	A	A	A	Rospa.

72	***Gymnoscopelus braueri***	A	A	A	A	A	P	P	A	A	A	A	A	A	Rospa.
73	***Gymnoscopelus fraseri***	A	A	A	P	A	P	P	A	P	A	A	A	A	Rospa.
74	***Gymnoscopelus microlampas***	A	A	A	P	A	P	P	A	P	A	A	A	A	Rospa.
75	***Gymnoscopelus nicholsi***	A	A	A	A	A	P	P	A	A	A	A	A	A	Rospa.
76	***Gymnoscopelus piabilis***	A	A	A	P	A	P	A	A	A	A	A	A	A	Rospa.
77	***Gymnoscopelus opisthopterus***	A	A	A	A	A	A	P	A	A	A	A	A	A	Rospa.
78	***Hintonia candens***	A	A	A	A	A	P	P	P	A	A	A	A	A	Rospa.
79	***Hygophum hanseni***	A	A	A	A	A	P	P	P	P	A	P	P	P	
80	***Hygophum hygomii***	A	A	A	P	A	P	P	P	P	A	A	A	A	Rospa.
81	***Hygophum proximum***	P	P	P	P	P	P	A	P	P	P	P	P	A	Rospa.
82	***Hygophum reinhardtii***	A	A	P	A	A	P	A	P	A	A	A	A	A	Rospa.
83	***Idiolychnus urolampus***	A	A	A	A	A	A	A	P	A	A	A	A	A	Rospa.
84	***Krefftichthys anderssoni***	A	A	A	A	A	P	P	A	A	A	A	A	A	Rospa.
85	***Lampadena anomala***	A	A	A	A	P	A	A	P	P	A	P	P	A	Rospa.
86	***Lampadena chavesi***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
87	***Lampadena dea***	A	A	A	A	A	P	P	A	P	A	A	A	A	Rospa.
88	***Lampadena luminosa***	A	A	A	P	P	P	A	P	P	A	P	P	A	Rospa.
89	***Lampadena notialis***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
90	***Lampadena speculigera***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
91	***Lampanyctodes hectoris***	A	A	A	A	A	P	A	A	P	A	A	A	A	Rospa.
92	***Lampanyctus alatus***	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.
93	***Lampanyctus australis***	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.
94	***Lampanyctus cuprarius***	A	A	A	A	P	A	A	A	A	A	A	A	A	Rospa.
95	***Lampanyctus festivus***	A	A	A	A	A	P	P	P	A	A	A	A	P	Rospa.
96	***Lampanyctus intricarius***	A	A	A	A	P	P	P	P	P	A	P	P	A	Rospa.
97	***Lampanyctus lepidolychnus***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
98	***Lampanyctus lineatus***	A	A	A	A	P	P	A	P	p	A	A	A	A	Rospa.

99	***Lampanyctus macdonaldi***	A	A	A	A	A	A	A	A	A	A	A	P	A	New record from WIO
100	***Lampanyctus macropterus***	A	A	A	P	P	A	A	P	P	A	A	A	A	Rospa.
101	***Lampanyctus nobilis***	A	A	A	P	P	P	A	P	P	A	P	P	P	
102	***Lampanyctus photonotus***	A	A	A	A	P	A	A	A	P	A	A	P	A	Rospa.
103	***Lampanyctus pusillus***	A	A	P	A	P	P	P	P	p	A	A	A	A	Rospa.
104	***Lampanyctus sp. A***	A	A	A	P	P	P	P	A	A	A	A	A	A	Rospa.
105	***Lampanyctus sp. B***	A	A	A	A	A	P	P	A	A	A	A	A	A	Rospa.
106	***Lampanyctus steinbecki***	A	A	A	A	P	P	A	P	P	A	A	A	A	Rospa.
107	***Lampanyctus tenuiformis***	A	A	A	P	P	A	A	P	P	A	A	P	P	
108	***Lampanyctus turneri***	A	P	P	P	P	P	P	P	A	P	P	P	P	
109	***Lampanyctus crocodilus***	A	A	A	A	A	A	A	A	A	A	A	P	P	New record from WIO
110	***Lampedna ponpifex***	A	A	A	A	A	A	P	A	A	A	A	A	A	Rospa.
111	***Lampedna urophaos***	A	A	A	A	A	A	A	A	A	A	P	P	P	New record from WIO
112	***Lampichthys procerus***	A	A	A	A	A	P	P	P	A	A	A	A	A	Rospa.
113	***Lobianchia dofleini***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
114	***Lobianchia gemellarii***	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.
115	***Loweina interrupta***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
116	***Loweina rara***	A	A	A	A	A	P	A	P	A	A	A	A	A	Rospa.
117	***Metelectrona herwigi***	A	A	A	A	A	P	P	P	A	A	A	A	A	Rospa.
118	***Metelectrona ventralis***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
119	***Myctophum affinae***	A	A	A	A	A	A	A	P	A	A	A	A	A	Rospa.
120	***Myctophum asperum***	A	A	P	P	P	P	A	P	P	A	P	P	P	

121	***Myctophum aurolaternatum***	A	P	P	P	P	P	A	P	P	A	P	P	P	
122	***Myctophum brachygnathum***	A	A	A	P	P	P	A	A	A	A	A	A	A	Rospa.
123	***Myctophum fissunovi***	A	A	P	A	P	P	A	P	A	A	A	A	A	Rospa.
124	***Myctophum lunatum***	A	A	A	P	P	A	A	P	A	A	A	A	A	
125	***Myctophum lychnobium***	A	A	A	A	P	A	A	P	A	A	A	A	A	
126	***Myctophum nitidulum***	A	A	P	P	P	P	P	P	P	A	P	P	P	Rospa.
127	***Myctophum obtusirostre***	A	A	P	P	P	P	A	P	P	A	P	P	P	Rospa.
128	***Myctophum ovacharovi***	A	A	A	A	A	A	A	P	A	A	A	A	A	
129	***Myctophum punctatum***	A	A	A	A	A	A	A	P	A	A	A	A	A	
130	***Myctophum phengodes***	A	A	A	A	P	P	P	A	P	A	A	A	A	Rospa.
131	***Myctophum selenops***	A	A	P	A	P	P	A	P	A	A	A	A	A	Rospa.
132	***Myctophum spinosum***	A	A	P	P	P	P	P	P	P	P	P	P	P	
133	***Nannobrachium niger***	A	A	A	A	P	A	A	A	A	A	A	A	A	Rospa.
134	***Nannobranchium achirus***	A	A	A	A	P	P	P	P	P	A	A	P	P	
135	***Nannobranchium atrum***	A	A	A	A	P	P	P	P	P	A	A	P	A	Rospa.
136	***Nannobranchium indicum***	A	A	P	A	P	P	A	P	A	A	A	A	A	Rospa
137	***Nannobranchium lineatum***	A	A	P	A	P	P	A	P	A	A	A	A	A	Rospa
138	***Nannobrachium wisneri***	A	A	A	A	A	P	P	P	A	A	A	A	A	Rospa.
139	***Notolychnus valdiviae***	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.
140	***Notoscopelus caudispinosus***	A	A	A	P	P	P	A	P	P	A	A	A	A	Rospa.
141	***Notoscopelus resplendens***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.

142	***Protomyctophu subparallelum***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
143	***Protomyctophum luciferum***	A	A	A	A	A	A	P	A	A	A	A	A	A	Rospa.
144	***Protomyctophum andriashevi***	A	A	A	A	A	P	P	P	A	A	A	A	A	Rospa.
145	***Protomyctophum bolini***	A	A	A	A	A	P	P	P	A	A	A	A	A	Rospa.
146	***Protomyctophum choridon***	A	A	A	A	A	A	P	P	A	A	A	A	A	Rospa.
147	***Protomyctophum normani***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
148	***Protomyctophum parallelum***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
149	***Protomyctophum tenisoni***	A	A	A	A	A	P	P	P	A	A	A	A	A	Rospa.
150	***Scopelopsis multipunctatus***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
151	***Symbolophorus barnardi***	A	A	A	A	A	P	P	P	P	A	A	A	A	Rospa.
152	***Symbolophorus evermanni***	P	A	P	P	P	P	P	P	P	P	P	P	P	
153	***Symbolophorus rufinus***	A	A	P	P	P	P	A	P	P	P	P	P	P	
154	***Symbolophorus boops***	A	A	A	A	A	P	P		A	A	A	A	A	Rospa.
155	***Taaningichthys bathyphilus***	A	A	A	A	A	A	P	P	P	A	A	A	A	Rospa.
156	***Taaningichthys minimus***	A	A	A	A	A	P	P	P	P	A	P	P	A	Rospa.
157	***Taaningichthys paurolychnus***	A	A	A	A	A	A	A	P	P	A	A	A	A	Rospa.
158	***Triphoturus nigrescens***	A	A	A	A	P	P	P	P	P	A	A	A	A	Rospa.

Present	Rospa- Records outside present sampling area
Absent	
New record	

Table 3.1.1 : References of Revalidated check list of Myctophids from WIO

Sl no of Myctophid species of Table 3.1	**References for revalidated check list of Myctophid species in Table 3.1**
1	Karuppasamy *et al.,*2006, 2010; Kinzer *et al.,*1993; Nair *et al.,*1999; Menon 2002; Hulley 1986 a,b,c; Globec 1993; Sebastine et al.2013;Gjosaeter 1977; Tsarin 1983; Bradbury *et al.,*1971;Dalpadado and Gjosaeter 1993; Alwis and Gjosaeter 1988 ; Valinassab 2005; Boopendranath *et al.,*2009
2	Fao 1997; Karuppasamy *et al.*2006, 2010; Kinzer *et al.*1993; Nair et al.1999;Menon 2002;Hulley 1986 a,b,c; Globec 1993 Alwis and Gjosaeter 1988; Gjosaeter 1977; Tsarin 1983; Dalpadado and Gjosaeter 1993; Valinassab 2005
3	Karuppasamy *et al.,*2006, 2010; Bradbury *et al.,*1971; Alwis and Gjosaeter 1988; Koubbi *et al.,*2011; McGinnis 1982; Hulley 1986 a,b,c;Menon 2002
4	Koubbi *et al.,*2011; Hulley and Duhamel 2009; Hulley 1986 a,b,c
5	Karuppasamy *et al.,* 2006, 2010; Kinzer *et al.,*1993; Menon 2002; Hulley and Duhamel 2009; Tsarin 1983; Dalpadado and Gjosaeter 1993; Bolin 1946; Hulley 1986 a,b,c
6	Karuppasamy *et al.,* 2006; Jayaprakash 1996, Menon 2002
7	Hulley and Duhamel 2009; Bradbury et al.1971
8	Hulley and Duhamel 2009; Hulley 1986 a,b,c
9	New record
10	Tsarin 1983
11	Bradbury *et al.,*1971; McGinnis 1982;Hulley 1986 a,b,c
12	Karuppasamy *et al.,* 2010; Menon 2002; Jayaprakash 1996; Tsarin 1983; Balachandran and Nizar 1990; Bradbury *et al.,*1971; Dalpadado and Gjosaeter 1993; McGinnis 1982; Hulley 1986 a,b,c
13	Menon 2002; Nafpaktitis 1978; Hulley 1986 a,b,c
14	Nafpaktitis 1978
15	Nafpaktitis 1978; Hulley 1986 a,b,c
16	Kinzer *et al.,*1993; Nair *et al.,*1999; Globec 1993; Nafpaktitis 1978; Tsarin 1983
17	New record
18	Tsarin 1983; Nafpaktitis 1978, 1984; Hulley 1986 a,b,c
19	Gjosaeter 1977; Nafpaktitis 1984
20	Koubbi *et al.,* 2011; McGinnis 1982
21	Nafpaktitis 1978; Taning 1928; Hulley 1986 a,b,c
22	Gjosaeter 1977; Hulley 1985; Nafpaktitis 1978
23	Nafpaktitis 1984
24	Alcock 1899; Hulley 1986 a,b,c; Menon 2002; Boopendranath *et al.,*2009
25	Menon 2002; Jayaprakash 1996; Balachandran and Nizar 1990; Nafpaktitis 1978; Koubbi *et al.,*2011; McGinnis 1982; Boopendranath *et al.,*2009
26	Karuppasamy *et al.,*2006, 2010; Menon 2002; Tsarin 1983; Bradbury *et al.*1971;Nafpaktitis 1978; Hulley 1986 a,b,c
27	Karuppasamy *et al.,* 2010; Menon 2002; Hulley 1986 a,b,c; Nafpaktitis 1978

28	Pillai *et al.,*2009, Bineesh *et al.*2010; Sebastine *et al.,*2013; Hulley and Lutjeharma 1995; Hulley 1986 a,b,c
29	Nafpaktitis 1978, 1995; Hulley 1984a,b; 1986 a, b,c
30	Nafpaktitis 1978; Hulley 1986 a,b,c; Boopendranath *et al.,*2009
31	Hulley and Lutjeharma 1995; Nafpaktitis 1978
32	Alwis and Gjosaeter 1988; Nafpaktitis 1978, 1995; Hulley 1984a,b,1986a, b,c
33	Nafpaktitis 1978; Hulley 1986 a,b,c
34	Nafpaktitis 1978; Gjosaeter 1977; Dalpadado and Gjosaeter 1993
35	Karuppasamy *et al.,*2006. 2010; Menon 2002; Nafpaktitis 1978; Hulley 1986 a,b,c; Tsarin 1983; Bradbury *et al.*1971; Boopendranath *et al.,*2009
36	Gjosaeter 1977; Tsarin 1983; Bradbury et al.1971; Nafpaktitis 1978; Hulley 1986 a,b,c; Boopendranath *et al.,*2009
37	Tsarin 1983; Hulley 1986 a,b,c
38	Froese and Pauly 2017
39	Koubbi et al.2011; Hulley 1986 a,b,c
40	Nafpaktitis 1978; Hulley 1986 a,b,c
41	Nafpaktitis 1978; Hulley 1986 a,b,c
42	Nafpaktitis 1978
43	Tsarin 1983; Bradbury *et al.,*1971; Alwis and Gjosaeter 1988; Nafpaktitis 1978
44	Koubbi *et al.,*2011; Nafpaktitis 1978; Hulley 1986 a,b,c
45	Froese and Pauly 2017
46	Nafpaktitis 1978; Gjosaeter 1977; McGinnis 1982; Hulley 1986 a,b,c
47	Karuppasamy *et al.,*2006; Menon 2002; Nafpaktitis 1978; Jayaprakash 1996; Tsarin 1983; Balachandran and Nizar 1990; Alwis and Gjosaeter 1988
48	Karuppasamy *et al.,*2006; Menon 2002; Nafpaktitis 1978; Hulley 1986 a,b,c
49	Menon 2002; Tsarin 1983; Bradbury *et al.,*1971; Nafpaktitis 1978; Hulley 1986 a,b,c
50	Bolin 1946
51	Nafpaktitis 1978; Gjosaeter 1977; Bradbury *et al.,*1971; Dalpadado and Gjosaeter 1993; Hulley 1986 a,b,c
52	Tsarin 1983; Bradbury et al.1971; Nafpaktitis 1978; Hulley 1986 a,b,c
53	Karuppasamy *et al.,*2006, 2010; Menon 2002; Nafpaktitis 1978; Hulley 1986 a,b,c
54	New record
55	Nafpaktitis 1978; Jayaprakash 1996; Tsarin 1983; Balachandran and Nizar 1990;Bradbury *et al.,*1971; Hulley 1986 a,b,c
56	Nafpaktitis 1978; Tsarin 1983
57	Hulley 1986 a,b,c
58	Hulley 1986 a,b,c
59	Bradbury *et al.,*1971; McGinnis 1982
60	New record
61	Kinzer *et al.,*1993; Nafpaktitis 1978; Gjosaeter 1977; Dalpadado and Gjosaeter 1993; Alwis and Gjosaeter 1988; Hulley 1986 a,b,c; Pillai et al.2009

62	Karuppasamy *et al.*2006, 2008; Menon 2002; Pillai *et al.,*2009; Sebastine *et al.,*2013; Nafpaktitis 1978; Hulley 1986 a,b,c; Alwis and Gjosaeter 1988; Boopendranath et al.2009
63	Hulley 1986 a,b,c
64	Karuppasamy *et al.,*2006,2008; Menon 2002; Bradbury *et al.,*1971; Tsarin 1983; Dalpadado and Gjosaeter 1993; Dalpadado and Gjosaeter 1993; Bolin 1946; McGinnis 1982
65	McGinnis 1982; Hulley 1986 a,b,c
66	McGinnis 1982; Hulley 1986 a,b,c
67	Koubbi *et al.,*2011;McGinnis 1982; Hulley 1986 a,b,c
68	Gjosaeter 1977; Koubbi *et al.*2011; Hulley 1986 a,b,c
69	Koubbi *et al.,*2011; Hulley 1986 a,b,c
70	Hulley 1986 a,b,c
71	Koubbi *et al.*2011; McGinnis 1982
72	McGinnis 1982; Hulley 1986 a,b,c
73	McGinnis 1982; Hulley 1986 a,b,c
74	Koubbi *et al.,* 2011; Hulley 1986 a,b,c
75	McGinnis 1982; Hulley 1986 a,b,c
76	Koubbi *et al.,* 2011, Hulley and Lutjeharma 1995; McGinnis 1982; Hulley 1986 a,b,c
77	Koubbi *et al.,*2011
78	McGinnis 1982; Hulley 1986 a,b,c
79	Koubbi *et al.*2011; McGinnis 1982; Hulley 1986 a,b,c
80	Bradbury *et al* 1971; McGinnis 1982; Hulley 1986 a,b,c
81	Karuppasamy *et al* 2006, 2010; Kinzer *et al* 1993; Menon 2002; Gjosaeter 1977; Tsarin 1983; Dalpadado and Gjosaeter 1993; Hulley 1986 a,b,c
82	Karuppasamy *et al* 2006, 2010; Menon 2002; Hulley 1986 a,b,c
83	Nafpaktitis 1984
84	Koubbi *et al* 2011;Hulley 1986 a,b,c
85	Hulley 1986 a,b,c
86	McGinnis 1982; Hulley 1986 a,b,c
87	McGinnis 1982; Hulley 1986 a,b,c
88	Tsarin 1983; Hulley 1986 a,b,c
89	Hulley 1986 a,b,c
90	Hulley 1986 a,b,c
91	Hulley 1986 a,b,c
92	Tsarin 1983; Bradbury *et al* 1971; Koubbi *et al* 2011; McGinnis 1982
93	Bradbury *et al* 1971; Koubbi *et al* 2011; McGinnis 1982; Hulley 1986 a,b,c
94	Menon 2002
95	Koubbi *et al* 2011; McGinnis 1982
96	Tsarin 1983; Koubbi et al 2011; McGinnis 1982; Hulley 1986 a,b,c

97	Koubbi *et al* 2011; McGinnis 1982; Hulley 1986 a,b,c
98	Tsarin 1983; Hulley 1986 a,b,c
99	Hulley 1986 a,b,c
100	Bradbury *et al* 1971; Tsarin 1983; Dalpadado and Gjosaeter 1993; Hulley 1986 a,b,c; Kinzer et al 1993
101	Gjosaeter 1977; Tsarin 1983; Bradbury et al 1971
102	Menon 2002
103	Jayaprakash 1996; Balachandran and Nizar 1990; Koubbi *et al* 2011; McGinnis 1982; Hulley 1986 a,b,c
104	Hulley 1986 a,b,c
105	Hulley 1986 a,b,c
106	Hulley 1986 a,b,c; Bolin 1946
107	Hulley 1986 a,b,c
108	Karuppasamy *et al* 2006, 2010; Menon 2002; Hulley 1986 a,b,c
109	New record
110	Froese and Pauly 2017
111	New record
112	Koubbi *et al* 2011; McGinnis 1982
113	Koubbi *et al* 2011; McGinnis 1982; Nafpaktitis 1978; Hulley 1986 a,b,c
114	McGinnis 1982; Jayaprakash 1996; Bradbury et al 1971; Nafpaktitis 1978; Hulley 1986 a,b,c
115	McGinnis 1982; Hulley 1986 a,b,c
116	Hulley 1986 a,b,c
117	Hulley 1986 a,b,c
118	Hulley and Lutjeharma 1995; McGinnis 1982; Hulley 1986 a,b,c,Koubbi *et al* 2011
119	Froese and Pauly 2017
120	Karuppasamy *et al* 2006; Jayaprakash *et al* 2006; Menon 2002; Bradbury *et al* 1971; Kawaguchi *et al* 1972; Tsarin 1983; Hulley 1986 a,b,c
121	Karuppasamy *et al* 2006; Menon 2002; Kawaguchi *et al* 1972; Tsarin 1983; Hulley 1986 a,b,c
122	Gjosaeter 1977; Alwis and Gjosaeter 1988
123	Karuppasamy *et al* 2006; Menon 2002; Pillai et al 2009; Hulley 1986 a,b,c
124	Tsarin 1983
125	Tsarin 1983; Bradbury *et al* 1971, Bolin 1946; Hulley 1986 a,b,c
126	Menon 2002; Kawaguchi *et al* 1972; Tsarin 1983; Bradbury et al 1971; Dalpadado and Gjosaeter 1993; McGinnis 1982
127	Menon 2002; Kawaguchi *et al* 1972; Tsarin 1983; Dalpadado and Gjosaeter 1993; Alwis and Gjosaeter 1988; Hulley 1986 a,b,c; Boopendranath *et al* 2009
128	Froese and Pauly 2017
129	Froese and Pauly 2017
130	Jayaprakash 1996; McGinnis 1982; Hulley 1986 a,b,c

131	Karuppasamy *et al* 2006;Menon 2002; Tsarin 1983; Hulley 1986 a,b,ca,b,c
132	Karuppasamy *et al* 2006; Menon 2002; Pillai *et al* 2009; Sebastine *et al* 2013; Jayaprakash 1996; Kawaguchi et al 1972; Tsarin 1983; Balachandran and Nizar 1990; Bradbury *et al* 1971; Dalpadado and Gjosaeter 1993;Hulley 1986 a,b,c; Boopendranath et al 2009
133	Bradbury *et al* 1971
134	Zahuranec 2000; McGinnis 1982
135	Zahuranec 2000
136	Zahuranec 2000
137	Zahuranec 2000
138	Zahuranec 2000
139	Bradbury *et al.*, 1971; Tsarin 1983; McGinnis 1982
140	Tsarin 1983; Hulley 1986 a,b,c
141	Hulley 1986 a,b,c
142	McGinnis 1982; Koubbi *et al.,* 2011; Hulley 1986 a,b,c
143	Hulley 1986 a,b,c
144	Hulley 1986 a,b,c
145	Hulley 1986 a,b,c
146	Hulley 1986 a,b,c
147	Koubbi *et al* 2011; McGinnis 1982; Hulley 1986 a,b,c
148	McGinnis 1982; Hulley 1986 a,b,c
149	McGinnis 1982; Hulley 1986 a,b,c
150	McGinnis 1982; Hulley 1986 a,b,c
151	Hulley 1986 a,b,c
152	Menon 2002; Gjosaeter 1977, Jayaprakash 1996; Tsarin 1983; Balachandran and Nizar 1990;Bradbury *et al* 1971; Dalpadado and Gjosaeter 1993; Alwis and Gjosaeter 1988; Hulley 1986 a,b,c
153	Menon 2002; Jayaprakash 1996; Tsarin 1983; Hulley 1986 a,b,c
154	Hulley and Lutjeharma 1995; Hulley 1986 a,b,c
155	McGinnis 1982;Hulley 1986 a,b,c
156	Hulley 1986 a,b,c
157	Froese and Pauly 2017; Nafpaktitis 1984
158	Jayaprakash 1996; Hulley 1985; Tsarin 1983; Balachandran and Nizar 1990; Hulley 1986 a,b,c.

Chapter 4

DISTRIBUTION AND ABUNDANCE OF MYCTOPHIDS FROM WESTERN INDIAN OCEAN

4.1 Introduction

The mesopelagic zone (200–1,000 m) or the "twilight zone" (dimly lit zone) makes up approximately 20% of the global ocean volume, plays important roles in biogeochemical cycling (Davison *et al.*, 2013), and holds potentially huge fish resources (John *et al.,* 2000; Webb *et al.,* 2010; Irigoien *et al.,* 2014). Mesopelagic fish are abundant along the continental shelf of Atlantic, Pacific, and Indian Oceans and in deep fjords, but have lower abundance offshore and in Arctic and sub-Arctic waters (Salvanes and Kristofferson 2001). The Global estimate of mesopelagic fish (999 million ton) by Lam and Pauly (2005) have been recently revised to 1000 million tonnes by Irigoien *et al.,* (2014). Family myctophidae commonly known as "lantern fishes" makes up about 65% of all mesopelagic fish and has a global biomass estimated at 660 million tons (Hulley 1994). Shilat and Valinassab (1998) estimated that about 75% of the total global catch of small mesopelagic fishes were myctophids.

Myctophids are small to medium sized fish (3 - 35 cm), most being under 15 cm in length with a compressed body, large eyes, large jaws and terminal mouth. They are generally fast growing fishes with relatively short life span, reaching sexual maturity early in their life span and have a high rate of mortality (Childress *et al.*, 1980; Gjosaeter and

Kawaguchi 1980). They are pelagic spawners, releasing eggs and seminal fluid into the water. External fertilization takes place in the pelagic waters and the tiny fertilized eggs are made buoyant by lipid droplets. The fertilized eggs and the hatched larvae are planktonic and drift with the currents until they develop locomotory organs (Sassa *et al.*, 2004a).

Family Myctophidae comprises of 250 species in 35 genera (Paxton, 1979). According to Nelson (2006), family Myctophidae is represented by 32 genera with 235 species. Recent taxonomic studies place the number of myctophid species in world oceans to 247 species, in 33 genera (Bailly 2015; Froese and Pauly 2017). Myctophids normally inhabit deeper waters beyond continental shelf edge, between 200 and 1000 m depths and undertake extensive diel migrations i.e.; ascending to shallow (<100 m) or surface waters (<5 m) at night and returning to deep waters (typically 250 to >1000 m) during the day (Shotton 1997). Myctophids resides during day time at depths where oxygen is extremely low (<0.1 ml O_2 l^{-1}) and forage in the oxygen rich surface layer at night (Kinzer *et al.*, 1993; GLOBEC 1993; Shilat and Valinassab 1998; Nair *et al.,* 1999; Klevjer *et al.,* 2012). Myctophid species of central equatorial Atlantic such as *Ceratoscopelus warmingii* and *Lampanyctus photonotus* have been reported to undertake diel migration down to 1250 m depth and during day time (Kinzer and Schulz 1985).

The diel vertical migration exhibited by myctophids has been postulated to be for foraging on the zooplankton present in the upper layers which form their major food item and to avoid predators. The vertical migration of large myctophid biomass play an important role in ocean energy dynamics through active transport of carbon out of the euphotic zone, excretion of dissolved organic carbon, and egestion of particulate organic carbon (Hudson *et al.,* 2012). Most vertically migrating fishes have gas bladders that store gases that help make the fish neutrally buoyant at any depth. The amount of energy spent on swimming can be greatly reduced if a fish is neutrally buoyant. Myctophids have a euphysoclistous swim bladder which is often gas-filled (Marshall 1960). Some species of myctophids have swim bladder reduced or filled with lipid. In many species as the fish grow and increase in size, swim bladders shrink and progressively gets filled with fat eg: *Stenobrachius sp*. and Diaphus (Marshal 1960). The swim bladders of large size myctophids become fat-invested with age (Butler and Pearcy 1972).

Some researchers believe that diel vertical migrations might have developed as a means of escaping predation by surface predators and/or vertical migration may have evolved simply because there is not sufficient food at mesopelagic depths to support the organisms that live there. They must return to the photic zone to take advantage of higher levels of primary production. In addition, by feeding in surface warmer waters and then returning to the deep colder waters to digest food, energy is conserved because metabolic rates are slower at low temperatures (Catul *et al.,* 2011; Dypvik *et al.,* 2012 a,b).Migrating patterns of myctophids vary with species, size groups, life history stages, sex, latitude, time and season. Myctophids form part of the Oceans Deep Scattering Layer (DSL) that are vertically narrow (hundreds of m) but horizontally extensive (continuous for thousands of km) layers containing fish and zooplankton and are readily detectable by echo sounders (Fay and Mckinley 2014). Myctophids play significant roles in the marine food web, acting as both prey and predator. As predator myctophid primarily feed on crustaceaous zooplankton like copepods, ostracods and euphasids etc and in turn lantern fishes form the prey of numerous fishes, seabirds and marine mammals (Schneider *et al.,*1984; Pearcy *et al.,*1988; Ohizumi *et al.,*1998; Beamish *et al.,*1999).

Myctophids are distributed throughout the world Oceans from polar to tropical waters and in waters over shelves and slopes to the open seas. They occupy Oceanic or pseudo-Oceanic, pelagic or epibenthic realms. In the northwest Atlantic Ocean myctophids are a major component of the mesopelagic icthyofauna (Backus *et al.,* 1970) with Myctophidae as the most diverse family and *Gymnoscopelus nicholsi* the most abundant species. Konstantinova *et al.*, (1994) examined the distribution of 40 species of myctophids by types of waters in the southwest Atlantic within the area of 40°30'- 47°00'S and 43°00'-67°00'W. In subarctic and mixed waters of the northern part of the Pacific Ocean, myctophids comprise 80 to 90% of the total catch of micro nekton (Gjosaeter and Kawaguchi 1980). Among the Myctophids collected by mid water trawl from the upper depth of 500 m of the water column off eastern Australia, 46 species were from warm core eddies (Brandt 1981). According to Pearcy (1964), three species of mesopelagic fish dominate the Pacific Ocean namely, *Lampanyctus leucopsarus, Diaphus theta,* and *Tarletonbeania crenularis.* Myctophidae were the dominant fish both in numbers and biomass (Kock 1992) among mesopelagic fishes of Southern Ocean. Total myctophid stock in the Southern Ocean is estimated to be approximately 275 million tonnes (Naumov 1985). A total of 62 species of myctophids recorded from historical surveys and from the Census of Antarctic Marine Life was used to model species assemblages in the Indian sector of the Southern Ocean by using generalized dissimilarity modelling (Koubbi *et al.,* 2011). Three species of the genus *Electrona* are abundant in the Southern Ocean, *Electrona antarctica, E. carlsbergi* and *E. risso*. Of these, *E. antarctica* is numerically dominant in mid water trawl samples taken throughout the Southern Ocean (Linkowski 1987).

Most lantern fishes are broadly tropical in distribution and are influenced by changes in environmental factors such as being entrained by fronts or transported by currents (Backus and Craddock 1982; Bekker 1985; Brandt 1981; Craddock *et al.,*1992; Figueroa *et al.,*1998; Gorbunova *et al.,* 1985; Hulley 1992; John *et al.,* 2000; Konstantinova *et al.,* 1994; Koubbi *et al.,* 2003; Rogahev *et al.,* 1996; Rojas *et al.,* 2002; Sameato 1988; Zelck and and Klein 1995). Arabian Sea (AS) is located in the tropical region, bounded in the north by land mass and its surface circulation patterns are forced by seasonally reversing monsoon ,north-easterly winds (winter or northeast monsoon) during November to February and strong south westerly winds (summer or southwest monsoon) during June to September. As a result Arabian Sea is biologically one of the most productive regions of the world's Ocean and its geographical location makes this basin a unique oceanographic entity. With the wind reversal, surface currents of the Arabian Sea undergo seasonal reversal and a strong seasonality is seen in the mixed-layer depth and phytoplankton biomass. The Somali Current and the associated upwelling along the coastal regions of Somalia, Arabia and the southern part of the west coast of India, the intense winds of the Findlater Jet and the associated wind curl, drive upward Ekman pumping extending the Arabian Sea upwelling along the coast of Arabia to several hundred km offshore (Bruce 1974; Smith and Bottero 1977; Swallow 1984; Bauer *et al.,* 1991). Open-ocean upwelling and lateral advection in summer (Bauer *et al.,*1991) and convective mixing due to surface cooling in winter (Banse and McClain 1986; Madhupratap *et al.,*1996a), maintain high primary productivity south of 15°N during summer, and north of 15°N during winter (Krey and Babenerd 1976; Brock *et al.,*1991; Banse 1994). Another interesting feature of Arabian Sea is the presence of permanent Oxygen Minimum Zone (OMZ) between 150-1000m depth (Wyrtki 1971; Qasim1982; Swallow 1984). An OMZ ecoregion is defined by DO levels below 0.5 ml l^{-1} concentration, a value that limits the distribution of many mesopelagic taxa (Vinogradov 1997; Childress and Seibel 1998; Sutton *et al.,* 2017).

The open waters sustain high primary productivity almost throughout the year. High surface productivity leads to considerable flux of organic particles to deep water (Nair *et al.,* 1989; Hakke *et al.,*1993) and high rates of oxygen consumption. High oxygen utilisation rates combined with the low oxygen content of waters entering the Arabian Sea from the east (Swallow 1984) generates a thick (150-1000 m) layer of OMZ (Naqvi 1991, 1994). The core of this OMZ occurs at about 200-500m depth. In the Arabian Sea, the OMZ is more pronounced in the central northern areas and acute oxygen deficiency is experienced in coastal waters only during summer upwelling (Naqvi, pers. comm). Thus, spatial variations in the above-mentioned processes result in a north south gradient in the OMZ, with larger oxygen deficiencies occurring in the north. These features make the Arabian Sea an interesting and almost unique area to analyse patterns of horizontal and vertical distributions of flora and fauna (Morrison and Olson 1992). The Arabian Sea OMZ is also famous for the largest stock of mesopelagic lantern fish (myctophids) associated with the upper boundary of OMZ or inhabiting this zone (Piontkovski and Al-Oufi 2014).

The first reference to the OMZ and its relation to zooplankton in the Arabian Sea was by Sewell and Fage (1948), followed by Vinogradov and Voronina (1961). The northern Arabian Sea is a paradox with regard to mesozooplankton in the upper layers: its biomass remains almost invariant despite seasonal variations in the primary productivity regime (Madhupratap *et al.,*1992, 1996a,b; Van Couwelaar 1997; Baars and Oosterhuis 1998; Baars 1999). The high zooplankton biomass in the Arabian Sea also apparently sustains a large biomass of mesopelagic fishes such as myctophids (Gjosaeter 1984). Patterns of horizontal distribution of myctophid species depend up on the oxygen conditions of the area (Kinzer *et al.,* 1993). In equatorial waters, the zonal thermocline and nutricline shoal toward the west rather than the east as in the Pacific and Atlantic oceans, a consequence of the Indian Ocean lacking easterly trade winds. The equatorial Indian Ocean is also strongly influenced by oscillations and perturbations that do not occur in other ocean basins, such as the Wyrtki Jets, the Madden-Julian Oscillation, and the Indian Ocean Dipole (International CLIVAR Project Office, 2006). The oxygen concentration of equatorial Indian Ocean is found to be greater than 0.5ml/l in all areas/seasons (Stramma *et al.,* 2008). Because of high oxygen content the diversity of myctophids are high in the equatorial Indian Ocean (Kinzer *et al.,* 1993).

Distribution and abundance of myctophids in the Indian Ocean region have been studied by several authors and they report that the myctophids form a major component in the mesopelagic fishes (Gjosaeter 1984; GLOBEC 1993; Valinassab *et al.,* 2007; Catul *et al.,* 2011; Vipin *et al*., 2012). Myctophids form an important component of the acoustically dense DSL (Shotton 1997; Menon 2004; Balu and Menon 2006). *Benthosema pterotum* is the dominant species in the Western and Northern Arabian Sea, followed by *Benthosema fibulatum* and *Diaphus* spp. (Gjosaeter 1977). In the Gulf of Oman, the acoustic measurements indicated a density of 25-63 *Benthosema pterotum* per m^2 surface area (Gjosaeter 1977). Gjosaeter (1977) reported a catch rate of 20 t h^{-1} of myctophids from the seas off Oman (20°-24°N lat and 57°-67°E long) at a depth of 130 m during day time using a pelagic trawl. Myctophid catches exceeding 400 $kg.h^{-1}$ were obtained from several stations located in north-western Arabian Sea (0°- 26°N, 43°-67° E long). Dalpadado and Gjosaeter (1993) reported the presence of 16 species of myctophids in the area 07°06'-08°27'N lat, 79°29'- 81°59'E long, off Sri Lanka, during the cruises with R.V. "Dr. Fridtjof Nansen". Kinzer *et al*., (1993) reported the presence of 11 species of myctophids from 18°-24°30'N lat, 62°- 67°E in the Arabian Sea. *Diaphus arabicus* was the dominant species between18° and 24°N in the Arabian Sea, contributing 66-73% of the myctophid samples, in terms of numbers (Kinzer *et al*., 1993). Observations on the mesopelagic fishes taken by mid water trawl in the equatorial region (03°S-03°N lat, 76°-86°E long) of Indian Ocean shows that the average catch of myctophids was higher in the southern side of the equator as compared to the northern side of the equator (Jayaprakash 1996).

Echosounder records show that many myctophid species aggregate in compact layers, especially during daytime when they are relatively quiescent. These aggregates are the primary component of the dense DSL. Their densities, which correspond to concentrations of five-ten individuals per cubic meter and trawl catches of up to 10 to 20 t/hr have led to commercial fishery feasibility trials (FAO 1997a). From observations of DSL, Tont (1976) classified DSL layer in to (i) migratory layer: a layer that migrates at least above 80 m; (ii) semi migratory layer: the layer that migrates upward toward the surface, but the upper limit of migration is clearly below the surface; (iii) static layer: a layer that shows no appreciable migratory characteristics. Similar findings were recorded from western and northern Arabian Sea by Gjosaeter (1977) in the surveys by R/V Dr. Fridtjof Nansen.

Studies conducted on the DSL of Indian EEZ during 1985-1986 have shown that myctophid migrates vertically from depths of 200–540 m during day to the surface during night. Raman and James (1990) reported that 31% of the DSL catch from the Indian waters are contributed by myctophids; with southeast coast contributing 64% and north east coast 35%. The common genera occurring in the DSL were *Diaphus*, *Lampanyctus*, *Diogenichthys*, *Hygophum*, *Symbolophorus*, *Bolinichthys*, *Benthosema* and *Myctophum*. Along the south-west coast of India, lantern fish (order myctophiformes) forms a major portion of by catch in the deep sea shrimp trawler (Boopendranath *et al.,* 2009; Sebastine *et al.,* 2013; Pillai *et al.,* 2009). Out of the five species obtained, *Diaphus watasei* contributed a major share to the myctophid fishery of Kerala. *Diaphus watasei* was the most dominant species at all the centres. 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 (1.7%) to the total myctophid catch. The other species contributing to the myctophid fishery are *Benthosema fibulatum* (1.9%) and the *Myctophum obtusirostre* (1.6%).

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

The present chapter details the distribution and abundance of myctophids in the Western Indian Ocean (WIO) north of 15^0S with focus on Eastern Arabian Sea. Results are based on surveys at DSL depths 0-600m along 74 stations using cosmos trawl, 45 m 4 equal panel myctophid trawl and 28m myctophid trawl. The chapter explains, the delineation of WIO to specific eco-regions based on presence/absence data on myctophids, species similarity/ dissimilarity between these eco-regions and the qualitative and quantitative aspects on the distribution and abundance of myctophids. An attempt is also made to correlate myctophid assemblages through Canonical Correspondence Analysis. Methodologies in sampling and data analysis are outlined in chapter 2.

4.2 Results

The present chapter describes the distribution and abundance of myctophids in the study area and explains the environmental factors that possibly support formation of distinct assemblages.

4.2.1 Regional Variations in species assemblages of Myctophids:

The study area (Figure 2.1) cover 15 stations in the Tropical North East Arabian Sea -NEAS [16^0N to 23.5^0N; East of 65^0 E], 37 stations in the Tropical South East Arabian Sea - SEAS [6^0N to 16^0N; East of 65^0 E], 10 stations in the West Equatorial Indian Ocean -WEIO [6^0N to 6^0S; west of 70^0E] & 4 stations in the Tropical South-West Indian Ocean -TSWIO [6^0S to 23.5^0S; west of 70^0E]. To assess the possibility of any spatial variability in myctophid distribution between the said regions, presence – absence of species in catch data were subjected to multivariate statistical analyses using ANOSIM (Analysis of Similarities test in Primer 6+). The ANOSIM test show significance (>0.1%) only between pairs WEIO & TSWIO (16.4%) which implies that both the regions have similar assemblages. Therefore, the WEIO & TSWIO are treated as a single assemblage and represented as the WEIO assemblage in the subsequent paragraphs of this chapter. ANOSIM for all the other pairs are not significant which indicate the occurrence of distinct assemblages in the NEAS, SEAS & WEIO (Table 4.1). However, the similarity between the WEIO & TSWIO is based on only limited data (10 WEIO & 4 TSWIO stations) and is therefore only indicative.

Table 4.1 : Result of ANOSIM

Group	Statistic	R significance level 1%	Possible permutations	Actual permutations	Number >=Observed
NEAS, SEAS	0.309	0.1	Very large	999	0
NEAS, WEIO	0.816	0.1	1307504	999	0
NEAS, TSWIO	0.987	0.1	3876	999	0
SEAS, WEIO	0.451	0.1	Very large	999	0
SEAS, TSWIO	0.723	0.1	101270	999	0
WEIO, TSWIO	0.158	16.4	715	715	117

The ANOSIM, clearly indicates the existence of three regions within the study area viz North Eastern Arabian Sea, NEAS (23.5-16°N and East of 65°E), South Eastern Arabian Sea, SEAS (16-6°N and East of 65°E), Western Equatorial Indian Ocean -WEIO (6°N- 16°S, West of 78°E) each of which have distinct myctophid species assemblages (Table 4.2). For further validation the presence-absence data of species between the regions were subjected to PERMANOVA test (Primer 6+), using Kulzsinsky resemblance. Multivariate analyses revealed that species composition was distinct in the three regions (PERMANOVA pseudo F=8.17, p=0.001), namely NEAS, SEAS and WEIO (Table 4.3).

Table 4.2 : Result of ANOSIM

Group	Statistic	R significance level 1%	Possible permutations	Actual permutations	Number >=Observed
NEAS, SEAS	0.309	0.1	Very large	999	0
NEAS, WEIO	0.738	0.1	37442160	999	0
SEAS, WEIO	0.505	0.1	Very large	999	0

Table 4.3 : Result of PERMANOVA

Groups	t	P(perm)
NEAS, SEAS	2.9964	0.001
NEAS, WEIO	3.246	0.001
SEAS, WEIO	2.5999	0.001

The differences and affinities among the regions were more clearly established using nonparametric multi- dimensional scaling (nMDS) technique based on Kulcsynski resemblance of species incidence data from the 65stations (Figure 4.1). These latitudinal trends in distribution of species were evident within the 50 - 600 m depth zones of all the three regions in the study area. The nMDS arranges sites in multidimensional space on the basis of ranked similarities (Bakus 2007) and aids in directly visualizing the level of similarity of individual sites. The goodness-of-fit statistic, called 'stress', is based on the differences between actual distances and their predicted values. In the nMDS plot, the study area (Western Indian Ocean) could be demarcated into three distinct regions, at 63% similarity, based on diversity and species composition between the regions. Only few stations formed an outlier (Figure. 4.1).

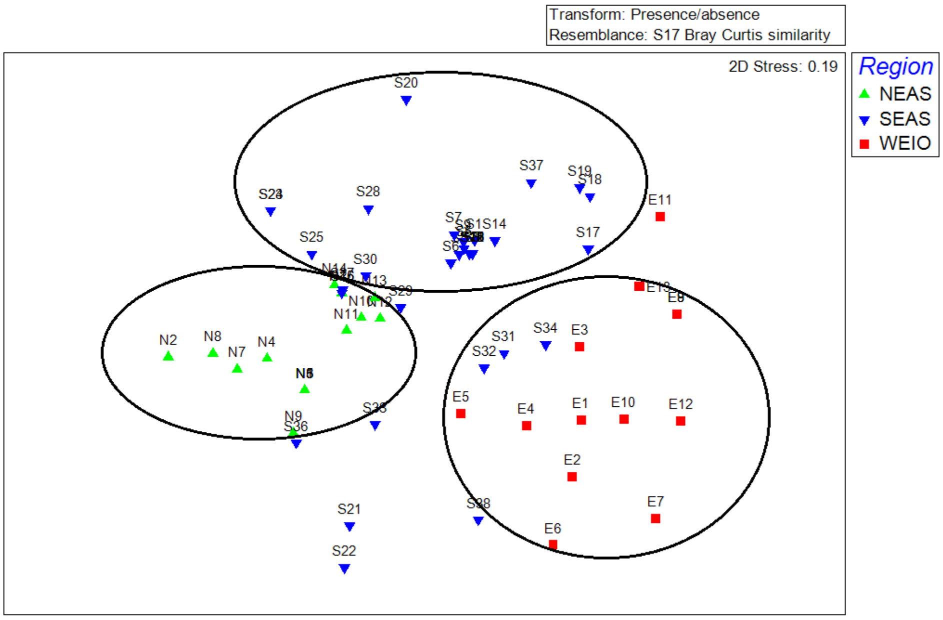


Figure 4.1 : nMDS plot showing the grouping of regions based on species occurrence

In order to identify the myctophid species causing the observed similarity or dissimilarity among the regions or clusters seen in the nMDS, Similarity Percentage (SIMPER) analysis was done using PRIMER 6 software. The simper analysis elucidates the species contributing to the differences between eco-regions. The results of the SIMPER quantify the contribution of each species to the observed similarity (or dissimilarity) between regions based on the differences between actual distances and their predicted values.

4.2.2 Similarity/ dissimilarity of myctophid assemblages in the three eco-regions:

SIMPER analysis was carried out to elucidate the species contributing differences between the regions.

4.2.2.1 NEAS: A total of 16 species were recorded from NEAS, whereas the species estimators Jacknife predict the occurrence of up to 20 species and Chaos 22.25 species with a Standard Deviation of 7.5. Percentage analysis based on diversity; show a similarity of 62.16% in species composition of NEAS (chapter 3, Figure 3.2). SIMPER analysis reveals that 7 species (Table 4.4) together contribute to 92% of this similarity among the stations of NEAS. The similarity causing species are *Diaphus arabicus* (24.27%), *Benthosema fibulatum* 18.11%, *Bolinichthys longipes* 17.14%, *Benthosema pterotum* 11.37%, *Ceratoscopelus warmingii* 7.82 %, *Diaphus thiollierei* 7.82% and *Diaphus garmani* 5.84%.

4.2.2.2 SEAS: A total of 45 species were recorded from SEAS, whereas the species estimators Jacknife 1 predict the occurrence of up to 59 species and Chao2, 57 ±8.5 species (chapter 3, Figure 3.3). SIMPER analysis reveal that 12 species (Table 4.5) contribute to 90% similarity among the stations of this region. The average species similarity of SEAS is *45.51%* with *Diaphus garmani contributing 12.55%, Benthosema fibulatum 11.64%, Myctophum spinosum 11%, Ceratoscopelus warmingii 9.02%, Lampanyctus turneri 8.99%, Diaphus thiollierei 8.6%, Diaphus lucidus 7.13%, Benthosema pterotum 5.76%, Diaphus signatus 5.71%. Bolinicthys indicus 4.12%, Diaphus perspicillatus 3.03 % and Diaphus similis 2.47%*.

4.2.2.3 WEIO: A total of 57 species were recorded from WEIO, and species estimators predict the occurrence of up to 64 species (Jacknife-1: 64 species & Chao-2: 60 ±4 species (Figure 4.2) in this region. SIMPER analysis revealed that 25 species (Table 4.6) contributed to 90% similarity among the stations of this region. The average similarity percentage is 33.16% with *Diaphus fragilis 11.25%, Diaphus lucidus 7.12%,* *Lampany ctus turneri 6.93% Diaphus fulgens 5.03%, Diaphus problematicus 3.72% , Diaphus perspicillatus 3.70%, Diaphus lutenki 3.65%, Myctophum asperum 3.19%, Electrona risso 2.98%, Diaphus lobatus 2.66%, Symbolophorus rufinus 2.57%, Diaphus Jenseni 2.37%, Bolinichthys indicus 2.36%, Symbolophorus evermanni 2.36%, Diaphus aliciae 2.25%, Diaphus brachy cephalus 2.11%, Lampadena urophaos 2.10%, Diaphus tangii 2.07%, Diaphus signatus 2.04% , Myctophum spinosum 2.02% ,Diaphus effulgens 1.97%, Bolinichthys nikolkai 1.85% , Diaphus antonbruuni 1.69%, Myctophum obtusirostre 1.57%, Bolinichthys longiceps1.46%, Benthosema fibulatum1.41%, Diaphus regani 1.34%, Diaphus thiollierei 1.32%, Benthosema pterotum 1.27%, Diaphus parri 1.25%, Lampanyctus tenui formis 1.24%.*

The dissimilarity in myctophid species between NEAS and SEAS is 64.58 %, NEAS and WEIO is 84.52% and SEAS and WEIO is 75.75%. Details are given in the table 4.7 to 4.9. Average dissimilarity in myctophid species of NEAS & SEAS is 64.58 and the percentage contribution of each species to the cumulative dissimilarity (91.27) among the 19 species are given in Table 4.7 above. Average dissimilarity between NEAS & WEIO is 84.52, 90% of which is explained by 43 species (Table 4.8). Between SEAS & WEIO the average dissimilarity is 75.57, 90.6 % of which is explained by 45 species as given in Table 4.9.

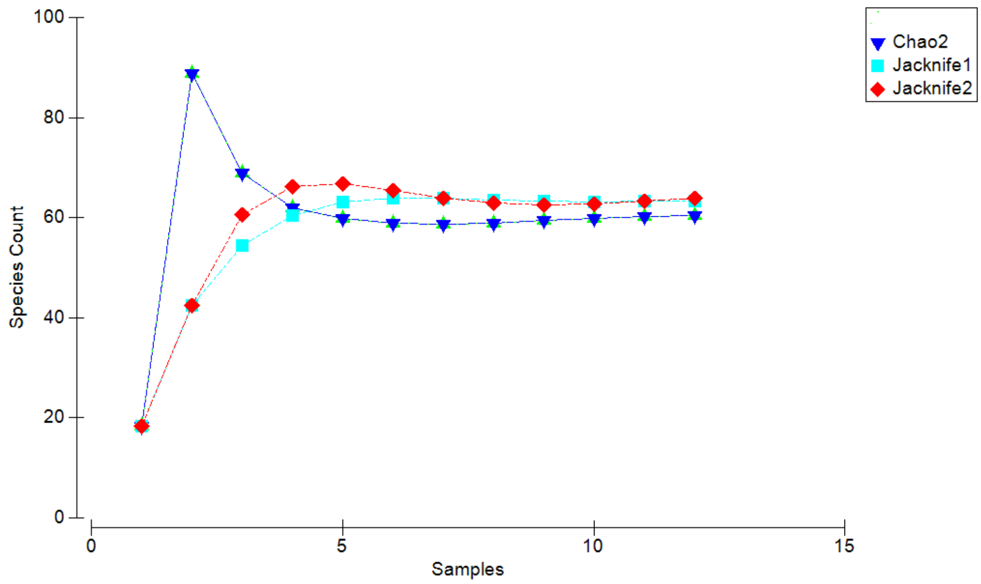


Figure 4.2 : Species accumulation curve of WEIO (species of WEIO+TSWIO)

Table 4.4 : The species causing similarity in NEAS

Group NEAS Average similarity: 60.61				
Species	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Diaphus arabicus	14.71	3.57	24.27	24.27
Benthosema fibulatum	10.98	1.6	18.11	42.38
Bolinichthys longipes	10.39	1.7	17.14	59.52
Benthosema pterotum	6.89	0.78	11.37	70.89
Ceratoscopelus warmingii	4.74	0.83	7.82	78.71
Diaphus thiollierei	4.74	0.83	7.82	86.52
Diaphus garmani	3.54	0.6	5.84	92.37

Table 4.5 : The species causing similarity in SEAS

Group SEAS Average similarity: 45.51

Species	Av.Sim	Sim/SD	Contrib%	Cum.%
Diaphus garmani	5.71	0.98	12.55	12.55
Benthosema fibulatum	5.3	0.91	11.64	24.2
Myctophum spinosum	5	0.94	11	35.19
Ceratoscopelus warmingii	4.1	0.87	9.02	44.21
Lampanyctus turneri	4.09	0.85	8.99	53.2
Diaphus thiollierei	3.91	0.88	8.6	61.8
Diaphus lucidus	3.24	0.76	7.13	68.92
Benthosema pterotum	2.62	0.66	5.76	74.69
Diaphus signatus	2.6	0.66	5.71	80.4
Bolinichthys indicus	1.88	0.51	4.12	84.52
Diaphus perspicillatus	1.38	0.48	3.03	87.55
Diaphus similis	1.12	0.42	2.47	90.01

Table 4.6 : The species causing similarity in WEIO

Group EIO Average similarity: 33.16

Species	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Diaphus fragilis	3.73	1.34	11.25	11.25
Diaphus lucidus	2.36	0.82	7.12	18.37
Lampanyctus turneri	2.30	0.82	6.93	25.30
Diaphus fulgens	1.67	0.65	5.03	30.33
Diaphus problematicus	1.23	0.52	3.72	34.05
Diaphus perspicillatus	1.23	0.52	3.70	37.75
Diaphus luetkeni	1.21	0.52	3.65	41.40
Myctophum asperum	1.06	0.53	3.19	44.59
Electrona risso	0.99	0.53	2.98	47.57
Diaphus lobatus	0.88	0.41	2.66	50.23
Symbolophorus rufinus	0.85	0.41	2.57	52.80
Diaphus Jenseni	0.79	0.41	2.37	55.17
Bolinichthys indicus	0.78	0.41	2.36	57.53
Symbolophorus evermanni	0.78	0.42	2.36	59.88
Diaphus aliciae	0.75	0.41	2.25	62.14

Diaphus brachycephalus	0.70	0.42	2.11	64.25
Lampadena urophaos	0.70	0.42	2.10	66.35
Diaphus taaningi	0.69	0.41	2.07	68.42
Diaphus antonbruuni	0.68	0.42	2.04	70.45
Diaphus signatus	0.67	0.42	2.02	72.48
Myctophum spinosum	0.65	0.41	1.97	74.45
Diaphus effulgens	0.61	0.31	1.85	76.30
Bolinichthys nikolayi	0.56	0.31	1.69	77.99
Myctophum obtusirostre	0.52	0.31	1.57	79.56
Bolinichthys longipes	0.48	0.31	1.46	81.02
Benthosema fibulatum	0.47	0.31	1.41	82.43
Diaphus regani	0.44	0.31	1.34	83.76
Diaphus thiollierei	0.44	0.31	1.32	85.08
Benthosema pterotum	0.42	0.31	1.27	86.35
Bolinichthys pyrsobolus	0.42	0.31	1.27	87.62
Diaphus parri	0.41	0.31	1.25	88.87
Lampanyctus tenuiformis	0.41	0.31	1.24	90.11

Table 4.7: Species contributing to dissimilarity between NEAS and SEAS

Groups NEAS & SEAS- Average dissimilarity = 64.58

Species	Av.Diss	Diss/SD	Contrib%	Cum.%
Bolinichthys longipes	4.88	1.24	7.55	15.17
Myctophum spinosum	4.4	1.24	6.81	21.98
Lampanyctus turneri	3.8	1.09	5.89	27.87
Benthosema pterotum	3.55	0.82	5.49	33.37
Ceratoscopelus warmingii	3.54	0.99	5.48	38.85
Diaphus lucidus	3.52	1.12	5.46	44.31
Diaphus thiollierei	3.48	1.01	5.38	49.69
Diaphus signatus	3.2	1	4.96	54.65
Diaphus fragilis	3.05	0.77	4.73	59.38
Diaphus garmani	3.03	0.74	4.69	64.07
Bolinichthys indicus	2.73	0.88	4.23	68.3
Benthosema fibulatum	2.35	0.6	3.64	71.95
Symbolophorus evermanni	2.34	0.74	3.63	75.58
Diaphus perspicillatus	2.24	0.87	3.47	79.05
Diaphus similis	2.04	0.79	3.16	82.21
Diaphus lobatus	1.91	0.75	2.96	85.17

Diaphus coeruleus	1.76	0.71	2.72	87.89
Symbolophorus rufinus	1.18	0.46	1.83	89.72
Hygophum proximum	1	0.46	1.54	91.27

Table 4.8 : Species contributing to dissimilarity between NEAS and WEIO.

Groups NEAS & WEIO Average dissimilarity = 84.52

Species	Av.Diss	Diss/SD	Contrib%	Cum.%
Diaphus arabicus	3.26	1.52	3.86	3.86
Benthosema fibulatum	2.89	1.2	3.42	7.27
Bolinichthys longipes	2.84	1.2	3.36	10.63
Diaphus lucidus	2.76	1.23	3.27	13.9
Diaphus garmani	2.74	1.23	3.24	17.14
Benthosema pterotum	2.61	1.08	3.09	20.22
Diaphus fragilis	2.6	1.13	3.08	23.3
Lampanyctus turneri	2.55	1.13	3.02	26.32
Diaphus fulgens	2.4	1.06	2.84	29.16
Diaphus problematicus	2.12	0.91	2.51	31.67
Diaphus perspicillatus	2.12	0.9	2.5	34.17
Diaphus luetkeni	2.07	0.93	2.45	36.62
Symbolophorus evermanni	1.93	0.91	2.29	38.9
Diaphus thiollierei	1.91	0.88	2.26	41.16
Myctophum asperum	1.88	0.92	2.22	43.38
Ceratoscopelus warmingii	1.87	0.84	2.21	45.59
Diaphus lobatus	1.85	0.79	2.19	47.78
Symbolophorus rufinus	1.83	0.82	2.16	49.94
Diaphus Jenseni	1.75	0.81	2.07	52.01
Electrona risso	1.73	0.97	2.05	54.06
Bolinichthys indicus	1.7	0.79	2.01	56.07
Diaphus aliciae	1.65	0.77	1.96	58.02
Diaphus effulgens	1.64	0.67	1.93	59.96
Diaphus signatus	1.62	0.86	1.91	61.87
Diaphus tangii	1.54	0.78	1.83	63.7
Bolinichthys nikolayi	1.53	0.67	1.81	65.51
Myctophum spinosum	1.53	0.83	1.81	67.32
Diaphus brachycephalus	1.52	0.82	1.8	69.12
Lampadena urophaos	1.51	0.82	1.79	70.91
Diaphus antonbruuni	1.47	0.83	1.74	72.64
Myctophum obtusirostre	1.46	0.67	1.73	74.37

Diaphus regani	1.33	0.65	1.57	75.94
Bolinichthys pyrsobolus	1.24	0.67	1.46	77.41
Diaphus parri	1.21	0.68	1.43	78.84
Lampanyctus tenuiformis	1.2	0.68	1.43	80.27
Taaningichthys minimus	1.17	0.56	1.38	81.65
Diaphus splendidus	1.13	0.69	1.34	82.99
Hygophum hanseni	1.1	0.55	1.3	84.29
Diaphus theta	1.08	0.53	1.28	85.56
Diaphus diadematus	0.97	0.56	1.15	86.71
Lampadena crocodiles	0.96	0.56	1.14	87.85
Myctophum nitidulum	0.93	0.57	1.1	88.96
Diaphus mollis	0.92	0.44	1.09	90.04

Table 4.9 : Species contributing to dissimilarity between SEAS and WEIO.

Groups SEAS & WEIO Average dissimilarity = 75.57

Species	Av.Diss	Diss/SD	Contrib%	Cum.%
Diaphus garmani	2.65	1.4	3.51	3.51
Diaphus fragilis	2.34	1.19	3.09	6.6
Benthosema fibulatum	2.17	1.06	2.88	9.48
Ceratoscopelus warmingii	2.13	1.09	2.82	12.31
Myctophum spinosum	2.09	1.01	2.77	15.07
Diaphus fulgens	2.09	1.05	2.77	17.84
Diaphus thiollierei	2.06	1.05	2.72	20.56
Benthosema pterotum	1.89	0.99	2.5	23.06
Diaphus perspicillatus	1.88	0.91	2.48	25.54
Diaphus signatus	1.86	0.98	2.47	28.01
Diaphus problematicus	1.85	0.9	2.45	30.45
Bolinichthys indicus	1.83	0.92	2.42	32.87
Diaphus luetkeni	1.81	0.92	2.39	35.26
Diaphus lucidus	1.8	0.85	2.38	37.65
Diaphus lobatus	1.79	0.88	2.37	40.01
Lampanyctus turneri	1.73	0.82	2.29	42.31
Myctophum asperum	1.67	0.92	2.21	44.51
Symbolophorus rufinus	1.65	0.83	2.18	46.7
Symbolophorus evermanni	1.6	0.85	2.11	48.81
Electrona risso	1.55	0.96	2.05	50.86
Bolinichthys longipes	1.55	0.8	2.05	52.9

Diaphus Jenseni	1.54	0.8	2.04	54.95
Diaphus aliciae	1.49	0.78	1.97	56.92
Diaphus effulgens	1.44	0.68	1.91	58.83
Diaphus tangii	1.4	0.78	1.85	60.68
Diaphus brachycephalus	1.38	0.82	1.83	62.51
Diaphus coeruleus	1.36	0.76	1.8	64.31
Lampadena urophaos	1.36	0.82	1.8	66.11
Myctophum obtusirostre	1.34	0.69	1.77	67.88
Bolinichthys nikolayi	1.33	0.67	1.76	69.64
Diaphus antonbruuni	1.31	0.82	1.73	71.37
Diaphus similis	1.29	0.78	1.7	73.07
Diaphus parri	1.17	0.72	1.55	74.62
Diaphus regani	1.17	0.64	1.54	76.16
Bolinichthys pyrsobolus	1.13	0.68	1.49	77.65
Lampanyctus tenuiformis	1.07	0.68	1.42	79.07
Diaphus splendidus	1.07	0.71	1.41	80.48
Diaphus mollis	1.07	0.55	1.41	81.89
Taaningichthys minimus	1.06	0.57	1.4	83.29
Hygophum hanseni	0.99	0.56	1.31	84.6
Diaphus arabicus	0.97	0.58	1.28	85.88
Diaphus diadematus	0.95	0.59	1.26	87.14
Diaphus theta	0.94	0.53	1.24	88.38
Myctophum nitidulum	0.86	0.58	1.14	89.52
Lampadena crocodiles	0.85	0.55	1.13	90.64

4.2.3 Distribution and abundance of Myctophids in Western Indian Ocean:

In NEAS important genus that contribute to total biomass are represented by 2 species of *Benthosema* (31%), one species each of *Bolinichthys* (21%), *Ceratoscopelus* (7%) and 7 species of *Diaphus* (40%). Out of 16 species recorded from NEAS, species contributing significantly to the total biomass are *Benthosema fibulatum* (36677 kg/km^2, 30%) *Bolinichthys longiceps* (23917 kg/ km^2, 20%), *Diaphus arabicus* (22768 kg/ km^2, 22%), *Ceratoscopelus warmingii* (5565 kg/ km^2, 8%) *Diaphus thiollierei* (9308 kg/ km², 9%), *Diaphus signatus* (7198 kg/km² 5%), *Diaphus garmani* (5565 kg/ km², 5%) (Figure 4.3).

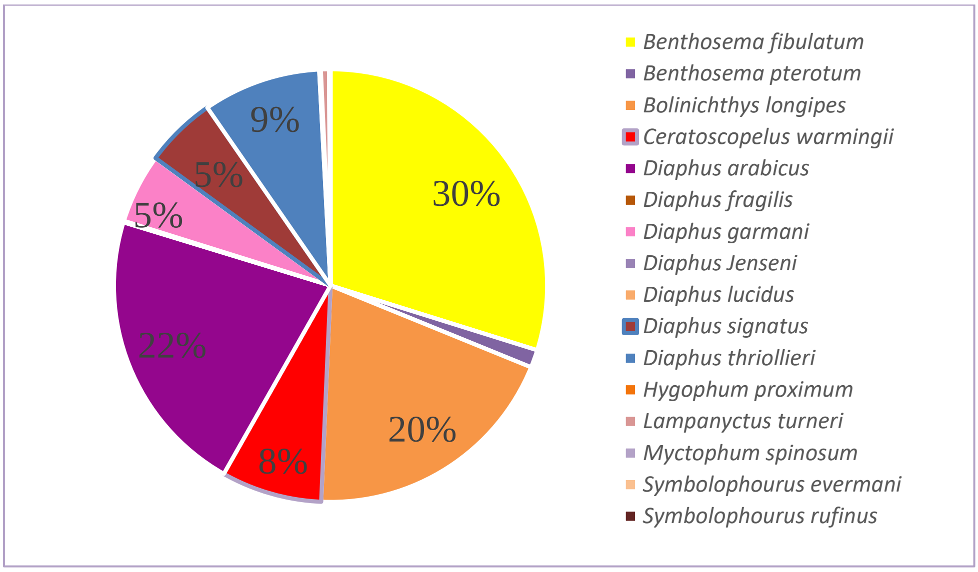


Figure 4.3 : Contribution of dominant myctophid species to the total biomass of NEAS

Important genus which contribute to total biomass of SEAS are *Benthosema* 31% (2 species), *Diaphus* 40% (23 species), *Bolinichthys* 21% (3 species) and *Ceratoscopelus* 7% (1 species). Main myctophid species that contribute significantly to the myctophid biomass of SEAS are *Benthosema fibulatum* (29939 kg/km2, 19%), *Benthosema pterotum* (19840 kg/km², 9%), *Diaphus thiollierei* (25970 kg/km², 17%), *Diaphus garmani* (19840 kg/km², 9%), *Diaphus arabicus* (172781 kg/km², 7%) *Diaphus lucidus* (15188 kg/km², 4%). *Myctophum spinosum* (23964 kg/km², 13%) *Bolinichthys longipes* (18006 kg/km², 8%), and *Ceratoscopelus warmingii* (13640kg/km², 3.3%) Figure 4.4).

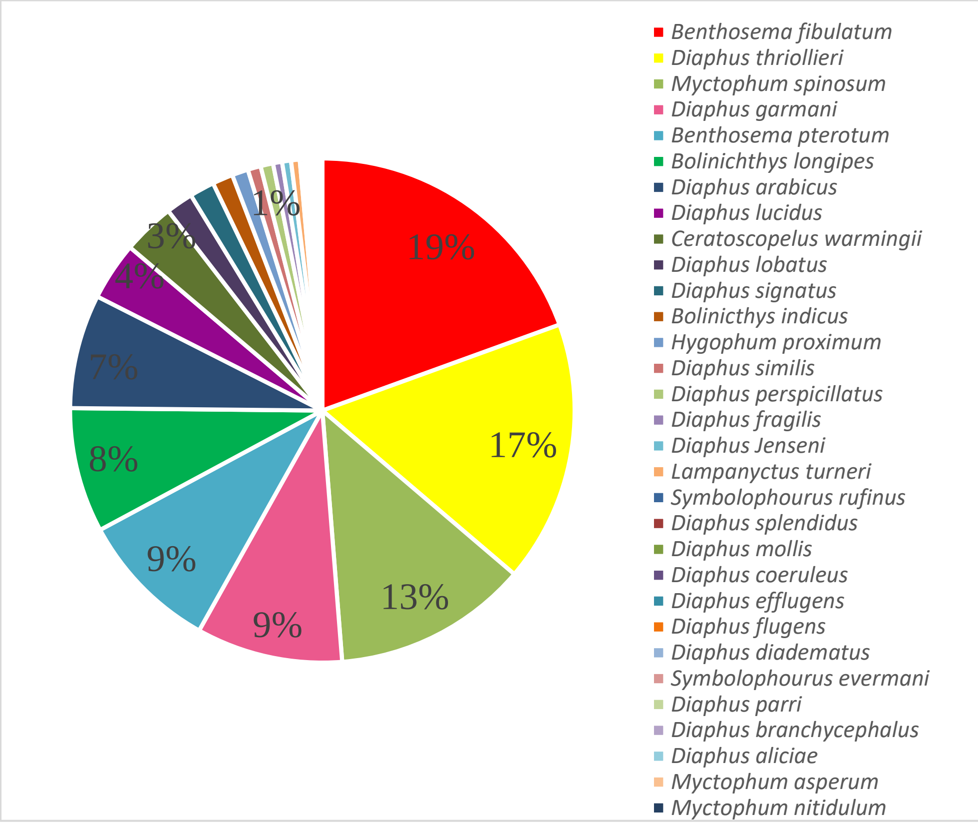


Figure 4.4 : Contribution of major myctophid species to the total biomass of SEAS

Prominent among the genus that contribute to the total biomass of WEIO are *Diaphus* 54% (24 species), *Lampanyctus* 15% (6 species), *Bolinichthys* 8% (5 species) and *Lampadena* 5% (4 species). Main myctophid species which contribute significantly to the biomass of WEIO are *Lampanyctus turneri* (6801.6 kg/ km^2, 12%) *Diaphus effulgens* (5587 kg/km^2, 10%) *Diaphus coeruleus* (5024 kg/ km^{2,} 9%), *Bolinichthys longipes* (3474 kg/km^2, 6%), *Diaphus fragilis* (3317.2 kg/km^2, 6%) *Hygophum hanseni* (2657 kg/km^2, 5%), *Diaphus jenseni* (2444.4 kg/km^2, 4%) and *Diaphus perspillatus* (2447 Kg/km^2, 4%) Fig (4.5).

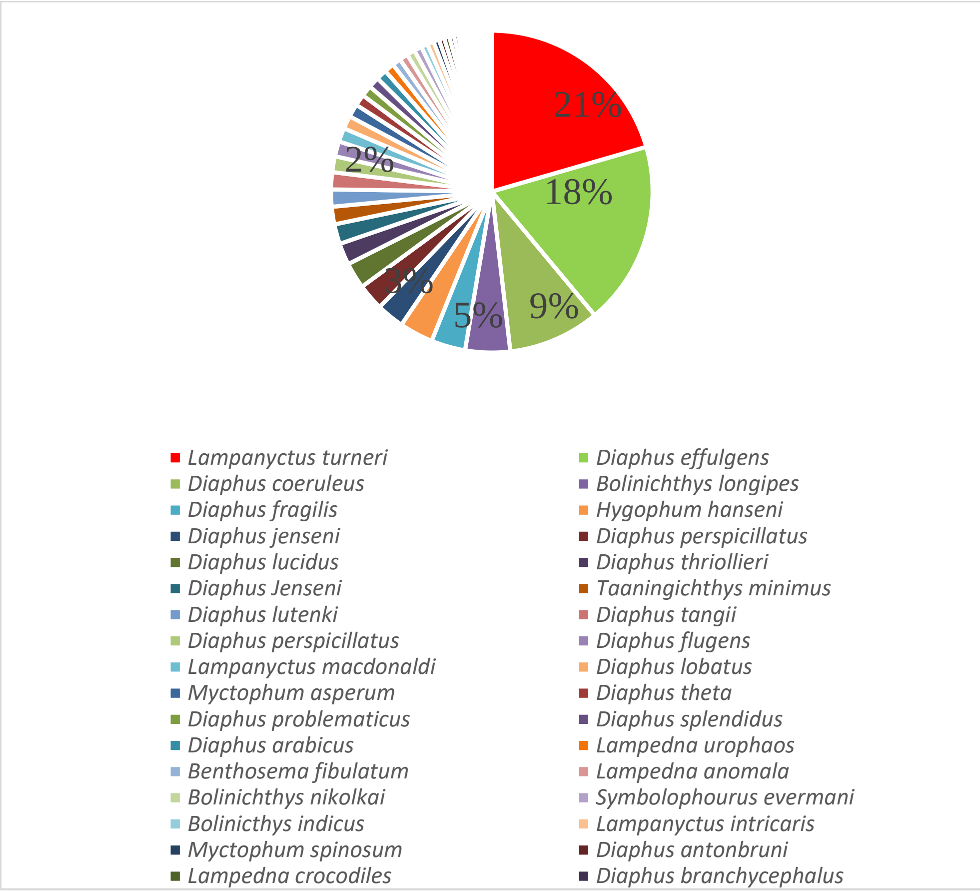


Figure 4.5 : Contribution of dominant myctophid species to the total biomass of WEIO

4.2.4 Distribution of species in study area.

Out of 59 myctophid species recorded from Western Indian Ocean 16 species namely *Benthosema fibulatum, B. pterotum , Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus aliciae, D. arabicus, D. garmani, D. jenseni, D. lucidus, D. signatus, Diaphus thiollierei, Hygophum proximum, Lampanyctus turneri, Myctophum spinosum, Symbolophorus evermanni, Symbolophorus* rufinus were distributed in all the three eco-regions (NEAS, SEAS and WEIO).

High concentrations of *B. fibulatum* were obtained from 110m depth station of NEAS (19°31.129 'N, 65°26.695 'E) at night and from the 223m depth station of SEAS (11˚09.97'N, 72˚58.629 'E) during day time. (Figure 4.6.1). Highest concentration of *Benthosema pterotum* was obtained from the 223m depth station of SEAS (11˚09.97 'N, 72˚58.629 'E) during day time (Figure 4.6.2). High concentration of *Bolinichthys longipes* was obtained from the 110m depth station of NEAS (18°20.880 'N, 69°25.550 'E) during night (Figure 4.6.3). *Bolinichthys indicus* in high concentrations were obtained from the 330m depth station of SEAS (11˚18.68 'N, 73˚35.362 'E) during day time (Figure 4.6.7). High concentration of *Ceratoscopelus warmingii* was obtained from the 100 m depth station of NEAS (20°08.671'N, 68°24.407 'E) during night time (Figure 4.6.8). High concentration of *Diaphus aliciae* in the 380-600m depth station of WEIO (00˚44.022 'S, 68˚03.990 'E) during day time and in the 100m depth station of NEAS (15°58.481'N, 65°29.986'E) NEAS during night (Figure 4.6.9). The 223m station of SEAS (07˚45.322'N, 70˚55.413'E) had the highest concentration of *D. fulgens* during day time (Figure 4.6.17) whereas *D. fragilis* was dominant in the catches from the 200 – 400 depths of SEAS (.8˚06.857'N, 71˚55.829'E) during day (Figure 4.6.18). *Diaphus garmani* had high concentration in the 223m station of SEAS during day time (11˚09.97'N, 72˚58.629'E) (Figure 4.6.19) and *Diaphus jenseni* had high concentration in the 250-348m depths of SEAS (8˚21.533'N, 72˚06.529'E) during day time (Figure 4.6.20). High concentration of *Diaphus lucidus* obtained from 10˚32.17'N, 73˚12.942'E at 300m depth during day time (Figure 4.6.22). *Diaphus signatus* was represented in high concentration at the 100m station of NEAS (20°08.671'N, 68°24.407'E) during night (Figure 4.6.29) whereas *D. thiollierei* had high concentration at the 223 m depth station of SEAS

(11˚09.97 'E, 72˚58.629 'N) at day time (Figure 4.6.34). High concentration *Hygophum proximum* was obtained from 13°01.549'N, 65°31.634'E at 120m during night (Figure 4.6.38) and high concentration of *Lampanyctus turneri* was obtained from NEAS at 20°08.671'N, 68°24.407'E at 100 m depth during Night (Figure 4.6.45). High concentration of *Myctophum spinosum* was obtained from 11˚09.97'N, 72˚58.629'E at 223m during day time (Figure 4.6.54) whereas *Symbolophorus evermanni* was obtained in high concentration from 07˚43.355 'S, 59˚09.451'E at 100-300m during night time (Figure 4.6.57) and *Symbolophorus rufinus* from the 304- 600 m depths of SEAS (07˚45.322'N, 70˚55.413'E) during day time (Figure 4.6.58).

Species common to NEAS and SEAS, NEAS and WEIO are *Benthosema fibulatum, B. pterotum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus aliciae, D. arabicus, D. garmani, D. jenseni, D. lucidus, D. signatus, Diaphus thiollierei, Hygophum proximum, Lampanyctus turneri, Myctophum spinosum, Symbolophorus evermanni, and Symbolophorus rufinus.*

Species common to SEAS & WEIO: Twenty five species out of the 59 myctophid species recorded from the Western Indian Ocean in the course of the present study have their distributional range within the SEAS & WEIO. They are absent in NEAS. The 27 species are; *Taaningichthys minimus, Bolinichthys pyrsobolus, Bolinichthys indicus, Diaphus brachycephalus, D. coeruleus, D. diadematus, D. diademophilus, D. effulgens, D. fulgens, D. lobatus, D. mollis, D. parri, D. perspicillatus, D. problematicus, D. splendidus, D. taaningi, D. aliciae, Hygophum hanseni, Lampanyctus intricarius, L. nobilis, Lampadena luminosa, L. urophaos, L. anomala, Myctophum asperum, M. aurolaternatum, M. nitidulum and M. obtusirostre.*

High concentration of *Taaningichthys minimus* was obtained from 02˚23.269'S, 63˚04.470 (Figure 4.6.59) whereas *Bolinichthys pyrsobolus* was distributed in high concentration at 05˚07.190N, 69˚04.122'E (400-506m depths) during day time (Figure 4.6.5). *Diaphus brachycephalus* had high concentration in the 150m station of SEAS (Figure 4.6.12) during day time (09˚51.311'S, 58˚36.344'E) and *D. coeruleus* was found in high concentration (Figure 4.6.13) at the 330m day station of WEIO (01˚41.188'S, 63˚38.006'N). Good catch of *D. diadematus* was obtained from the 220m day station of WEIO (15˚26.541'S, 56˚48.034) (Figure 4.6.14) and maximum catch of *D. diademophilus* was from the 220m night station of WEIO (15˚26.541'S, 56˚48.034'E) (Figure 4.6.15). *D. effulgens* was distributed in SEAS & WEIO with high concentration obtained from the 223m station of WEIO (04˚30.286 'S, 60˚45.869 'E) during night time (Figure 4.6.16). High concentration of *D. lobatus* was obtained from the 223m day station of SEAS (11˚09.97'N and 72˚58.629'E) (Figure 4.6.21) and *D. mollis* was concentrated in the 250-348 m depths of SEAS (8˚21.533'N, 72˚06.529'E) during day time (Figure 4.6.24). Maximum occurrence of *D. parri* was in the 55m depth station of SEAS (08˚06.354 'N, 73˚22.682E) during night operations (Figure 4.6.25). *Diaphus perspicillatus* was found in high concentration at the 320 m depth station of SEAS (8˚08.933'N, 76˚15.115'E) at day time (Figure 4.6.26) and *Diaphus problematicus* was present in with high concentration at the 403 m depth station of WEIO (14˚24.681 'S, 57˚15.592'E) during day time (Figure 4.6.27). was present only in 3 stations in WEIO and 3 stations in SEAS with High concentration of *Diaphus splendidus* was obtained from SEAS (8˚21.533'N, 72˚06.529'E) at 250-348m during day time (Figure 4.6.31) whereas *Diaphus taaningi* had high concentration at 30-50m depths of WEIO (02˚23.269 'S, 63˚04.470'E) during night (Figure 4.6.32).

Hygophum hanseni had high concentration in the 330m day station of WEIO (01˚41.188 'S, 63˚38.006'E) (Figure 4.6.37). *Lampanyctus intricarius* had high concentration in the 380-600 m depths of WEIO (00˚44.022 S, 68˚03.990'E) during day time and in the 100m night station of WEIO (04˚30.286 'S, 60˚45.869'E) (Figure 4.6.40). *Lampany ctus nobilis* was abundant in the 89-300m night stations of WEIO (07˚43.355S, 59˚09.451 'E) (Figure 4.6..42) whereas *Lampadena luminosa* was obtained in high concentration from the 300-400m depth stations of SEAS (9˚00.953'N, 73˚06.717E) and WEIO (03˚53.184 'S, 66˚22.248 'E) (Figure (4.6.48) during the day operations and *Lampadena urophaos* in high concentrations were obtained from the 400m day station of WEIO (03˚53.184 'S, 66˚22.248 'E) (Figure 4.6.49). *Lampadena anomala* was present in high concentrations in SEAS (8˚21.533N, 72˚06.529 'E) and WEIO (05˚07.190 'N, 69˚04.122 'E) between 250-500m depths during the day time (Figure 4.6.46). *Myctophum asperum* (Figure 4.6.50), *Myctophum aurolaternatum* (Figure 4.6.51) and *Myctophum nitidulum* (Figure 4.6.52) were obtained in high concentrations from the 300-360 m day station of SEAS (9˚00.953'N, 73˚06.717'E). *Myctophum obtusirostre was most* abundant in the 220m night station of WEIO (15˚26.541 'S, 56˚48.034) (Figure 4.6.53).

Species restricted to eco-regions: Of the 59 species recorded from WIO, 14 species are restricted to the WEIO and 2 species are found only in SEAS. The species endemic to WEIO are *Bolinichthys supralateralis, Bolinichthys nikolayi, Diaphus antonbruuni, Diaphus luetkeni, Diaphus theta,* *Electrona risso, Lampadena anomala, Lampadena luminosa, Lampanyctus macdonaldi, Lampanyctus photonotus, Lampanyctus tenuiformis, Lampanyctus crocodiles, Nannobrachium achirus, and Nannobrachium atrum.* Species that are found only in SEAS include *Diaphus watasei* and *Diaphus similis.*

Bolinichthys nikolayi was abundant in the 30-50 m night station of WEIO (02˚23.269'S, 63˚04.470'E) (Figure 4.6.4*) and Bolinichthys supralateralis* in the 220-400m depths of WEIO (02˚28.622'S, 67˚39.312'E during day time (Figure 4.6.6). Distribution of *B. nikolayi* is a new record to WEIO. Night collections from the 100m depth station of WEIO (04˚30.286'S, 60˚45.869'E) had good collections of *Diaphus antonbruuni* (Figure 4.6.10). High concentration of *Diaphus luetkeni* were obtained in day collections from the 400m depth station of WEIO (05˚27.666'S, 65˚52.820'E) (Figure 4.6.23) and *Diaphus regani* was abundant in the 300m day station south of WEIO (07˚43.355S, 59˚09.451'E) (Figure 4.6.28). *Diaphus theta* was distributed in high density at the 100m night station of WEIO (04º 30.286 'N, 60º45.869 'E) (Figure 4.6.33).

Electrona risso and Nannobrachium achirus had peak distribution south of WEIO (07˚43.355 S, 59˚09.451'E) in 300m day stations (Figure 4.6.36 & 4.6.55). *Nannobrachium atrum* was obtained from only one station of WEIO (00˚44.022 S, 68˚03.990'E) at 110m depth during night time (Figure 4.6.56). Similarly*, Lampanyctus festivus* was present in only one station south of WEIO (15˚26.541 S, 56˚48.034E) at 220m depth during day time (Figure 4.6.39) and *Lampanyctus macdonaldi* was obtained from a single station in WEIO (05˚27.666'S, 65˚52.820'E) at 400m depth during the day time Figure (4.6.41). *Lampanyctus photonotus* was concentrated in the 400-506m day stations of WEIO (05˚07.190N, 69°04.122'E) and (03°53.184'S, 66°22.248'E) (Figure 4.6.43). *Lampany ctus tenuiformis* was present in high concentration in the 400m day stations of WEIO (05°27.666'S, 65°52.820'E) and in the 100-300m night stations south of WEIO (07°43.355 S 59°09.451'E)(Figure 4.6.44). *Lampanyctus crocodiles* was obtained in high concentration from the 380-600 day stations of WEIO (00°44.022'S, 68°03.990'E) (Figure 4.6.47).

Among the two species that are exclusive of SEAS, *Diaphus watasei* was obtained only from the 223m night stations of SEAS (10°67.894'N and 66°58.797'E) and (11°09.97'N, 72°58.629'E) (Figure 4.6.35) was distributed only in SEAS High concentration of *Diaphus similis* was obtained from the 223m depth station (11°09.97'N, 72°58.629'E) during day time (Figure 4.6.30).

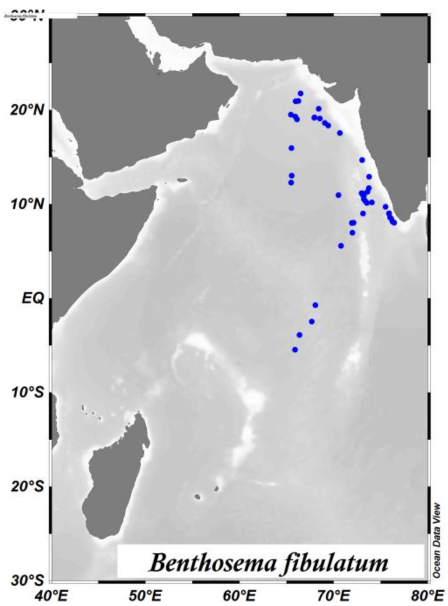


Figure 4.6.1

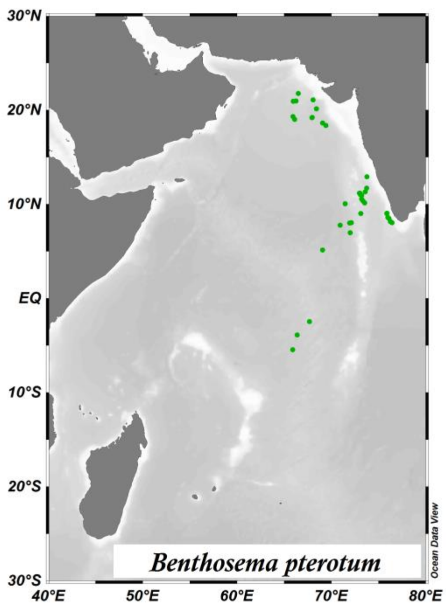


Figure 4.6.2

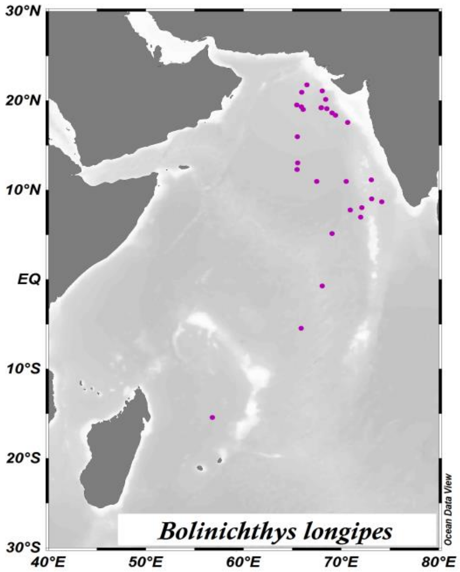


Figure 4.6.3

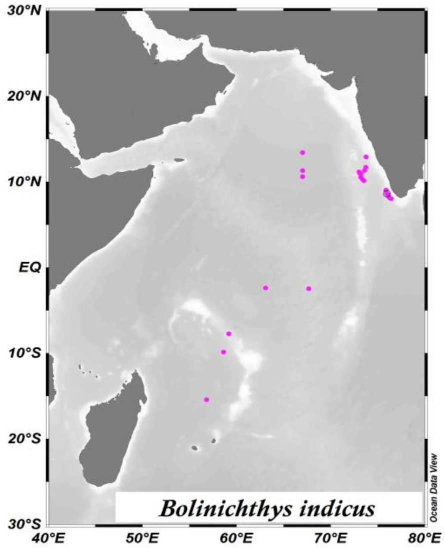


Figure 4.6.7

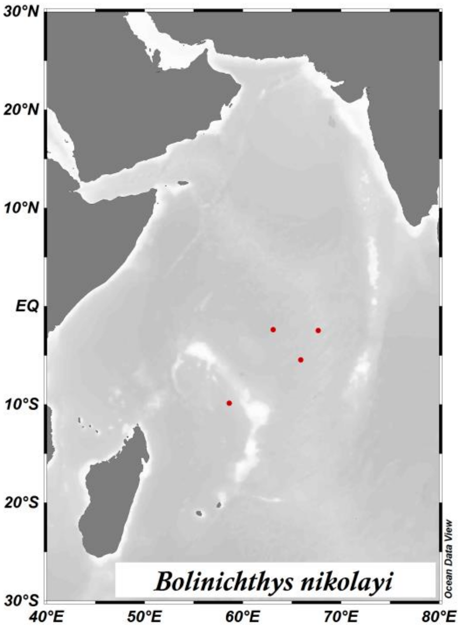


Figure 4.6.4

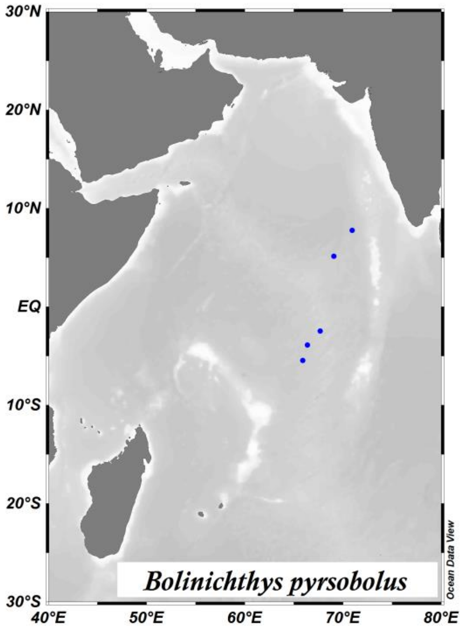


Figure 4.6.5

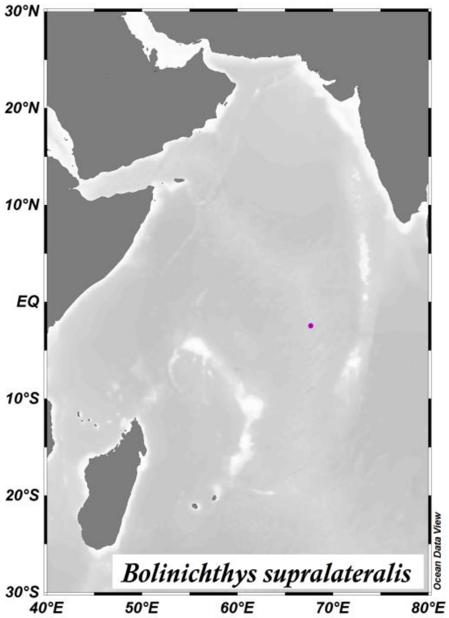


Figure 4.6.6

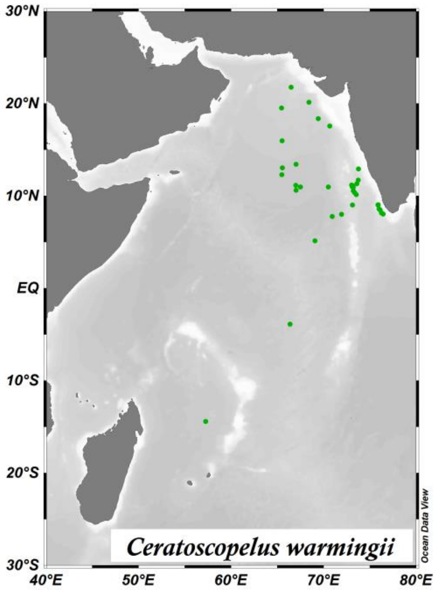


Figure 4.6.8

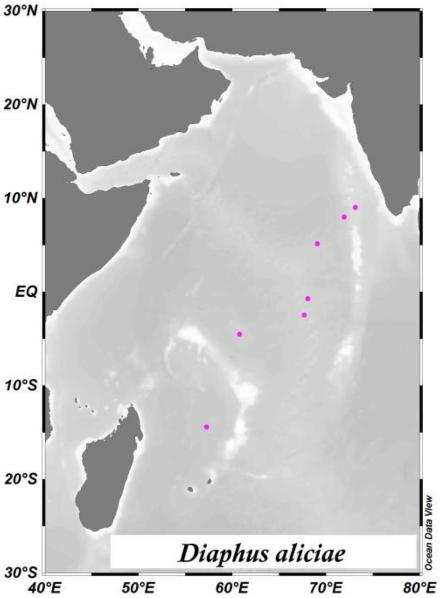


Figure 4.6.9

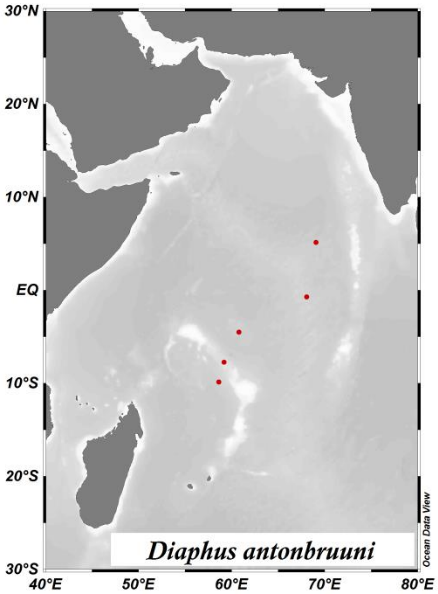


Figure 4.6.10

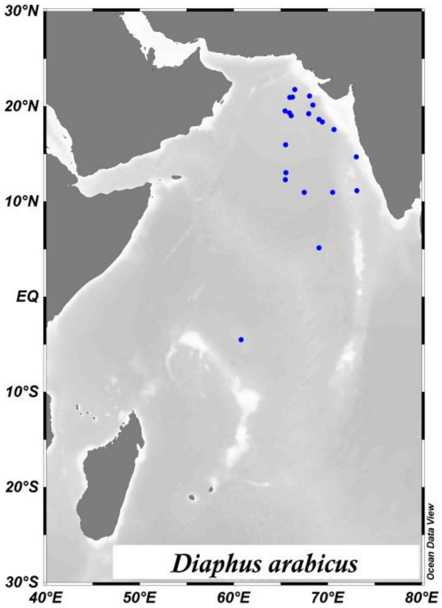
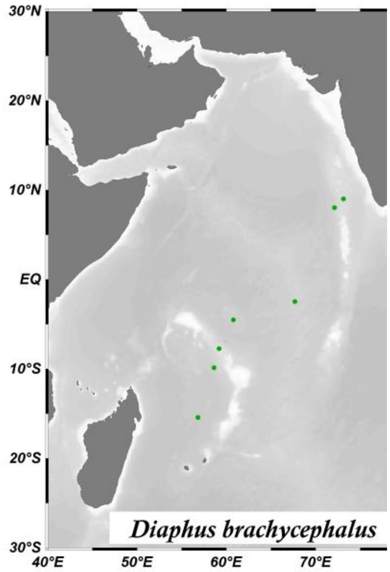


Figure 4.6.11



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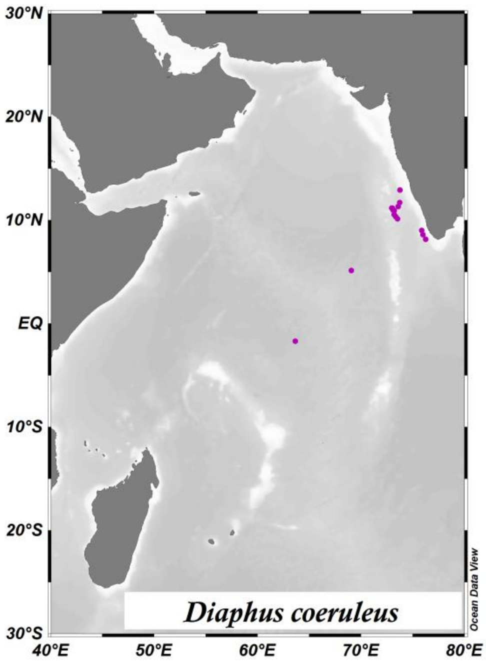

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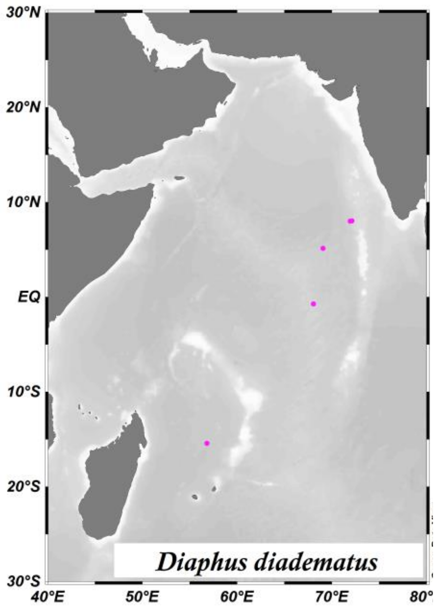

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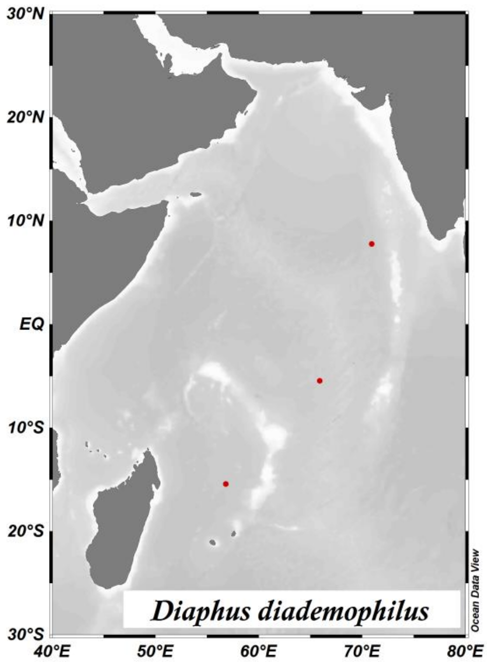

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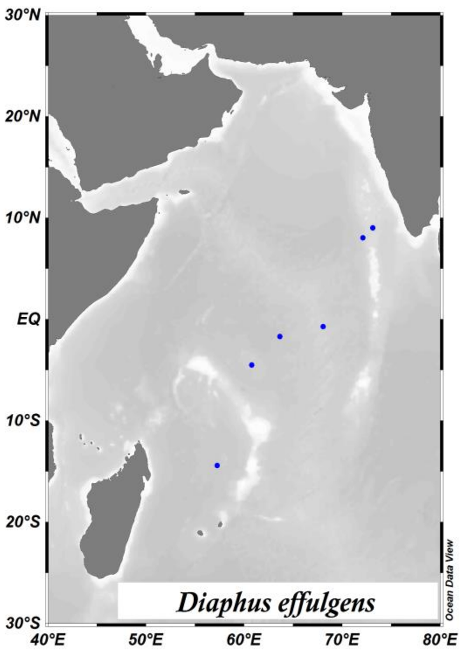

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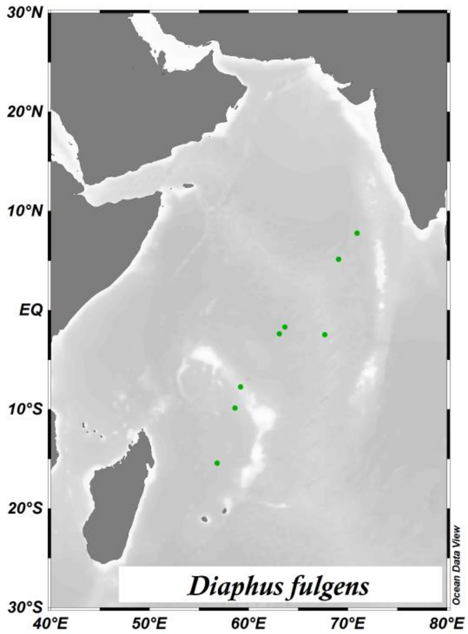

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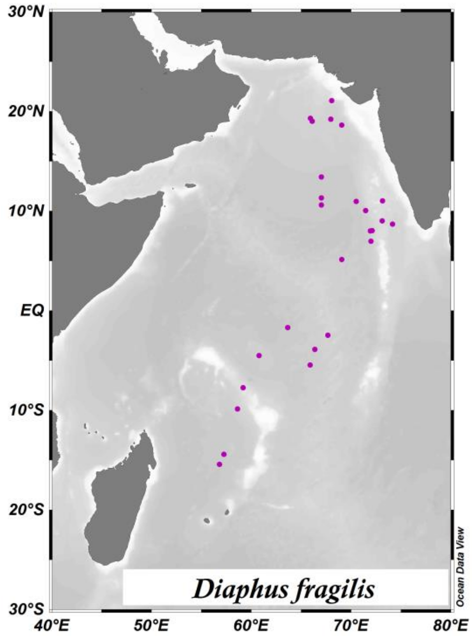

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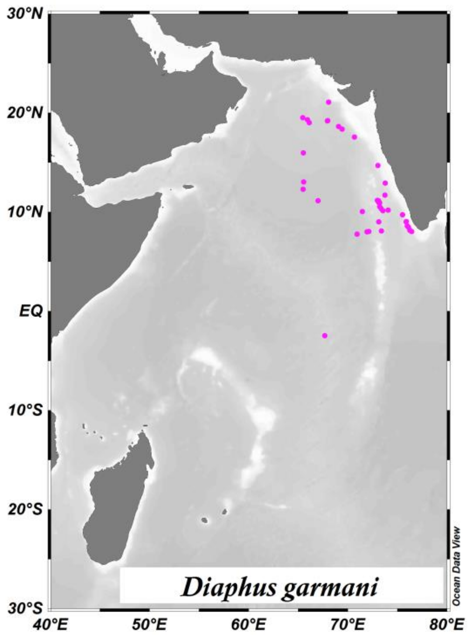

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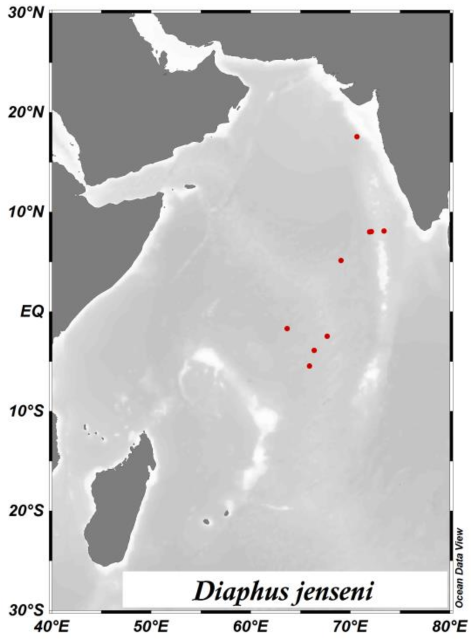

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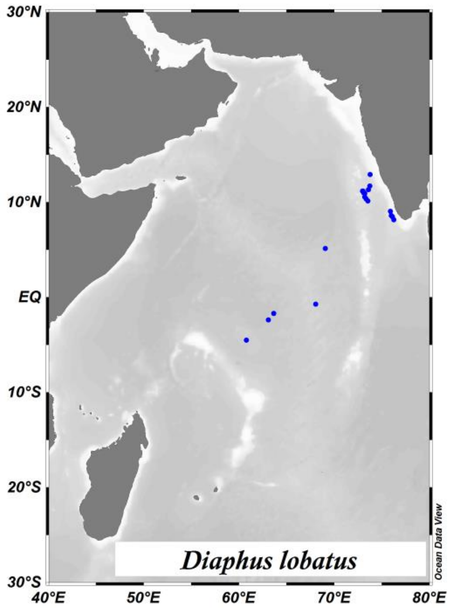

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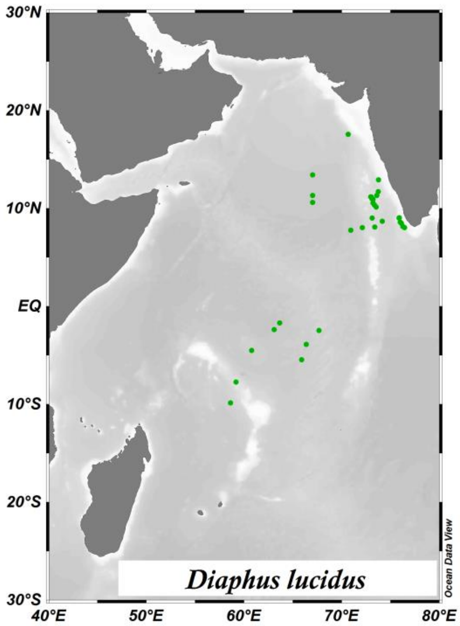

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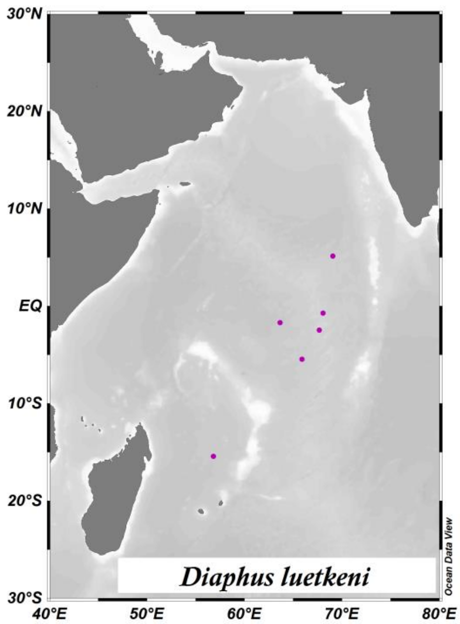

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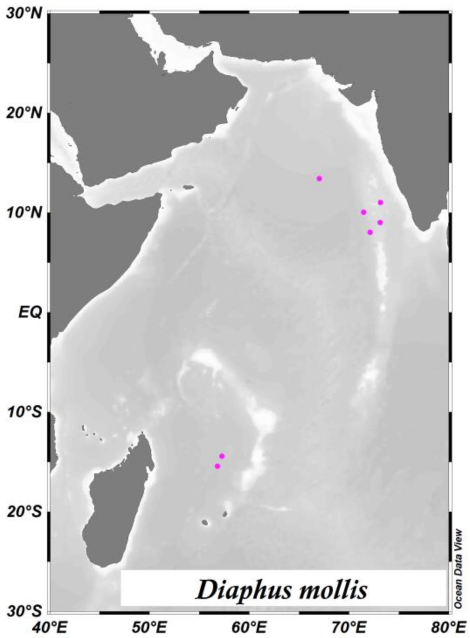

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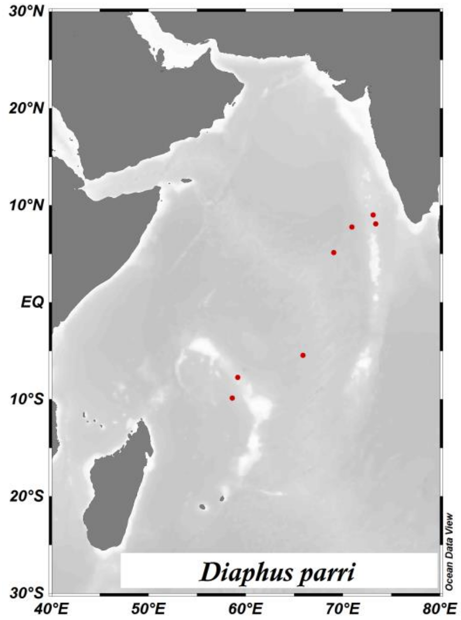

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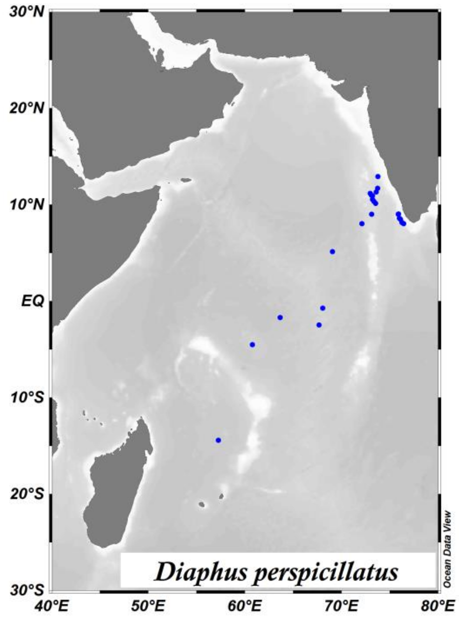

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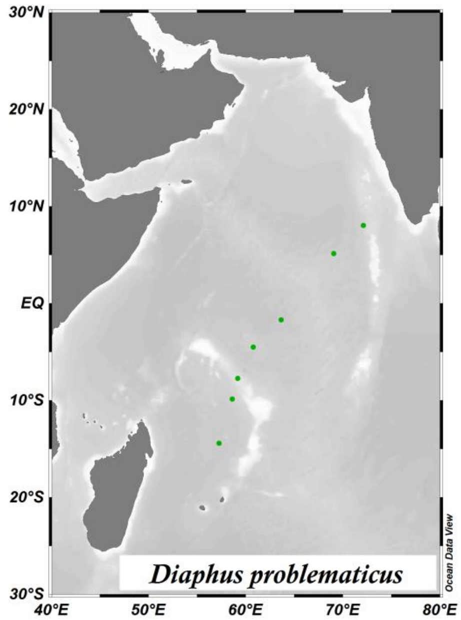

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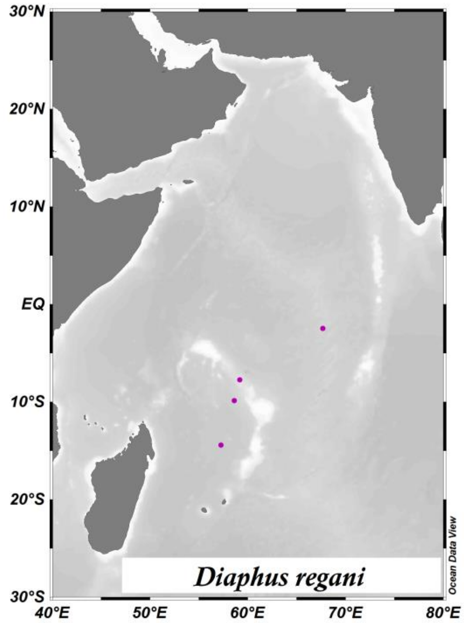

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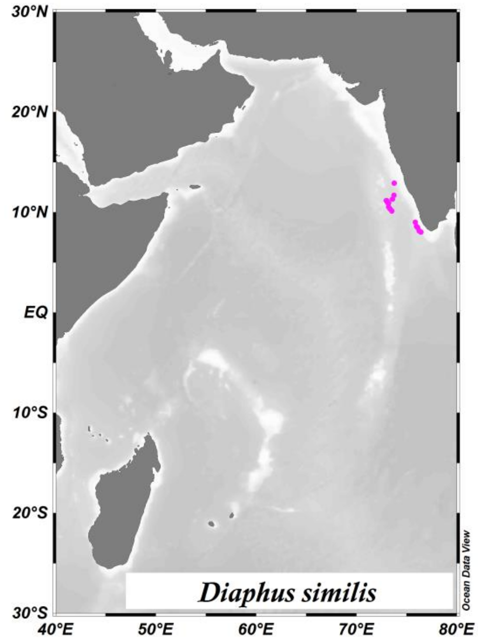

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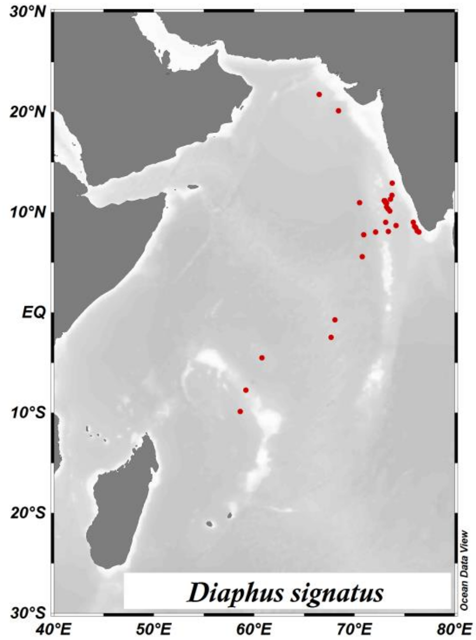

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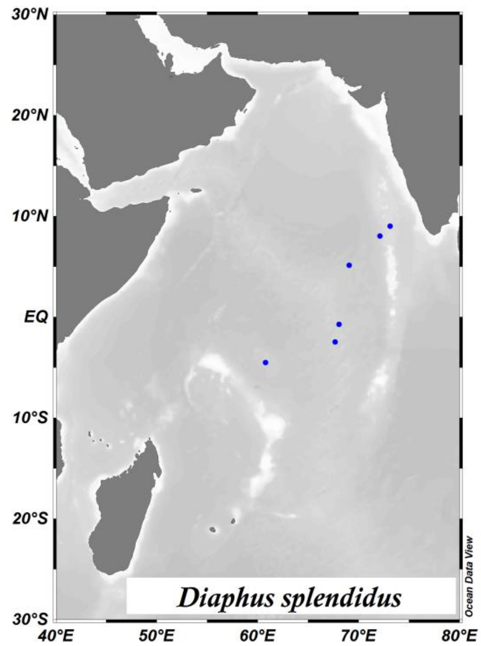

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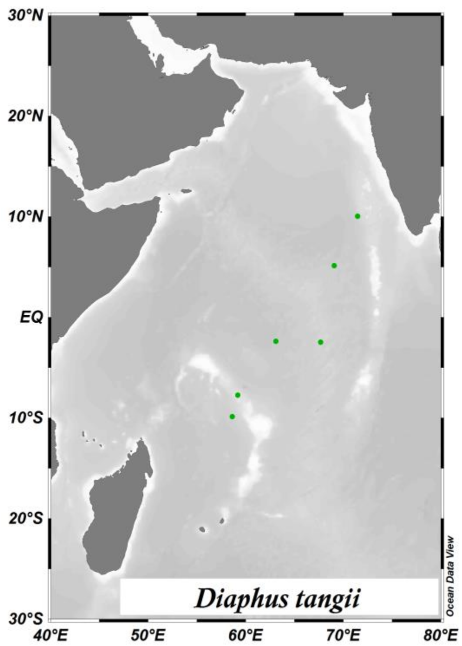

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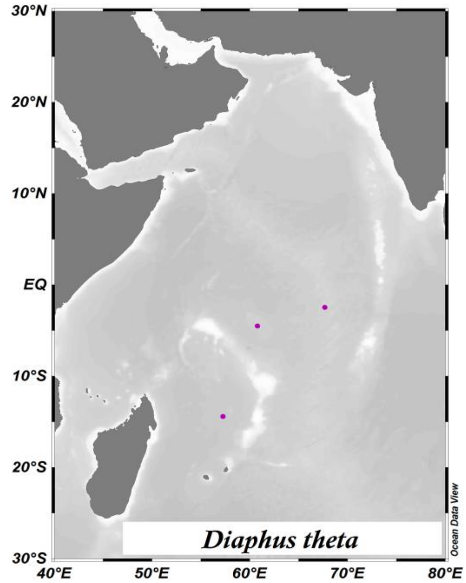

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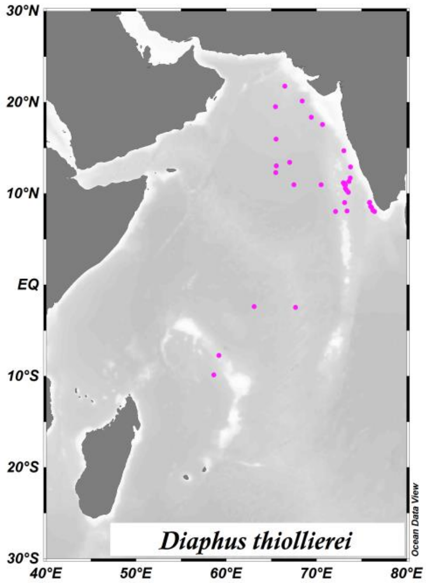

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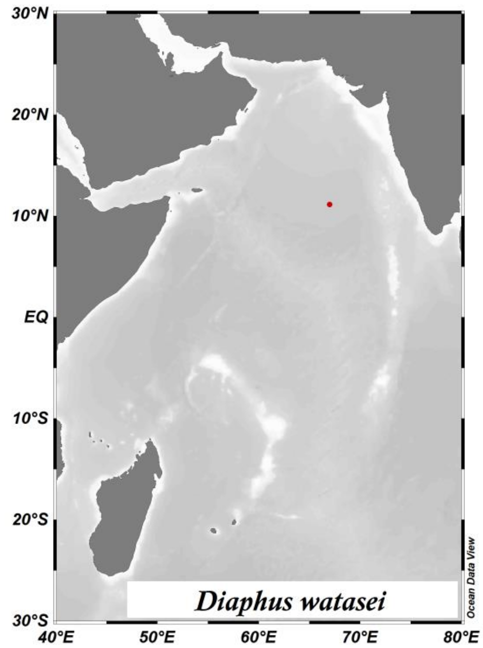

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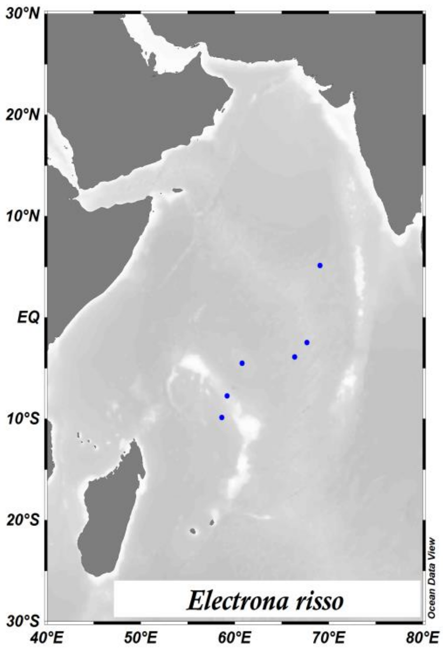

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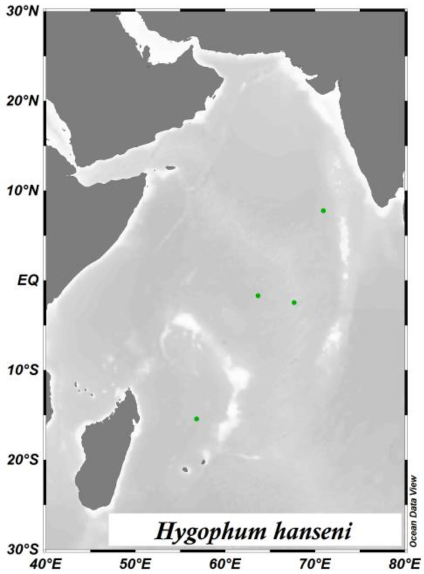

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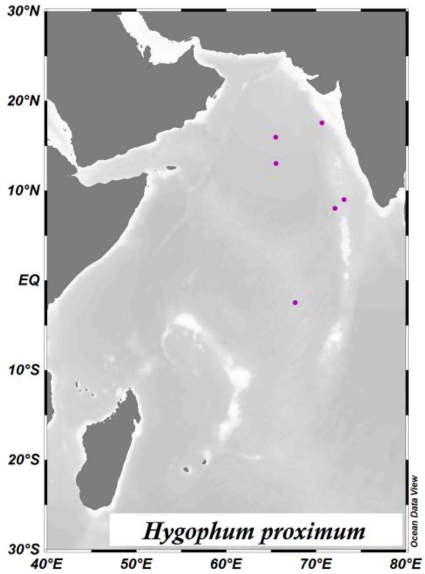

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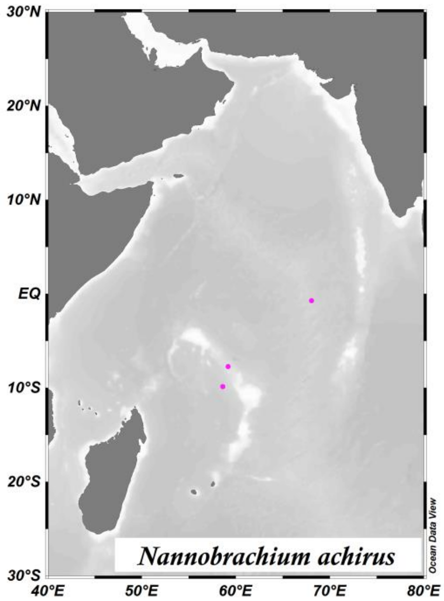

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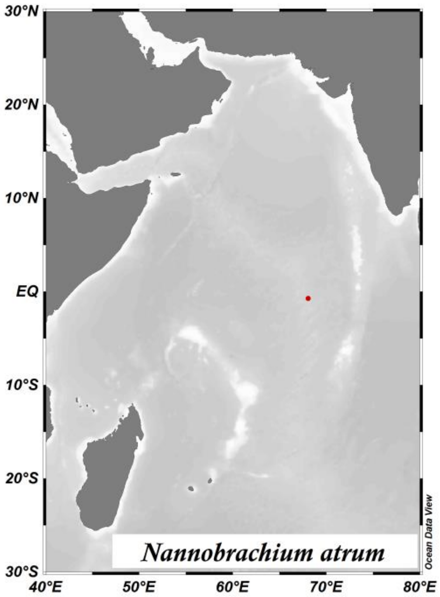

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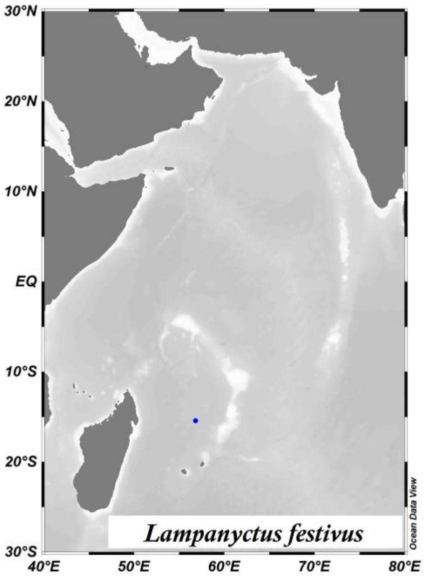

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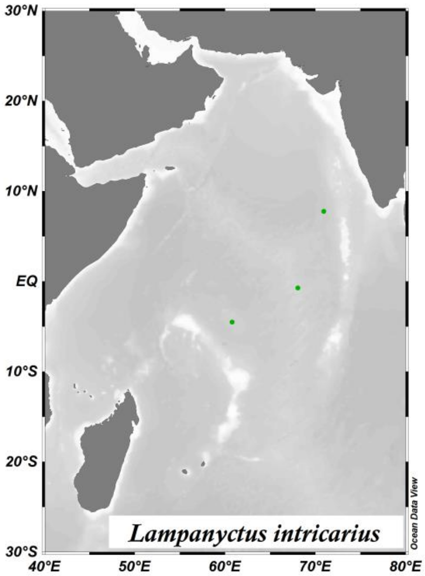

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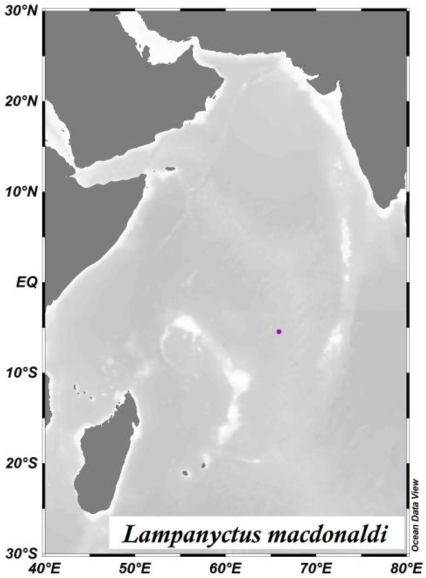

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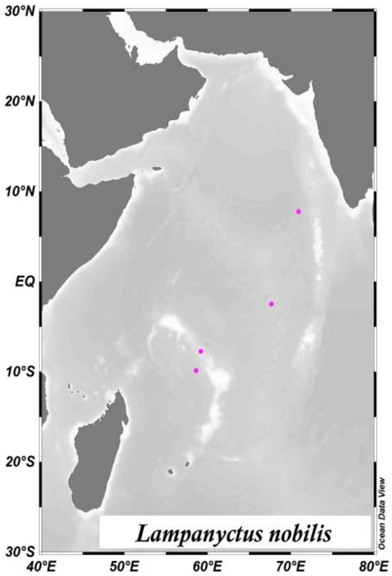

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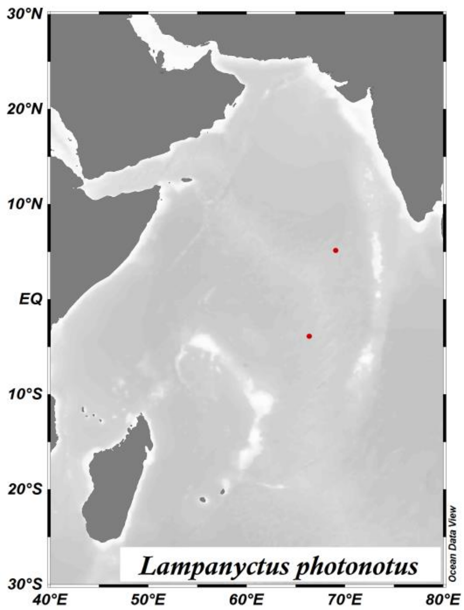

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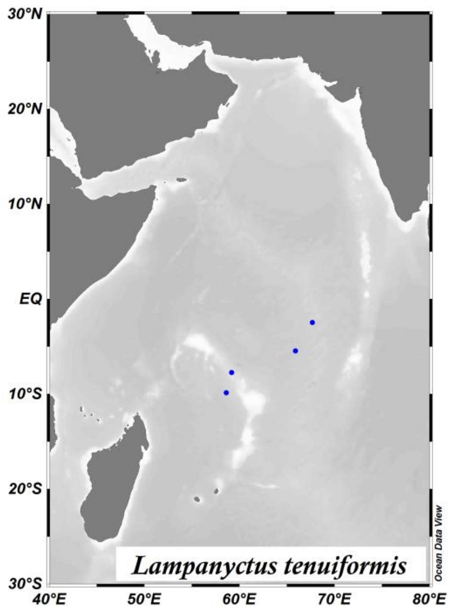

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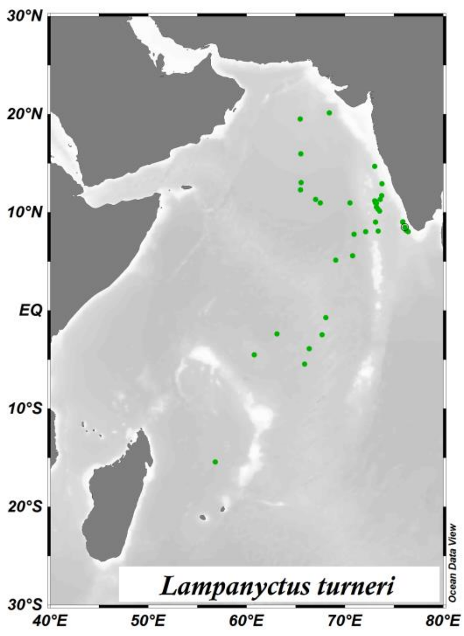

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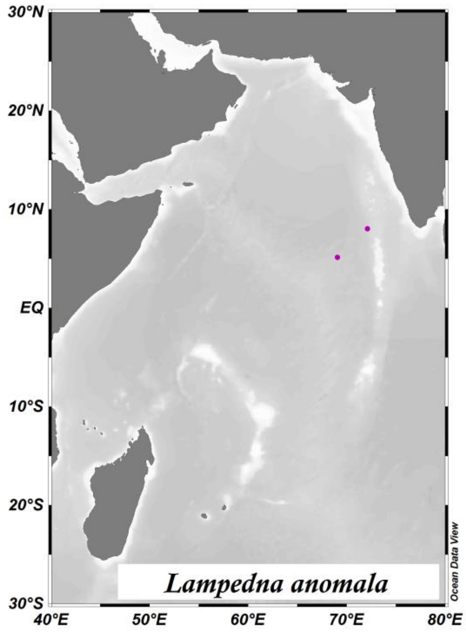

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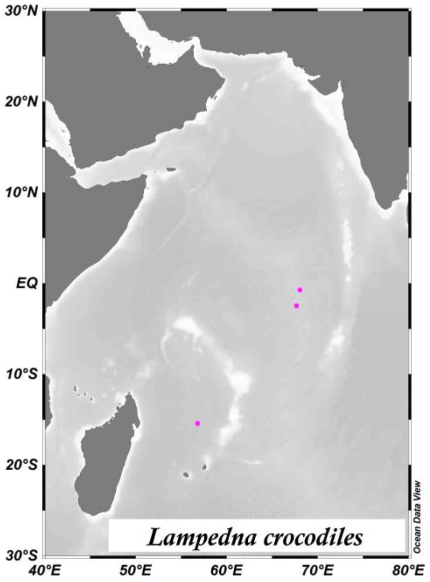

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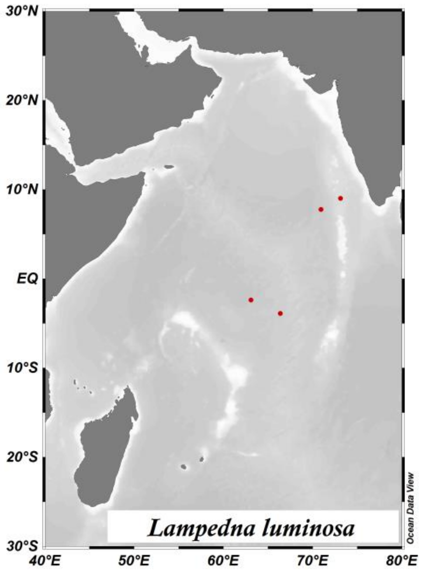

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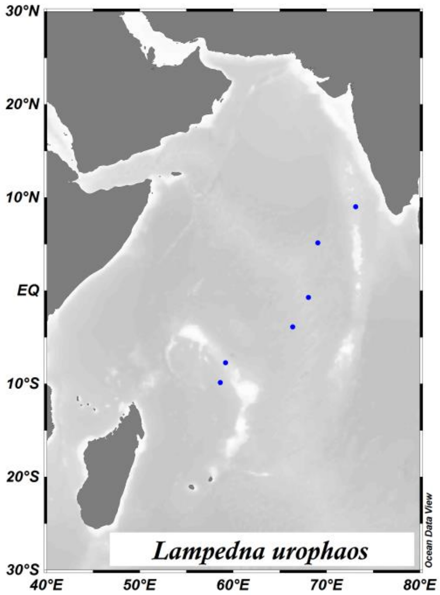

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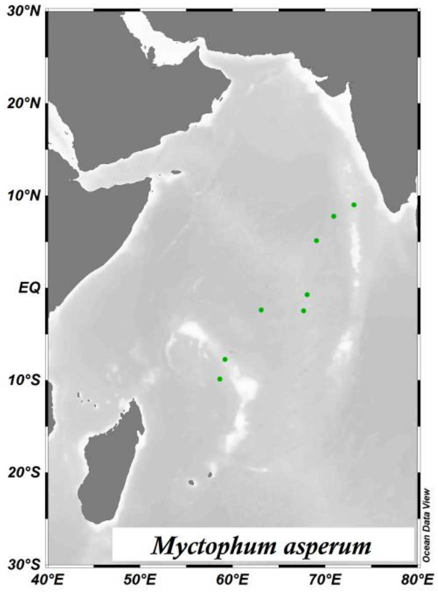

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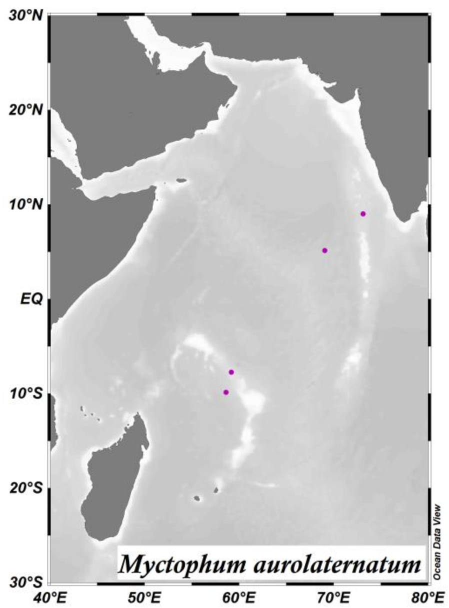

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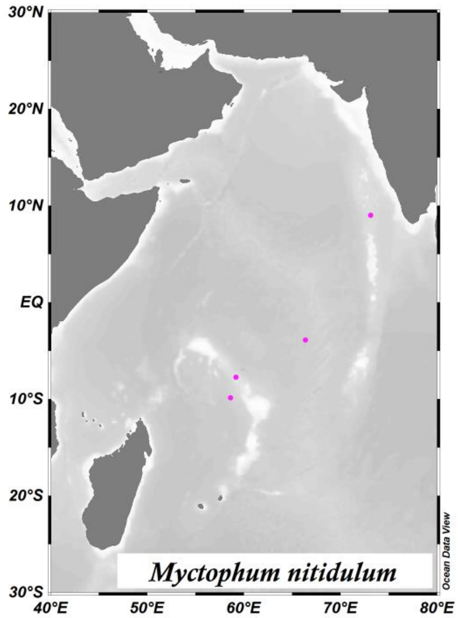

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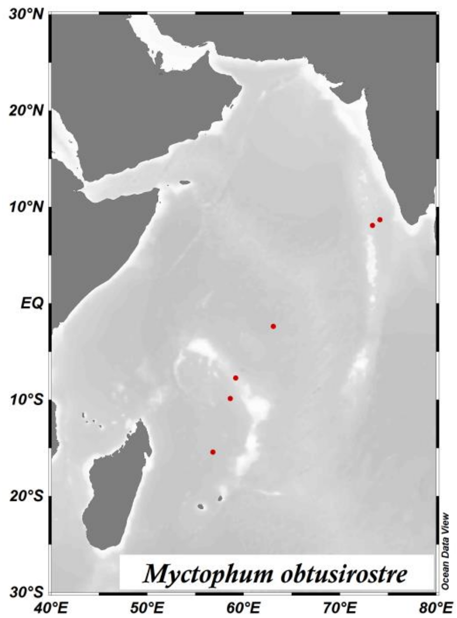

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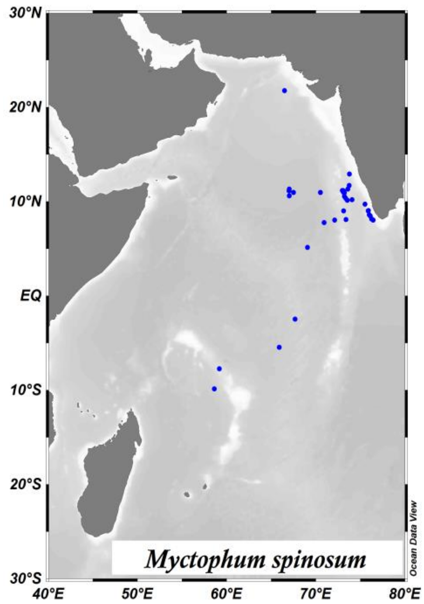

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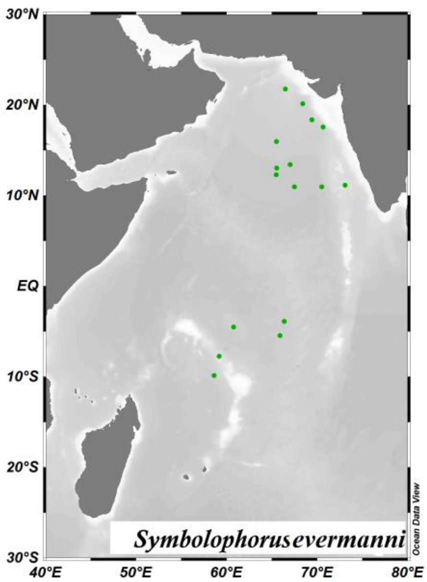

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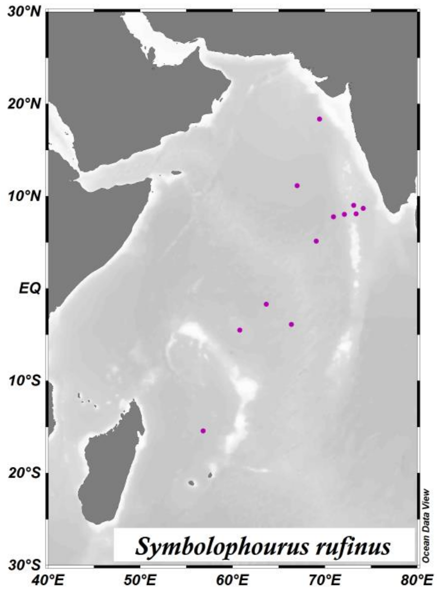

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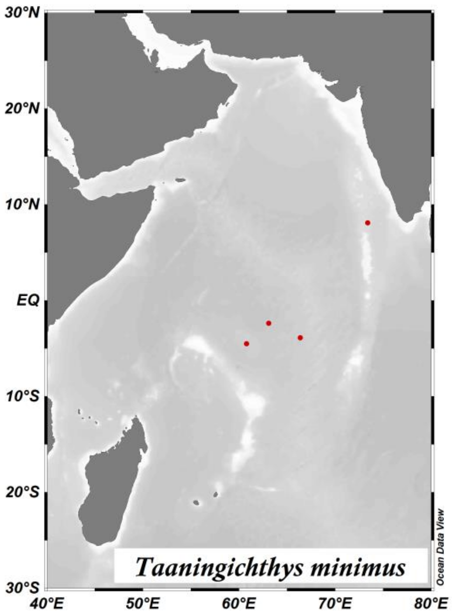


Figure 4.6.59

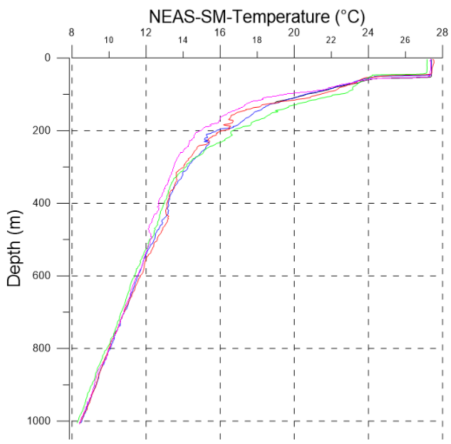
Figure 4.6.1 - 4.6.59 : Distribution of Myctophids in WIO

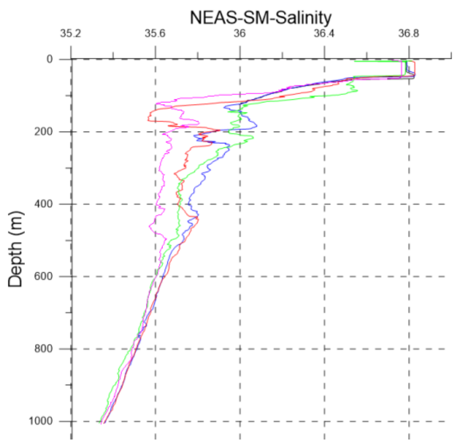
4.2.5 Linking Myctophid assemblages & environment.

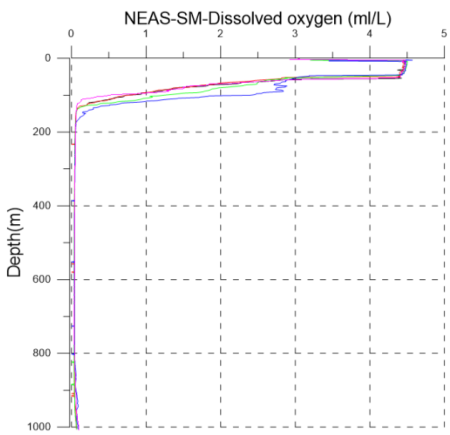
The NEAS, SEAS and WEIO experiences three distinct seasons, the summer monsoon (SM) from June to October; Winter Monsoon (WM) from November to end of February , interspaced by Spring Inter monsoon (SIM) from March to end May. Vertical CTD profiles on temperature, salinity and DO up to 1000m depth of the sampling areas are given in Figures (4.7- 4.12). In the WIO, seasonality is restricted to upper water column while deeper waters remain near stable.

Sea Surface Temperature (SST) in NEAS varied from 27°C during SM, to 29°C during WM and 25.6°C during SIM whereas the bottom temperature (1000m) during SM season was 8 °C, WM season was 7°C and SIM season was 9°C. The SM surface salinity of 36.7 PSU decreases to 35.5 PSU at 1000m whereas during WM surface salinity 33.7 PSU increases to 35.04 PSU at 1000m depth and during SIM the surface salinity of 36- 37 PSU decrease to 35.4 PSU at 1000m depth. Density (Sigma t) increases from surface to bottom in all the three seasons. The top of thermocline depth (TT) during SM was between 44-53m and Bottom of thermocline (BT) between 198-264m. During WM, TT was at 15-42m and BT at 270-372m. In SIM the TT & BT were at 32-66m and 298-319m respectively. During the three seasons in NEAS the Oxygen concentration at the surface waters ranged between 4.2-4.7 ml/L. With increase in depth a sharp decrease in Oxygen was found. At certain depths the oxygen concentration was found to be less than 0.2ml/l and represent the Oxygen Minimum Zones or OMZ. OMZ during SM starts between 127-145m and last till 1000m depth (CTD data only up to 1000m depth). In WM the OMZ starts at 124-173m and during SIM between 150-161m depth and lasts till 1000m. Similar observations on the DO levels of EAS have been reported by the JGOFS-India group (De Sousa *et al.,* 1996) wherein average values of DO in the EAS is reported as 17.5 μM (0.39 /ml/L) for Inter monsoon, 10.6 μM (0.24 /ml/L) for WM and 18.2 μM (0.41 ml/L) for SM season.

Sea Surface Temperature (SST) in NEAS varied from 27°C during SM, to 29°C during WM and 25.6°C during SIM whereas the bottom temperature (1000m) during SM season was 8 °C, WM season was 7°C and SIM season was 9°C. The SM surface salinity of 36.7 PSU decreases to 35.5 PSU at 1000m whereas during WM surface salinity 33.7 PSU increases to 35.04 PSU at 1000m depth and during SIM the surface salinity of 36- 37 PSU decrease to 35.4 PSU at 1000m depth. Density (Sigma-t) increases from surface to bottom in all the three seasons. The top of thermocline depth (TT) during SM was between 44-53m and Bottom of thermocline (BT) between 198-264m. During WM, TT was at 15-42m and BT at 270-372m. In SIM the TT & BT were at 32-66m and 298-319m respectively. During the three seasons in NEAS the Oxygen concentration at the surface waters ranged between 4.2-4.7 ml/L. With increase in depth a sharp decrease in Oxygen was found. At certain depths the oxygen concentration was found to be less than 0.2ml/l and represent the Oxygen Minimum Zones or OMZ. OMZ during SM starts between 127-145m and last till 1000m depth (CTD data only up to 1000m depth). In WM the OMZ starts at 124-173m and during SIM between 150-161m depth and lasts till 1000m. Similar observations on the DO levels of EAS have been reported by the JGOFS-India group (De Sousa *et al.,* 1996) wherein average values of DO in the EAS is reported as 17.5 μM (0.39 /ml/L) for Intermonsoon, 10.6 μM (0.24 /ml/L) for WM and 18.2 μM (0.41 ml/L) for SM season.


NEAS-SM-Temperature (°C)
8 10 12 14 16 18 20 22 24 26 28
0 200 400 600 800 1000
Depth (m)


NEAS-SM-Salinity
35.2 35.6 36 36.4 36.8
0 200 400 600 800 1000
Depth (m)


NEAS-SM-Dissolved oxygen (ml/L)
0 1 2 3 4 5
0 200 400 600 800 1000
Depth(m)

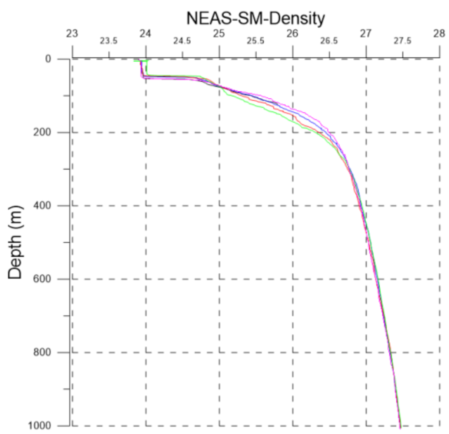

NEAS-SM-Density
23 23.5 24 24.5 25 25.5 26 26.5 27 27.5 28
0 200 400 600 800 1000
Depth (m)

Figure 4.7 : CTD profiles of temperature, salinity and dissolved oxygen and Density in the NEAS during SM

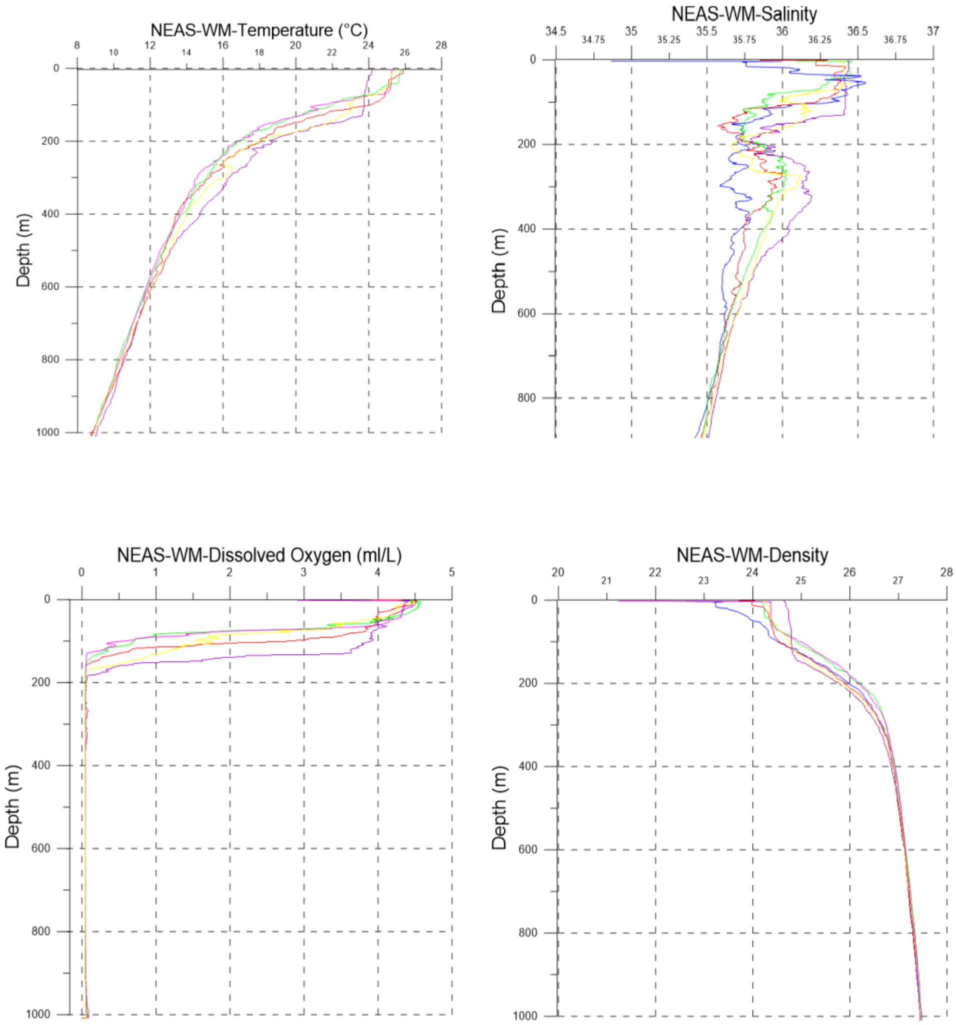


Figure 4.8 : CTD profiles of temperature, salinity and dissolved oxygen and density in the NEAS during WM

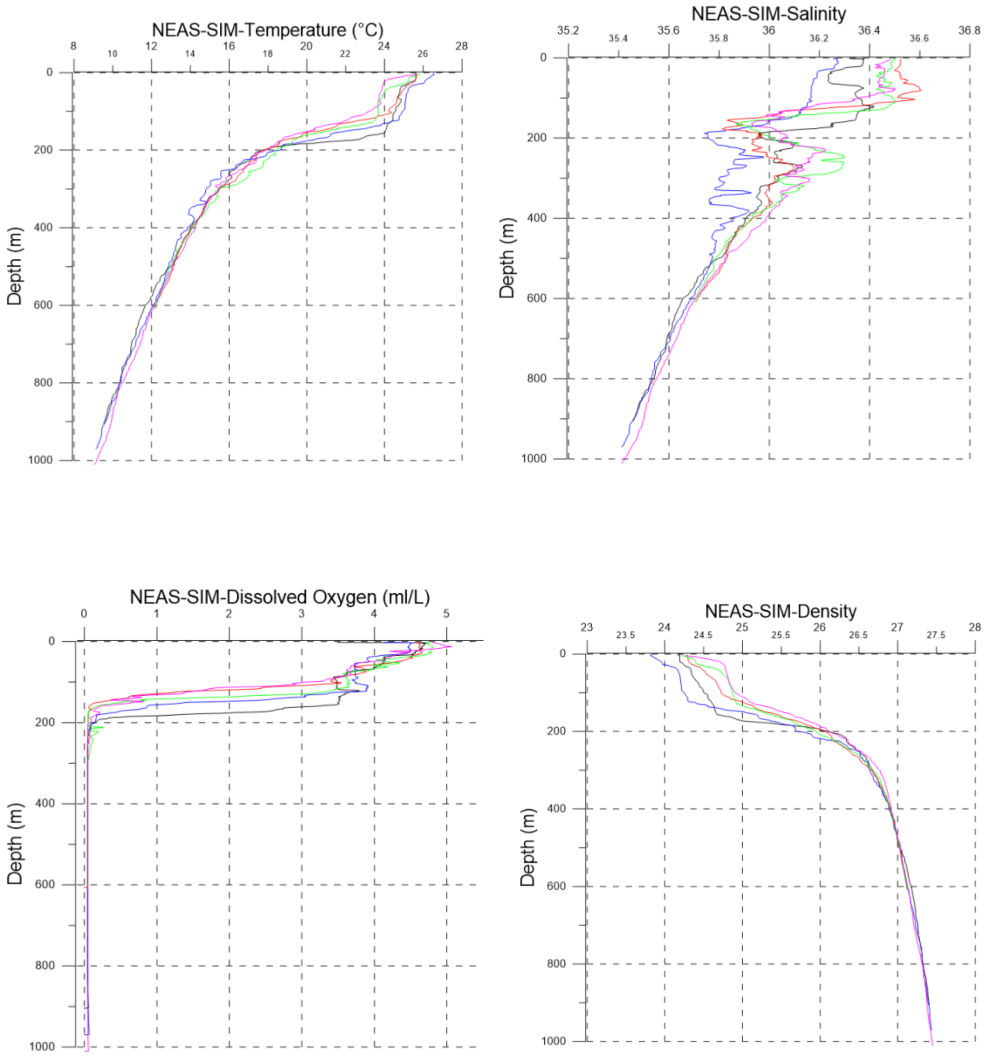


Figure 4.9 : CTD profiles of temperature, salinity and dissolved oxygen and density in the NEAS during SIM

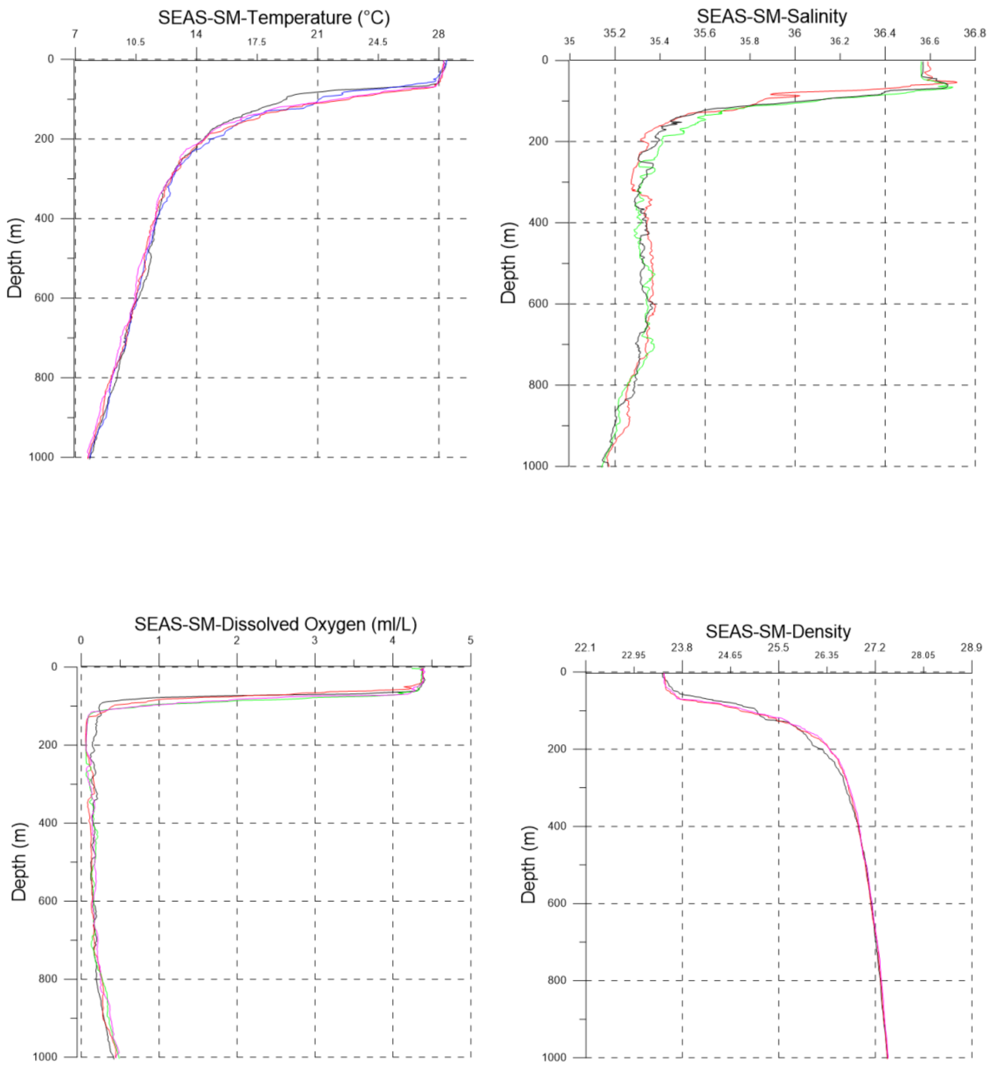


Figure 4.10 : CTD profiles of temperature, salinity and dissolved oxygen and density in the SEAS during SM

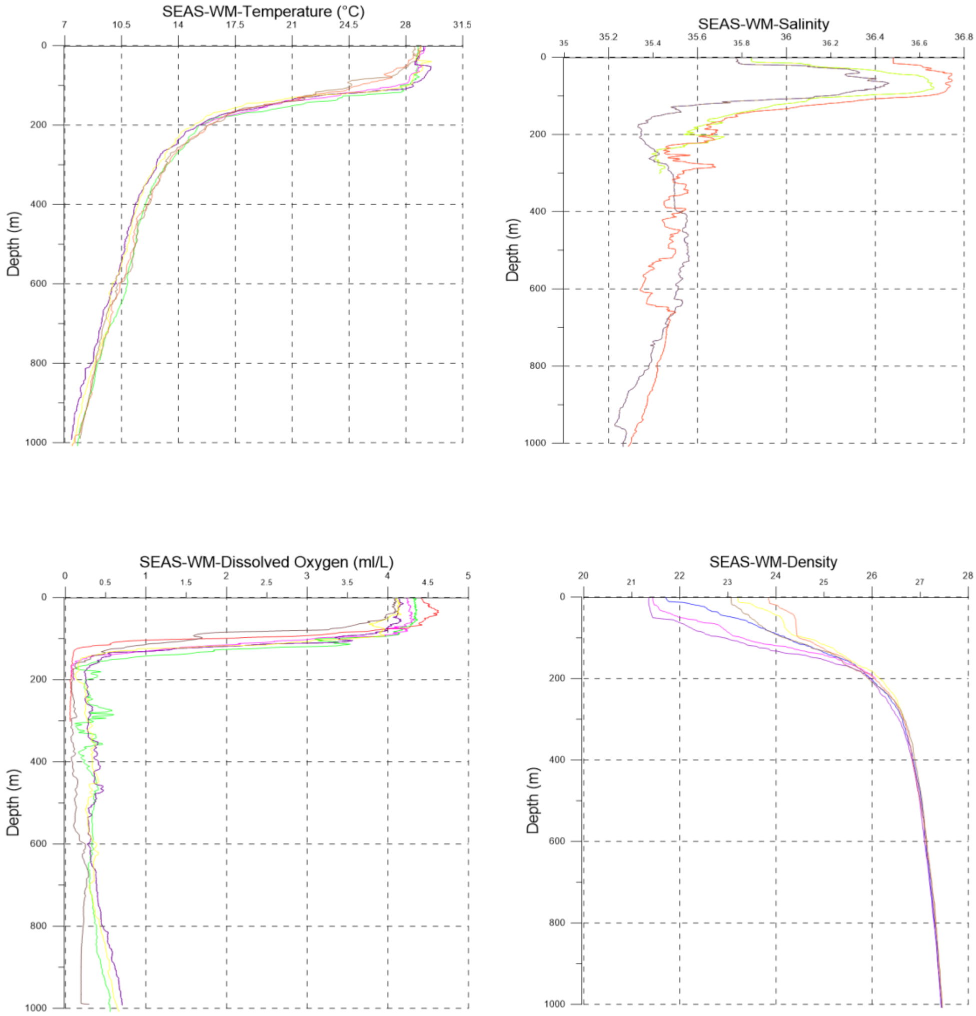


Figure 4.11 : CTD profiles of temperature, salinity and dissolved oxygen and density in the SEAS during WM

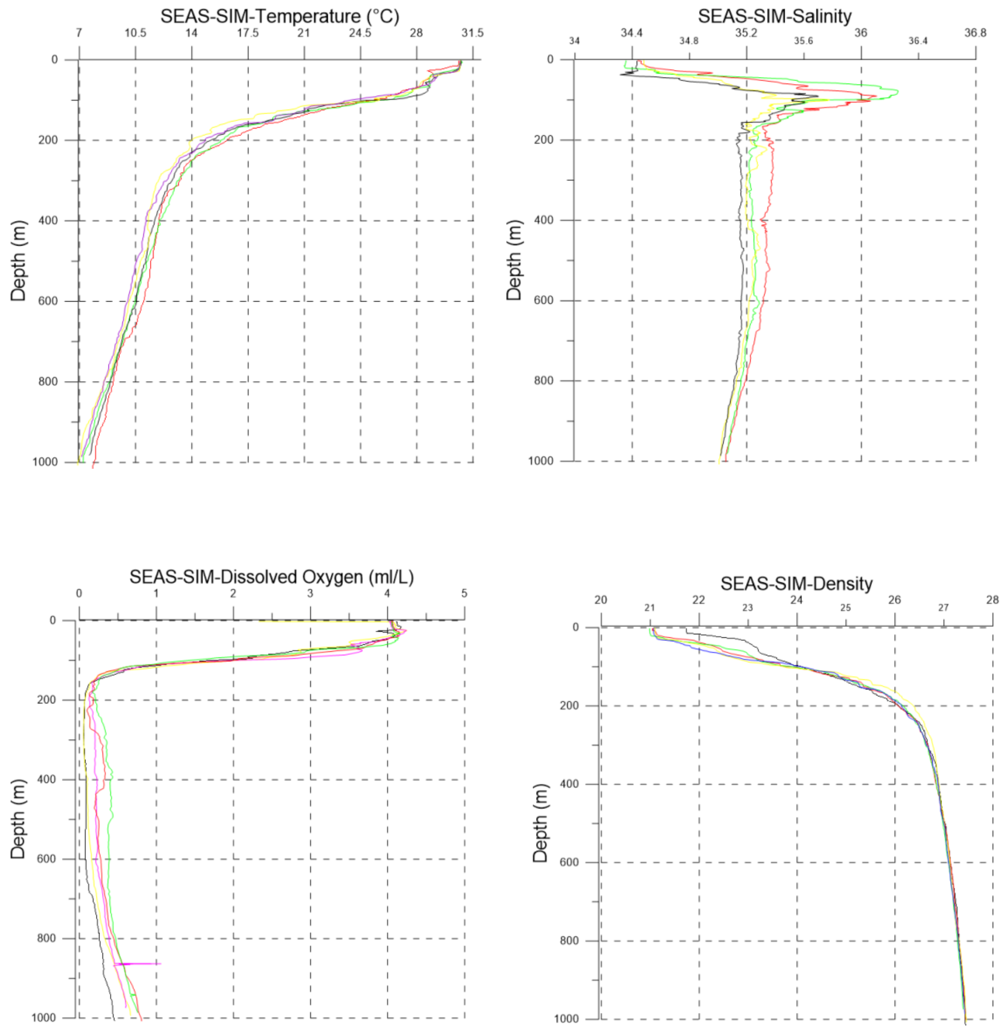


Figure 4.12 : CTD profiles of temperature, salinity and dissolved oxygen and density in the SEAS during SIM

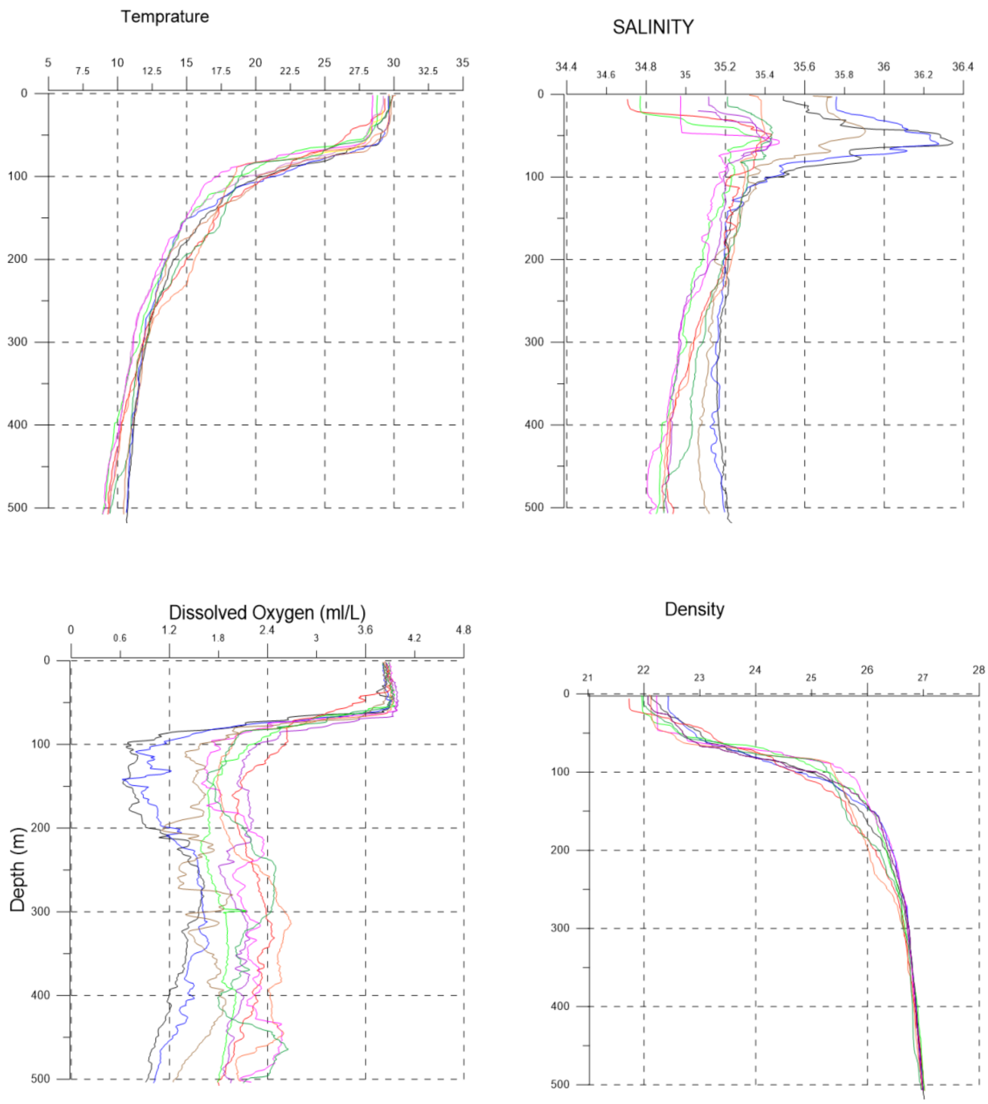


Figure 4.13 : CTD profiles of temperature, salinity and dissolved oxygen and density in the WEIO during SM

In WEIO only summer monsoon cruise data is available and the CTD sampling depth ends at 500m. SST decreases from 29.86°C to 10.6°c at 500m depth. Salinity seems to decrease from surface to bottom depths. OMZ was absent till 500m depth and density increases with increasing depth.

SST of SEAS during SM, WM and SIM were 28°C, 27.7°C and 30.7°C respectively and dropped to 7.8°C, 7°C and 9°C at 1000 m depth. Salinity remains between 34 – 35.7 PSU from surface to 1000m and the density show a gradual increase from surface to 1000mdepth. (TT) was between 12-61m during WM, 10-31m during SM and 22-29m during SIM. BT was between 173-197m in SM, 226-232 in WM and between 29-34m during SIM. The OMZ extend between 98- 304m (top) and 304m to 809m (bottom) during SM; between 133 -157m and 616-853m during WM and between 140-178m and 671m during SIM.

Canonical correspondence analysis (CCA) was carried to elucidate the influence of environmental factors on the Myctophid assemblages in the study area. The CCA axis 1 (Eigen value 0.424) and axis 2 (Eigen value 0.205) explained 61.7% and 29.6% respectively of the variation in the data (Table 4.11). The CCA axis 1 was the major axis separating stations based on operation depth and depth related factors (DO, salinity, temperature, density) into shallower and deeper sites. Out of 59 species recorded from WIO, only 38 species which had strong presence (represented in more than 50% of the sites) in WEIO/SEAS/NEAS were selected for CCA based on the Similarity analysis of Simper. Species selected for CCA and their range in tolerance to the 5 environmental variables are given in Tale 4.12, Figure 4.14.

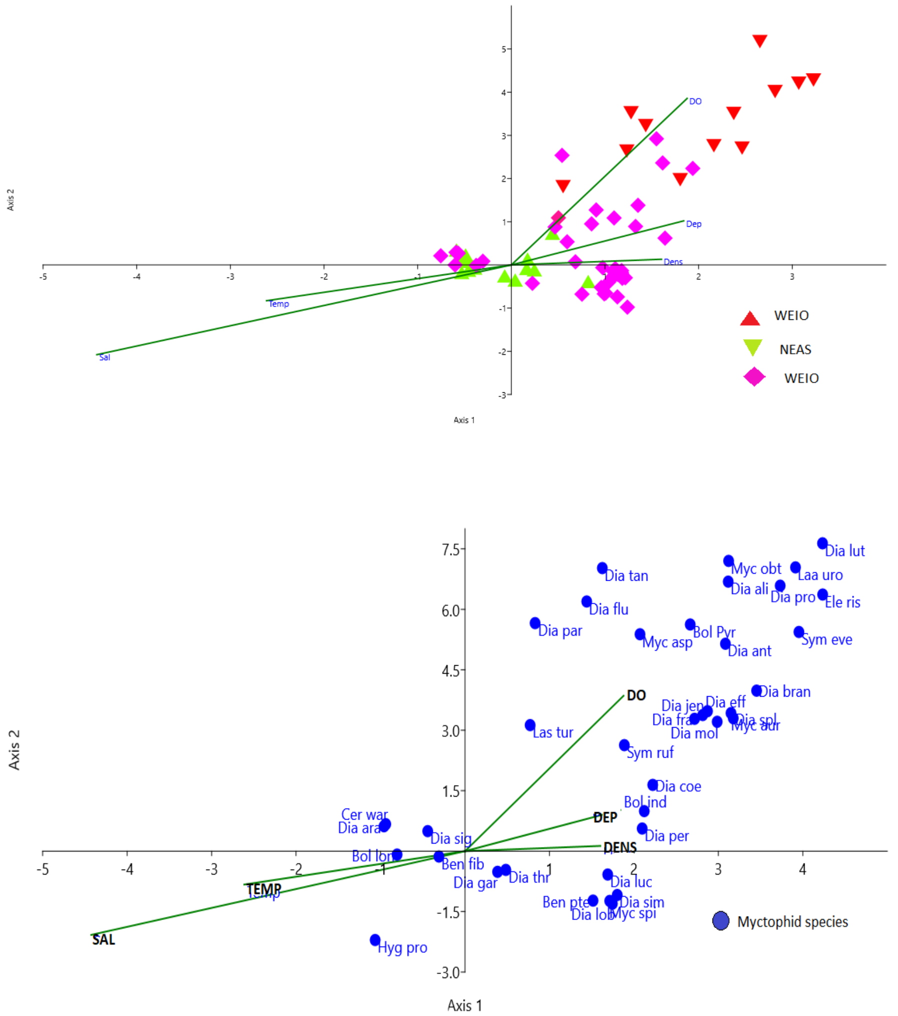


Figure 4.14 : Canonical Correspondence Analysis (CCA) plot showing scatter plot (a) showing Sites in the study area (b) important influential species

Table 4.11 : CCA axis values

Canonical correspondence

Axis	Eigenvalue	%
1	0.424	61.73
2	0.205	29.86
3	0.057	8.41

4.2.6 Biomass estimation

Biomass estimate of myctophids are restricted to the Eastern Arabian Sea (NEAS & SEAS) due to limitations in data strength and spatial coverage in WEIO. The conventional methods of biomass estimation of myctophids are mid-water trawling and acoustic techniques. Acoustic estimation of myctophid biomass is not attempted in the present study, since another group at CMLRE is exclusively working on this. Biomass estimates in the present study are based on mid-water trawl surveys using 45m mid water trawl and 49.5m Cosmos trawl. Since myctophids are known to concentrate in the DSL, the depth of the DSL was first ascertained by checking the EK-60 soundings (Figure 4.15).

Depths of DSL at various trawl stations in SEAS & NEAS are given in Figure 4.16 a&b At all such depths the thickness of the primary DSL was estimated from echograms. Most of the trawl operations were conducted in the primary DSL during the mornings/ evenings and night, when the DSL was relatively shallow and trawl operations were much easier and efficient. Maximum density of myctophids was recorded in the depth ranges 200-600m during day and 20-90m during night, both in SEAS & NEAS. From the acoustic data of EK 60 the

Deep scattering layer (D1) in NEAS was found between 10-140m during night time and during day time multiple layers were observed. D1 layer was between 15-80m and D2 layer was seen between 220-400m (Figure 4.16 a,b). In SEAS after sunset between 18.00hrs to 6.00 am dense thick layer of DSL (N1) was seen below surface which extended up to 120m. During day time one to two and rarely three layers were observed at three to four stations. The D1 layer was below 100m and D2 layer was below 200m. However at the remaining stations the DSL layer was seen below 200m which extended up to 600m in some stations (Figure 4.16b).

Figure 4.15 : Echogram from EK60 (38 KHz and 120 KHz)

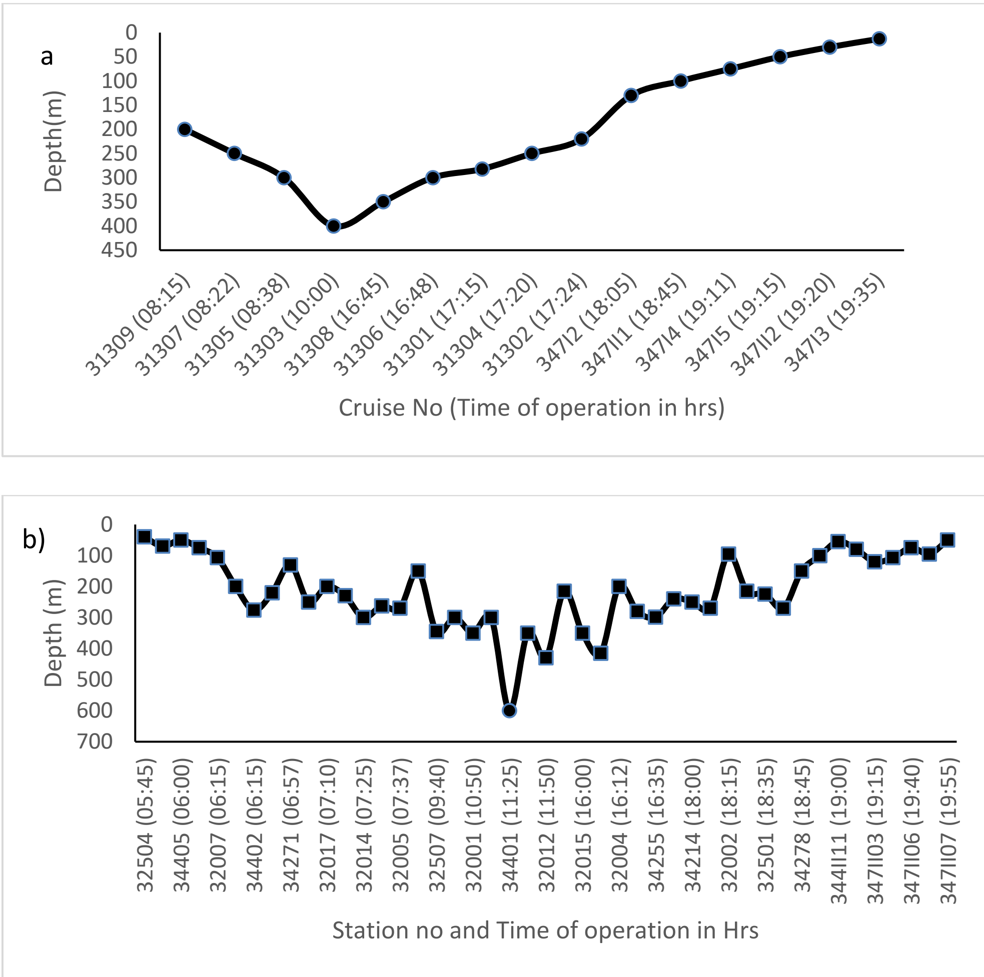


Figure 4.16 : Occurrence of DSL in each depth with regard to time in a) NEAS b) SEAS

Catch in weight of myctophids varied for the day/night operations. In NEAS night trawl catches were comparatively more (highest catch of 76836.590 kg/km2, from 17.53°N, 70.66°E) as compared to day catch. In SEAS highest catch density of 115816.14 Kg/km2 (9.019°N, 75.82°E) was obtained in Day catches whereas night catches were relatively less. To account for the observed variations in catches occurrence of species in day/night catches were compared.

Fig 4.17 shows the distribution of myctophids during day and night with regard to their depths. Most of the species were obtained from 200- 600m during day time from the study area. *D. watasei* was obtained between 100-300m depth during day and during night time most of them were obtained between surfaces to 200m. *Lampanyctus festivus* was only present in night station and was absent in day station. *Bolinichthys pyrsobolus, B. supralateralis, Diaphus coeruleus, D. watasei, Lampanyctus macdonaldi, L. crocodiles, Lampadena anomala, L. luminosa, L. urophaos* were present in the day collections not in the night and because as there were no corresponding night sampling in the area were day sampling was done, there presence/absence in night collections could not be ascertained. It appears that variations in the day/night catches are not due to species avoidance/aggregation, but are rather governed by the depth of the DSL which makes the trawl operations difficult/efficient.

Using the catch data, biomass of myctophids in each 2ºLat X 2ºLong grids (120NM X 120 NM) were estimated by the Swept Area method (Pauly 1983) modified to integrate the DSL thickness, assuming that the DSL occupy the entire length and breadth of each grid. Catch per unit area was multiplied with the area of each grid to derive biomass per grid and the cumulative biomass of all grids in an area is considered as the biomass from that area. (Table 4.13).

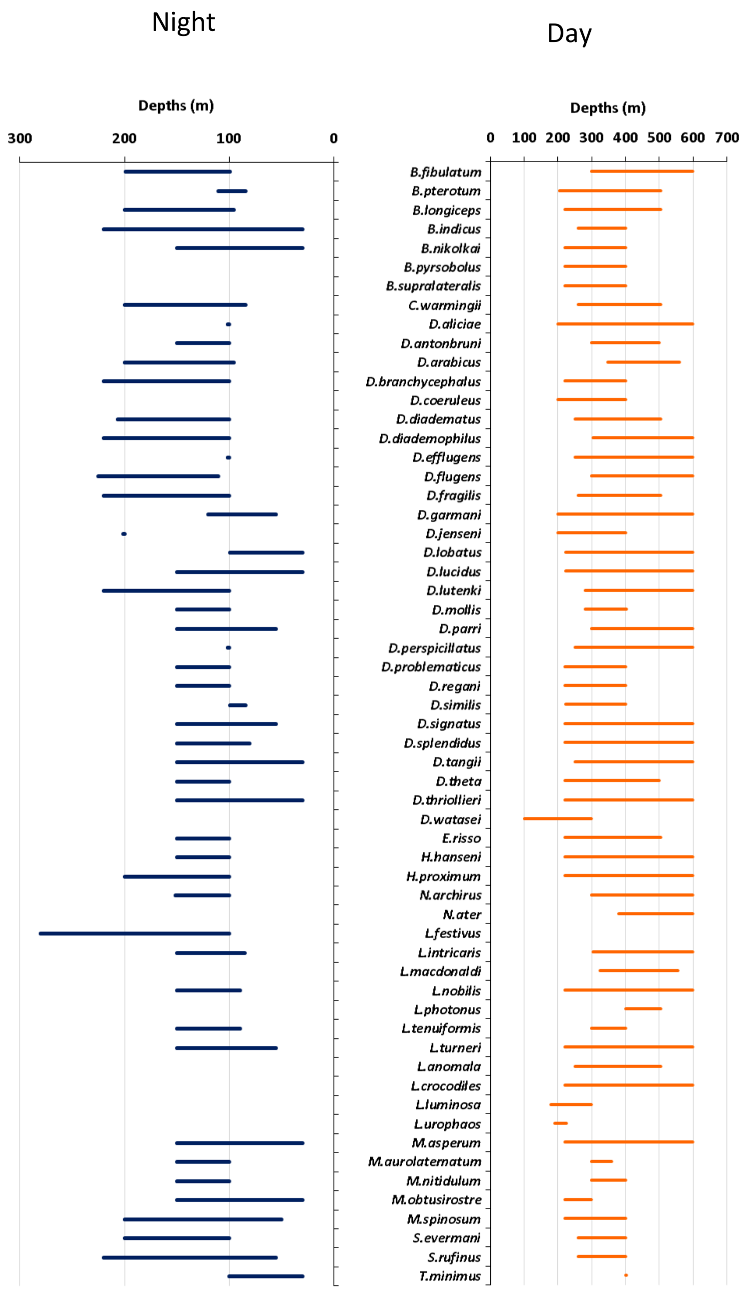


Figure 4.17 : Day and Night occurrence of Myctophid species with regard to the depth from the study area

The total Myctophid biomass obtained from NEAS and SEAS using swept area method was 17.903458.8 tonnes (Seventeen million nine hundred and three thousand four hundred and fifty eight). The abundance of myctophids varied in north and south waters of Eastern Arabian Sea. In NEAS myctophid constituted about 9.213048 tonnes (Nine million two hundred and thirteen thousand forty eight hundred) and in SEAS the biomass of myctophid was estimated to be 8690410.288 tonnes (Eight million six hundred and ninety thousand four hundred and ten) (Table 4.13).

Highest biomass from NEAS (76836.50 kg/km^2 and 60212.7 hg/km^2) were obtained from 17°56.77N lat 70°65.2E long and 20°08.67lat, 68°40.1 long during winter monsoon night operations. From SEAS high biomass of 115816.14 kg/km2 was obtained from station 8°59.820 N lat and 75°55.3 E long during day time of summer monsoon season.

Table 4.13: Biomass estimated using swept area method from NEAS and SEAS

Biomass	NEAS (tonnes)		SEAS (tonnes)		Total - NEAS+ SEAS (tonnes)	
Myctophid Biomass	9213048	Nine million two hundred and thirteen thousand forty eight hundred	8690410.29	Eight million six hundred and ninty thousand four hundred and ten	17903458.8	Seventeen million nine hundred and three thousand four hundred and fifty eight
Mesopelagic assemblage Biomass	11215547.9	Eleven million two hundred and fifteen thousand five hundred and fourty seven	52562242.3	Fifty two million five hundred and sixty two thousand two hundred and forty two	63777790.2	Sixty three million seven hundred and seventy seven thousand seven hundred and ninety

4.3 Discussion

This present study provide a baseline information on distribution and abundance of myctophids in the poorly studied tropical waters of Eastern Arabian Sea and Equatorial waters and also give insights to the major hydrographic factors influencing them. A glimpse to the extent of myctophid distribution and biomass in the Eastern Arabian Sea and WEIO are provided, although we were not able to cover the entire WIO.

Highest biomass from NEAS (76836.50 kg/km^2 and 60212.7 kg/km^2) were obtained from 17°56.77N lat 70°65.2E long and 20°08.67 N lat, 68°40.1E long during winter monsoon night operations. From SEAS high biomass of 115816.14 kg/km^2 was obtained from station 8°59.820 N lat and 75°55.3 E long during day time of summer monsoon season.

4.3.1 Regional Variations in species assemblages of Myctophids:

Eco-regions are the areas of ocean that contain geographically distinct assemblages of natural communities and species (Spalding *et al.,* 2007). Eco-regions of global oceans near surface are identified into distinct provinces on the basis of regional primary productivity and oceanography (Longhurst 2007), whereas bio-geographical classification of the deep-pelagic ecosystems in the mesopelagic zone is based on available biotic and abiotic datasets. The biogeographic classification depicts the daytime distribution of large scale mesopelagic faunal communities, based on which 33 eco-regions are recognized world over. Of the 33 eco regions recognized, 20 are oceanic while 13 are distant neritic (Beklemishev 1971). As per the classification adopted by Sutton *et* *al.,* 2017, the North Indian Ocean (NIO) have 3 distinct neritic eco-regions namely; the Arabian Sea (eco-region-14) encompassing the seas around Arabian Gulf, Iran, Iraq, Pakistan and the offshore waters of NEAS; the Somali current (eco-region- 16) representing the seas off Somalia extending towards the Central Arabian Sea; the Northern Indian Ocean (eco-region-17) representing northern part of South Equatorial Indian Ocean (SEIO), the NEIO, part of SEAS and the Indian coastal stretch of NEAS.

Analysis of presence / absence data on myctophid species from the Western Indian Ocean north of 15^0S through ANOSIM, PERMANOVA test and nMDS clearly depicts the presence of 3 distinct myctophid assemblages in the study area, representing the eco-regions NEAS, SEAS & WEIO. While the distributional pattern of the myctophid assemblages of WEIO & NEAS are consistent with the eco-regions 17 & 14 of Sutton *et al.,* 2017, the myctophid assemblage of SEAS is found to be significantly different from that of NEAS & WEIO. Based on Physical, chemical and biological attributes, Sanjeevan *et al.,* (2009, 2014) identified the SEAS (6^0 N to 16^0 N) as an Eastern Boundary Upwelling System (EBUS) distinct from the NEAS and the Lakshadweep Sea Ecosystem which lie south and south-west of SEAS.

4.3.2 Species similarity/ dissimilarity in eco-regions.

In the present study, the number of species obtained from WEIO were quite high (57 species) followed by SEAS (45 species) and NEAS (16 species). 92% of the observed similarity in NEAS are explained by 7 species. Observed dissimilarity between NEAS & SEAS are explained by 19 species and between NEAS & WEIO by 45 species. In the SEAS

12 species together contributed to 90% of the observed similarity. Together 45 species accounted for 75.75% of the dissimilarity between SEAS & WEIO. For the WEIO; 25 species out of the 57 species recorded accounted for 90% of the similarity and 45 species together accounted for the dissimilarity between SEAS & WEIO.

Among the 59 species recorded from WIO in the present study, 16 species were represented in all the 3 eco-regions. Species common to NEAS, SEAS & WEIO are given at para.4.2.4. These species therefore are expected to have wide geographical distribution and possibly may have better ability to tolerate wide range of environmental conditions. There are 25 species common to SEAS & WEIO [include WEIO (6^0N to 6^0S) and the area south of 6^0S up to 15^0S both of which have similar species assemblages, but are not represented in the NEAS. Details of these species are given at para. 4.2.4 (Species common to SEAS & WEIO). Since these species occupy both SEAS & WEIO, but are not represented in the NEAS, these species may have lesser range of environmental tolerance, as compared to the species occupying all the three eco-regions. It is interesting to note that 13 out of these 25 species fall under the Genus Diaphus. There are 14 species that are exclusive to WEIO and not represented in NEAS & SEAS and two species that are exclusive to SEAS (para.4.2.4, species restricted to eco-regions) indicating that these species have rather narrow tolerance limits to changes in environment.

Along the Western Indian Ocean, species distribution of myctophids have been studied off South Africa (Grindley and Penrith 1965; Hulley 1972) and off Kenya and Somalia (Kotrhavs 1972;

Gjosaeter 1981 a, b). Species recorded through these studies include *Benthosema fibulatum, B. pterotum, Hygophum hygomii, Myctophum spinosum, M. obtusirostre, M. asperum, M. aurolaternatum, Symbolophorus evermanni, Diaphus garmani, D. nielseni, D. watasei, D. suborbitale, D. thiollierei, D. perspicillatus* and *Lampanyctus sp.* The most abundant species were *Benthosema fibulatum*, followed by *Diaphus perspicillatus. D. nielseni* was also fairly common in the catches. *Diaphus watasei* was often abundant in bottom trawl catches. Nafpaktitis and Nafpaktitis (1969) and Nafpaktitis (1978) reported highest diversity of mid-water fish in the intermediate depths of equatorial waters between 0 ° and 10°S, while samples collected further north between 15°N and 18°N in the Arabian Sea contained only about a quarter of the fish species observed near the equator.

Menon (2002) reported the presence of 27 species in the Indian Ocean between 6°-21° N lat. and 67°-76°E long. *Benthosema fibulatum, Benthosema pterotum, Bolinichthys longipes, Diaphus aliciae, Diaphus fragilis, Diogenichthys panurgus, Lampanyctus turneri* and *Myctophum aurolaternatum* were widely distributed (6°-21°N lat; 67°-76°E long). Distribution of one species (*Hygophum proximum*) was restricted to south of 15° N whereas 18 species viz, *Centrobranchus sp., Ceratoscopelus warmingii, Diaphus lucidus, Diaphus perspillatus, Diaphus phillipsi, Diaphus problematicus, Diaphus signatus, Diaphus watasei, Hygophum reinhardtii, Lampadena sp., Myctophum asperum, Myctophum fissunovi, Myctophum nitidulum, Myctophum obtusirostre, Myctophum selenops, Myctophum spinosum, Symbolophorus evermanni* and *Symbolophorus rufinus* were restricted to north of 15°N lat. This study reports higher diversity of myctophid species between 6°-10° N lat and 73°-75° E long, with more than ten species.

Kinzer *et al*., (1993) reported the presence of 11 species of myctophids viz., *Benthosema fibulatum, Benthosema pterotum, Bolinichthys longipes, Diaphus arabicus, Diaphus lobatus, Diaphus thiollierei, Diogenichthys panurgus, Hygophum proximum, Lampanyctus macropterus, Myctophum aurolaternatum* and *Symbolophorus rufinus*, from 18°- 24°30'N lat; 62°- 67°E long in the Arabian Sea. *Diaphus arabicus* was the dominant species between 18° and 24°N in the Arabian Sea, contributing 66-73% of the myctophid catch in terms of numbers.

Forty four species of myctophids recorded in the north western Indian Ocean are reported from south of 4°N lat. The basic species of this community *Triphoturus sp., D. jenseni* and *D. malayanus* constitute 35.2% of all the lantern fishes in numbers. The predominant ones in biomass are *Ceratoscopelus warmingii, D. fragilis and D. perspicillatus* which together make up 40.3% of the total biomass of myctophids. *D. luetkeni, D. problematicus, D. richardsoni, D. suborbitalis, D. splendidus, Lampanyctus turneri, L. nobilis, L. intricarius and Myctophum selenops* of the genera *Centrobranchus* and *Lampanyctus* were encountered only south of 4 °N lat. *Diaphus brachycephalus* were recorded in the north-western part of the ocean (0 - 4°N). The species *Myctophum lunatum* was encountered in the 0-5 °N lat, 54-60° E long of Indian Ocean. *Myctophum asperum* was considered to be endemic in the seas of the Indo-Malayan archipelago. Most of the specimens of *Myctophum lunatum* were caught south of 4°N and totally replaced by *Myctophum asperum.* North of 4-5°N lat. *Benthosema fibulatum* predominates the catches. Karuppasamy *et al.,* (2006) reported 28 species of myctophids in the DSL of Indian EEZ of Arabian Sea with higher species diversity in tropical and subtropical latitudes. Observations on the mesopelagic fishes in the equatorial region (03°S-03°N lat , 76°-86°E long) of Indian Ocean (Jayaprakash, 1996) shows that the average catch of myctophids was higher in the southern side of the equator as compared to the northern side. The myctophids constituted 61.3% of the mesopelagic samples from this region. Species such as *Diaphus effulgens, Symbolophorus rufinus, Myctophum spinosum, Lampanyctus pusillus, Lobianchia gemellarii, Triphoturus nigrescens* and *Ceratoscopelus war mingii* were present between 03°S to 03°N, while *Diaphus perspicillatus, Diaphus splendidus and Myctophum phengodes* were limited to northern latitudes (0-3°S) and *Symbolophorus evermanni* and *Bolinichthys photothorax* were limited to southern latitudes (0-3°S). Among the myctophids of north western Indian Ocean, three species have a wide tropical range viz, *Lampanyctus alatus, Notolynchus valdiviae* and *N. candispinosus*. Three species have distant-neritic tropical type of range *viz Benthosema fibulatum, B. pterotum* and *Diaphus regani*. The rest of the myctophid species are confined to the central and equatorial water masses. *Notolynchus valdiviae, Lampanyctus nobilis* and *Lampedna luminosa* are circum-tropical species. Twenty nine species of myctophids from 14 genera are reported from north of 4° N lat. *Lampanyctus macropterus, Triphoturus sp., Hygophum proximum* and *Diaphus nielseni* together constitute 52.9% of the myctophid numbers. *Lampanyctus macropterus* is the most abundant species (18.1%) in number. By biomass the dominant ones are *H. proximum* (17.9%) and *Diaphus signatus (17.2*%) which together constitute 35.1 % of catch (Tsarin 1983). *Benthosema pterotum* was the dominant species in the Western and Northern Arabian Sea, followed by *Benthosema fibulatum* and *Diaphus spp.* (Gjosaeter, 1977). Most of the *Diaphus jenseni* are found south of 4°N and are replaced by *D. malayanus* north of 4 °N lat (Becker & Borodulina 1978, Nafpakitis 1978). Nair *et al.,* (1999) reported the presence of myctophid larvae in the DSL of Arabian Sea and in the upper layers of the open ocean between 15° and 21° N. *Diaphus arabicus* formed 80% of the myctophid larvae, *Benthosema pterotum* 15 % and *Benthosema fibulatum*, 5%.

4.3.3 Myctophid assemblages & Environment.

Environmental variations that influence species assemblages are characterised through CCA analysis. The relationships between biological assemblages of species and their environment are best established by the CCA which is a multivariate analysis (Braak and Verdonschot 1995). CCA visualizes the differential habitat preference (niche) of taxa through an ordination diagram by extracting from the measured environmental variables, synthetic gradients (ordination axes) that maximize niche separation among species. Niche separation is expressed as the weighted variance of species centroids (weighted average of the gradient value of the sites at which the species occurs). The primary result of a CCA is an ordination diagram where the coordinates of the site points are the values (scores) of the sites on the two best synthetic gradients (axes-1 &2). Derived quantitative variables run from the origin (centre) of the diagram outward. In the ranking the origin (0, 0) indicates zero correlation.

Among the 5 environmental variables selected for CCA correlations are mainly explained by the DO with density also showing positive correlation with species assemblage. Species assemblages of sites in the present study are best explained by tolerance range of species to low oxygen levels. WEIO assemblages are characterised by species assemblage that need higher DO, whereas the assemblage of SEAS is dominated by species that can tolerate intermediate levels of DO as compared to WEIO & NEAS. NEAS on the other hand is occupied by species that tolerates very low DO levels.

Data collected in the course of the present study clearly depict seasonal and regional variations in the environmental variables especially the DO and density. Sub surface DO levels are high in the WEIO and show a decreasing trend towards north. Water Density is high in the north and decreases towards south (Table 4.10). The WEIO is characterized by the presence of low temperature (9.5), low saline (34.82) and less dense waters (26.98 at 500m depth) with higher DO (1.66 ml/L) levels all through the year. Presence of Antarctic Bottom Waters in the WEIO is mainly responsible for these conditions (Haine et al., 1998). The sub-surface water characteristics of SEAS vary with seasons. SM in SEAS is characterized by moderate coastal upwelling (Habeebrehman 2008; Muraleedharan and Kumar 1996; Kumar 2006; Smitha *et al.,* 2008) and strong offshore Ekman transport influenced by the offshore propagating Rossby waves associated with the coastally trapped Kelvin waves (Smitha *et al.*, 2008). The Upsloping of bottom waters enhanced through the upwelling mode of Kelvin make the intermediate depths (500m depth) of SEAS low in oxygen (0.15ml/L) content and high in density (27.03). The oxygen deficiency in the intermediate depths (500m) during WM & SIM are mainly due to the decomposition of organic matter exported from the euphotic zone (Smitha *et al.,* 2008). However DO levels at 1000m depths are relatively higher. In the NEAS perennial suboxic (DO <0.2 ml/L) conditions persist in the intermediate water columns (500 & 1000m depths) during all the 3 seasons, as these waters are occupied by the dense Arabian Sea

High Saline Waters (ASHSW) and Persian Gulf Waters (PGW) that are poor in DO (Kumar and Prasad 1999, Prasad *et al.*, 2001).

The environmental settings and physical forcing mechanisms prevailing the WEIO, SEAS & NEAS are explained in Chapter-1. Species that prefer highly Oxygenated waters with relatively low temperature and salinity and high density (WEIO waters) include *Bolinichthys pyrsobolus, Diaphus aliciae, Diaphus coeruleus, Diaphus diadematus, Diaphus effulgens, Diaphus fragilis, Diaphus jenseni, Diaphus luetkeni, Diaphus splendidus,* and *Symbolophorus rufinus.* The species associated with intermediate levels of Oxygen, temperature, salinity and density (SEAS) are *Benthosema pterotum, Bolinichthys indicus, Diaphus garmani, Diaphus perspicillatus, Diaphus luetkeni, Diaphus perspicillatus, Diaphus problematicus Diaphus similis, Diaphus lobatus, Diaphus lucidus, Diaphus thiollierei, Lampanyctus turneri, Myctophum spinosum* and *Symbolophorus evermanni.* The species which can thrive under low Oxygenated waters with relatively high temperature and salinity (NEAS) are represented by *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus signatus, Myctophum asperum, Diaphus arabicus,* and *Hygophum proximum.*

Hulley (1981) studied the taxonomy and zoogeography of 124 myctophid species giving their distribution and some information on temperature limits. The association of *Myctophum selenops and Notolynchus valdiviae* with warm waters that we obtained in this study was also reported by Hulley (1981) who suggested that adult *Myctophum selenops* distribution is associated with warm water gyre systems in the Atlantic Ocean. The association of *Benthosema suborbitale, Myctophum* *affine, Dampanyctus dumerilii* and *Lampanyctus guentheri* with low temperatures are consistent with the results obtained by Hulley (1981). Adults of *B. suborbitale* avoid warmer and more saline waters in its tropical distribution, and highest abundances of this species were recorded in temperatures between 15 and 17.5°C in the northern Sargasso Sea (Hulley 1981). Adults of *Lampanyctus guentheri* have a shallower distribution at night and have a relationship with low temperatures (15°C) at 200 m in the western North Atlantic (Hulley 1981). *Myctophum affine* distribution is limited to isotherm 15°C and *Diaphus dumerilii* is absent from the minimum region of high temperature off Brazil and *D. splendidus* is limited to 18 °C and *Myctophum nitidulum* is associated with warm water currents, but along the Brazilian coast *Diaphus splendidus* was related with warmer water while the *M. nitidulum* was more abundant in low temperatures (Hulley 1981).

The extreme oxygen deficiency of the Arabian Sea at mid depth has been well documented (Dietrich *et al.,* 1966; Wyrtki 1973; Swallow, 1984; Qasim 1982; Sen Gupta and Naqvi 1984). According to Nafpakits and Nafpakits (1978) *D. arabicus and D. lobatus* "seem to be restricted to anoxic waters of the Arabian Sea". Similar avoidance by some myctophid species of O_2 minimum layers was noted by Wisner (1974) from the eastern Pacific Ocean. Species such as *Diaphus arabicus* and *Benthosema pterotum* appear to be particularly adapted to low oxygen conditions in the northern Arabian Sea (Goodyear and Gibbs 1969). Among the genus *Diaphus, only D. arabicus, D. thiollierei and D. lobatus* seem to tolerate the O_2-deficient waters (Nafpaktitis 1978; Kinzer 1993).

4.3.4 Distribution & Abundance:

The largest concentration of myctophid is reported from the Indian Ocean, particularly in the northern Arabian Sea including the Gulf of Aden, the Gulf of Oman and the coast of Pakistan (Gjosaeter 1981a, 1981b, 1981c, 1984; Shilat and Valinassab, 1998; Jayabalan, 2011). Results of the present study have shown that the myctophid species diversity of SEAS (45 species) is much higher compared to NEAS (16 species). The biomass of 9.21 million tons estimated for the NEAS through the present study is contributed by 7 species of Diaphus (40%), 2 species of Benthosema (31%) one species each of Bolinichthys (21%) and Ceratoscopelus (7%). These 11 species account for 99% of the myctophid biomass of NEAS. On the other hand, the estimated biomass of 8.69 million ton of myctophid in the SEAS is supported by 29 species. The catch per unit area of the most abundant species (*Benthosema fibulatum*) show sharp decrease from 36677 Kg/Km^2 (NEAS) to 29939 kg/Km^2 in SEAS which implies that with increase in species diversity the dominance of any species in the total biomass gets reduced.

Highest abundance of myctophids in NEAS (17° N, 20°N Lat and 70° and 68°E Long) was during January and in SEAS high abundance was obtained during the month of October (5°N and 69°E). In WEIO, abundance was high during the month of September. Raman and James (1990) study, on distribution and abundance of myctophids in the EEZ of India using IKMT as sampling gear, showed that myctophids form 31% of the total fish biomass in the DSL of Eastern Arabian Sea. They reported peak abundance of myctophids in waters along 69°30’E longitude and 18°30’N to 21°30’N latitudes and in the waters north of 15° N between 68° and 73° E longitudes where the OMZ prevails most. Highest number of myctophids (1092 per hour IKMT haul) was recorded from a station off Northern Arabian coast (23°30'N; 65°00'E). The myctophids formed about 72% and showed wide distribution covering major parts of the near shore, offshore and oceanic regions. The abundance of myctophids varied in waters north and south of 15°N lat. Off northwest coast myctophids formed about 53.4% of the fish biomass in the DSL and dominance was noticed in certain pockets along the Ratnagiri- Mormugoa areas (15°-17° N), off Bombay (19°-20°N) and in the northern Arabian waters (23°30'N). Off southwest coast, myctophids were about 46% of the total fish biomass of the DSL (Raman and James1990) and the density was maximum along the continental slope waters near Mangalore and off Cochin areas. Highest number in the IKMT catches (1548 myctophids per hour) using IKMT, was recorded from a station (9°30'N 74°00' E), off Cochin. Studies by Menon (2004), has shown maximum abundance along west coast as 10.4 g 1000m^{-3}, between 19º and 20°N during day time IKMT hauls.

4.3.5 Day/night and seasonal variations

Results of the present study show that myctophid biomass is comparatively higher in NEAS than the SEAS. In NEAS maximum biomass was obtained in Night hauls whereas in SEAS the myctophid biomass was highest in Day hauls. However, night sampling was less in SEAS as compared to NEAS. Aron (1962) found that regardless of depth, night hauls caught substantially greater biomass than day hauls. The cause of this difference may be due to the migration of fishes to greater depths beyond the range of net. Another possibility may be due to better escapement and greater scatter during day (Raman and James 1990).

Diel vertical migration of mesopelagic organism is recognized today as the biggest movement of biomass on earth (Hays 2003), with major consequences for ecology (Ramirez-Llodra *et al.,* 2010) and biogeochemical cycling (Robinson *et al.,* 2010). Mesopelagic migrators are believed to be an important component of the biological pump, since they feed near the surface during the night and defecate at depth during day (Robinson *et al.,* 2010). As per FAO (1998) during the day the DSL migrate down to 200-400m depth but after sun set they migrate towards the surface. The main food of lantern fishes are zooplanktons and therefore these dial migrations are probably for eating the zooplanktons. The upper layers of the DSL in north western Indian Ocean is occupied by *Diaphus nielseni* which probably rise closer to the surface than any other myctophid species. *Diaphus fragilis, Bolinichthys longipes* and *Notolychnus valdiviae* occupy greater depths. *Diaphus problematicus, Diaphus richardsoni, Diaphus signatus*, majority of *Lampanyctus* species and large myctophids such as *Diaphus fragilis* and *Ceratoscopelus warming* predominate the medium depths. Species of *Diaphus and Lampanyctus* predominate at the lower depths (Tsarin 1983).

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

May), 1.94 g 1000m^{-3} in the post-monsoon season (October-January) and lowest in the monsoon period (June-September). Gjosaeter (1977) reported higher abundances in spring than the summer and the autumn cruises. In the Arabian coast and the oceanic area between 20° and 24°N, *Benthosema pterotum* was the dominant species in autumn, whereas *Benthosema pterotum* and *Benthosema fibulatum* were about equally abundant in early spring (Gjosaeter 1977). In the Gulf of Aden, West of 47°E, *Symbolophorus evermanni* was the dominant species in autumn, whereas *Benthosema pterotum* was abundant in spring and summer (Gjosaeter 1977). *Benthosema pterotum* is one of the most common and numerous species in the western (Gulf of Oman-Somali region) and the eastern (along west coast of India) Arabian Sea and is also the largest single species stock of fish in the world (Gjosaeter 1984; U.S GLOBEC 1993; FAO 1997a,b; Valinassab *et al.,* 2007; Karuppasamy *et al.,* 2008a). In the eastern Arabian Sea, *Diaphus arabicus* and *Hygophum proximum* are common forms (Gjosaeter 1984; Kinzer *et al.,* 1993; FAO 1997a,b).

4.3.6. Biomass of myctophids in the Eastern Arabian Sea: Using Swept Area method, the present study estimated the biomass of myctophids in EAS to be 17.90 million tons. Myctophids contribute 28.07% of the DSL biomass of EAS (63.78 m tonnes). Myctophid biomass of NEAS (9.21 m ton) is higher than that estimated for SEAS (8.69 m tonnes). In NEAS myctophids form 82.75% of the DSL biomass (11.22 m tonnes), whereas in SEAS it contributes to only 16.53% of the DSL biomass (52.26 m tonnes).

Mid water trawls has been reported to be appropriate for catching myctophids based on various reviews regarding scattering areas, habit and ecology of the resources (Anon, 1998). The estimated biomass of EAS including both NEAS and SEAS is 17 million tonnes dominated by the genus Diaphus. However, the most abundant species in NEAS and SEAS is found to be *Benthosema fibulatum*. In NEAS myctophid was abundant at 18°N and 70º E and in SEAS at 8°59N and 71ºE. Sebatine *et al.,* (2013) reported myctophids in the by catch of deep sea shrimp trawlers off Kollam and off Kasargode, along the south-west coast of India (8º 20' - 12° 38' N; 74º 20' - 76° 25' E) with an annual average landing of 2667 t of myctophids during 2009 – 2011.

Studies by Central Marine Fisheries Research Institute (CMFRI), Cochin on Deep Scattering Layers in the India EEZ (1997-2002) using Isaac-Kidd Midwater Trawl (IKMT), estimated a biomass of 100,000 tonnes of myctophids mostly dominated by *Diaphus sp*. Myctophid biomass along the Indian EEZ of Arabian Sea is dominated by Diaphus spp (Balu and Menon 2006). *Diaphus watasei* and *Diaphus luetkeni* were the abundant species in the deep sea trawler by catch off the southwest coast of India followed by *Myctophum spinosum* and *Myctophum obtusirostre* (Boopendranath *et al.,* 2009). Contribution of myctophids was 17% in the Bay of Bengal in which northeast coast contributed 35%, and southeast coast 64%. Abundant stocks of Myctophids are reported in the Gulf of Oman and off North Africa (Haque *et al.,* 1981).

The biomass estimates of *Benthosema pterotum* in the Oman Sea (Iranian waters) range from 1 to 4 million tonnes with an average of 2.3 million tonnes. Highest densities were seen in the Western Oman Sea and this resource has been suggested as a target for commercial exploitation (Valinassab 2005; Valinassab *et al.,* 2007, 2013).

Boopendranath *et al.,* (2009) and Pillai *et al.,* (2009) have reported that myctophids are the major component in the by-catch of deep sea shrimp trawlers operating off Kerala. Gjosaeter (1977) reported a catch rate of 20 t h^{-1} of myctophids from the seas off Oman (20°-24°N lat and 57°-67°E long) at a depth of 130 m during day time using a pelagic trawl and catches exceeding 400 kg h^{-1} from several stations located in north-western Arabian Sea (0°-26°N; 43°-67°E long). Acoustic survey's indicates a regular four-fold variation in stock size of myctophid fishes as compared to trawl catches. Acoustic methods are considered more reliable for estimation of biomass of mesopelagic fish (Benoit-Bird *et al.,* 2001). One of the reasons for this, could be that the fishes show net avoidance by detecting the gear visually or by sensing turbulence in water. (Benoit-Bird *et al.,* 2001; Yasuma *et al.,* 2006). However, Target Strength (TS) data for myctophids are currently very limited (Koslow *et al.,* 1997; Benoit-Bird *et al.,* 2001; Yasuma *et al.,* 2003).

4.3.7. Myctophid Fishery. Available information on stock abundance of mesopelagic indicates that there is enormous scope for development of this fishery in the Indian Ocean particularly in the Arabian Sea (Gjosaeter and Kawaguchi 1980; Gjosaeter 1984; Raman and James 1990; GLOBEC 1993). Though mesopelagic fish stocks are known to be abundant in the world oceans, few countries have commercial fisheries targeting myctophids. The Sultanate of Oman has initiated commercial fishery of mesopelagic fishes from Persian side of Oman Sea, exclusively for fish meal production in Iran (Shaviklo 2012). The mesopelagic fish estimates for South African area is 5.5-8.5 million tonnes.

Commercial fishing trials on myctophids during 1995–1998 using a pelagic trawls, reported average catches of 24 to 28 tonnes day^{-1} from Iranian waters (Valinassab *et al.,* 2007) Average catch of myctophids In the trial commercial fishing on myctophids in Oman waters (in 1996) average catches of 20 tonnes day^{-1} were obtained (Valinassab *et al.,* 2007). The former Soviet Union began a trawl fishery in 1980 at the Antarctic Polar Front for *Electrona carlsbergi,* with annual catches initially varying between 500 and 2500 tonnes. Harvesting continued up to 1993, but at that point it was no longer considered economically viable (ASOC 1996; Kock 2000). Around South Georgia and Shag Rocks, experimental fishing of *Electrona carlsbergi* between 1988 -1990 gave average annual yields of 20 000 t year^{-1} which increased to 78 488 t in 1991 (Hulley 1996). Limited exploitation also occurs off South Africa, where annual purse-seine landings of *Lampanyctodes hectoris* are between 100 and 42400 tonnes.

Majority of the myctophids are not used for direct human consumption due to their high lipid or wax ester content, but are used as predator fish feed, poultry feed, animal feed and crop fertilizers (Lekshmy *et al.,* 1983; Balu *et al.,* 2006). Exceptions are *Diaphus coeruleus*, *Gymnoscopelus nicholski* and *G. bolini* which are considered edible. Fishery for these species existed in the Southwest Indian Ocean and Southern Atlantic in the late 1970's (Nafpaktitis 1982; Hulley 1985; FAO 1997; Balu *et al.,* 2006). Commercial fishing of myctophids exclusively for fish meal production by an onshore fish processing company in the Qeshm Island located in the Persian Gulf, Iran, is also reported. Globally, several attempts have been made to utilize myctophids for human food. Some successful projects were carried out in Iran for processing myctophids to food products (Shaviklo 2012). There is no targeted fishery for myctophid fishes in India, but studies report landing of myctophids as by catch of deep sea shrimp trawlers (Boopendranath *et al.,* 2009; Pillai *et al.,* 2009; Sabastine *et al.,* 2013).

Table 4.10 : Range of DO, Density, Salinity and Temperature of NEAS, SEAS and WEIO in SM, WM and SIM from different depths- Surface, 100m, 500m and 1000m

Depth (m)	DO(ml/l)			Density			Salinity (PSU)			Temperature (°C)		
	SM	WM	SIM	SM	WM	SIM	SM	WM	SIM	SM	WM	SIM
	Range	Range	Range	Range	Range	Range	Range	Range	Range	Range	Range	Range
						NEAS						
S	3.20-4.47	4.42-4.54	4.50-4.86	23.83-23.94	23.23-24.35	23.81-24.28	36.54-36.81	35.76-36.45	36.26-36.47	27.15-27.51	24.78-27.16	25.55-25.67
100	0.5-2.39	0.50-2.95	3.00-3.78	20.64-25.56	24.52-24.99	24.25-24.91	35.88-36.42	35.73-36.41	36.16-36.54	19.50-22.44	21.22-24.04	23.17-24.90
500	0.038-0.042	0.043-0.046	0.043-0.046	27.03-27.05	27.00-27.05	27.02-27.04	35.64-35.74	35.60-35.80	35.77-35.82	12.18-12.43	12.14-13.00	12.76-13.02
1000	0.066-0.096	-9.99E-0.07	-9.99E-0.056	27.45-27.47	27.46-27.48	27.12-27.45	35.76-36.45	35.31-35.40	35.41-35.70	8.25-8.47	8.25-8.89	8.95-9.44
						SEAS						
S	4.37-4.43	4.10-4.35	4.05-4.12	23.45-23.48	20.97-23	20.98-21.74	36.56-36.59	33.59-35.77	34.35-35.29	28.28-28.42	27.72-29.08	30.59-30.67
100	0.40-0.82	1.64-3.52	1.38-1.98	24.81-25.11	22.90-24.3	23.74-24.10	35.84-36.09	35.93-36.21	35.51-36.04	21.06-22.80	24.63-28.44	23.77-25.56
500	0.13-0.17	0.04-0.35	0.08-0.39	270.2-27.04	26.90-27.07	27.00-27.03	35.23-35.36	35.20-35.55	35.51-36.04	10.87-11.08	10.62-11.27	10.46-11.37
1000	0.43-0.48	0.26-1.00	0.44-0.80	27.41-27.42	27.11-27.64	27.39-27.45	35.16-35.32	35.02-35.43	35.00-35.15	7.72-7.87	7.31-8.15	6.79-7.51
						WEIO						
S	3.83-3.89	-	-	21.7-22.43	-		34.70-35.49	-	-	28.45-29.86	-	-
100	0.73-2.61	-	-	24.4-25.60	-		35.17-35.42	-	-	17.16-21.15	-	-
500	0.9-2.10	-	-	26.97-27.01	-		34.82-32.21	-	-	8.95-10.76	-	-

4.12 : Range of environmental parameters of species taken from DSL depth of three areas

Sl no	Species list for CCA	Species code	NEAS	SEAS	EIO	Depth (m)	Salinity (PSU)	Density	Temp (°C)	DO (ml/l)
1	*Benthosema fibulatum*	Ben fib	p	p	p	84-391	34.8-36.5	24.03-26.9	9.5-29.5	0.042-2.66
2	*Benthosema pterotum*	Ben pte	p	p	p	84-502	34.8-36.5	22.9-27.05	9.7-27.6	0.042-3.16
3	*Bolinichthys longipes*	Bol lon	p	p	p	95-502	34.8-36.59	22.19-27.05	9.5-29.5	0.042-3.902
4	*Bolinichthys indicus*	Bol ind	a	p	p	40-400	34.9-35.4	22.19-26.8	10.9-29.5	0.063-3.9
5	*Bolinichthys pyrsobolus*	Bol Pyr	a	p	p	304-502	35.2-34.9	26.7-27.05	9.7-10.9	0.62-2.3
6	*Ceratoscopelus warmingii*	Cer war	p	p	p	84-502	34.8-36.5	23.7-27.05	9.7-25.25	0.06-3.12
7	*Diaphus aliciae*	Dia ali	a	p	p	100-502	34.8-36.5	25.1-26.9	9.5-19.2	0.4-3.12
8	*Diaphus antonbruuni*	Dia ara	p	p	p	100-502	34.8-35.2	25.1-26.9	9.5-19.24	1-2.25
9	*Diaphus arabicus*	Dia ant	a	a	p	95-502	34.8-35.19	24.03-26.9	10.69-25.25	0.042-2.66
10	*Diaphus brachycephalus*	Dia bran	a	p	p	100-350	35.19-36.59	25.1-26.8	10.9-19.2	0.44-3.17
11	*Diaphus coeruleus*	Dia coe	a	p	p	99-502	34.9-35.9	25.2-26.8	10.69-19.29	0.1-2.08
12	*Diaphus effulgens*	Dia eff	a	p	p	100-500	35.04-35.37	25.1-26.8	25.1-26.8	0.44-.12
13	*Diaphus fulgens*	Dia flu	a	p	p	40-502	34.8-35.2	22.1-27.05	22.1-27.05	0.6-3.17
14	*Diaphus fragilis*	Dia fra	p	p	p	100-502	34.9-35.48	22.9-26.9	22.9-26.9	0.04-3.17
15	*Diaphus garmani*	Dia gar	p	p	p	55-500	34.8-36.3	22.9-27.05	22.9-27.05	0.04-3.59
16	*Diaphus Jenseni*	Dia jen	p	p	p	55-502	34.8-35.9	22.9-26.9	22.9-26.9	0.08-2.20
17	*Diaphus lobatus*	Dia lob	a	p	p	40-502	34.8-35.9	22.1-26.9	22.1-26.9	0.10-3.9
18	*Diaphus lucidus*	Dia luc	p	p	p	40-500	34.8-35.9	22.19-27.05	22.19-27.05	0.06-3.9
19	*Diaphus luetkeni*	Dia lut	a	a	p	220-502	34.9-35.4	26.01-26.9	9.5-16.2	0-3.17
20	*Diaphus mollis*	Dia mol	a	p	p	100-403	34.9-35.57	22.94-26.82	11.5-27.6	0.06-3.17

21	*Diaphus parri*	Dia par	a	p	p	55-502	34.9-35.9	22.9-27.05	10.1-28.6	0.4-3.5
22	*Diaphus perspicillatus*	Dia per	a	p	p	84-502	34.8-35.3	25.1-26.9	9.5-20.09	0.10-3.12
23	*Diaphus problematicus*	Dia pro	a	p	p	100-502	34.9-35.19	25.1-26.9	10.6-19.2	1-3.12
24	*Diaphus similis*	Dia sim	a	p	a	55-500	34.8-36.5	22.9-27.05	11.3-20.09	0.1-1
25	*Diaphus signatus*	Dia sig	p	p	p	84-400	35.1-35.37	25.1-26.8	9.5-28.6	0.1-3.59
26	*Diaphus splendidus*	Dia spl	a	p	p	100-502	34.8-35.2	25.1-26.9	9.5-19.2	0.4-2.3
27	*Diaphus tangii*	Dia tan	a	p	p	40-502	34.9-35.5	22.1-26.9	10.6-29.5	1-3.9
28	*Diaphus thiollierei*	Dia thr	p	p	p	40-400	34.9-36.5	22.19-26.8	10.9-29.5	0.06-3.90
29	*Electrona risso*	Ele ris	a	a	p	100-502	34.8-35.19	25.1-26.9	9.7-19.24	1-2.47
30	*Hygophum proximum*	Hyg pro	p	p	p	100-350	34.9-36.2	24.7-26.8	10.9-23.5	0.08-2.3
31	*Lampanyctus turneri*	Las tur	p	p	p	40-502	34.8-36.3	22.19-27.05	9.52-29.5	0.06-3.9
32	*Lampadena urophaos*	Laa uro	a	p	p	150-502	34.8-35.2	25.6-26.9	9.7-16.8	0.4-2.4
33	*Myctophum asperum*	Myc asp	a	p	p	40-502	34.8-35.3	22.19-27.05	9.5-29.5	0.4-3.9
34	*Myctophum aurolaternatum*	Myc aur	a	p	p	150-502	35-35.22	25.6-26.9	10.69-16.8	0.4-2.47
35	*Myctophum obtusirostre*	Myc obt	a	p	p	55-300	35-35.9	22.1-26.6	11.58-29.5	0.2-3.9
36	*Myctophum spinosum*	Myc spi	p	p	p	55-502	34.9-36.5	22.9-27.05	10.14-28.63	0.06-3.59
37	*Symbolophorus evermanni*	Sym eve	p	p	p	100-400	34.8-36.5	24.1-26.8	9.7-25.2	0.042-3.9
38	*Symbolophorus rufinus*	Sym ruf	p	p	p	55-502	34.8-35.9	23.9-26.9	9.7-28.6	0.2-3.17

Chapter 5

BIOLOGY OF MYCTOPHIDS

5.1 Introduction

Myctophid fishes are important components in oceanic ecosystems (Gjoaeter and Kawaguchi, 1980), and dominate the micronektonic-mesopelagic fish community (*Yatsu et al., 2005*), occurring throughout the world's oceans (Robison 1984). Morphology and taxonomy of mesopelagic fishes (Huang and Yang 1983; Yang *et al.*, 1996) are well studied. Some specific studies dealt with their biology and diet by Gilbert and Cramer (1897) and Jiang *et al.*, (2017). However information on length-weight relationship, age and growth, spawning season, fecundity/ age at maturity and estimates of biomass which are required for sustainable utilization and management of myctophid resources of the Western Indian Ocean are scarce (Vipin 2016). Biological studies of myctophids are restricted to reports on few selected species that are commercially important (Valinassab *et al.,* 2007; Karuppasamy *et al.*, 2008; Shekarabi *et al.*, 2015). Biological attributes of myctophids such as Length-Weight Relationships, Relative Condition factor, food and feeding, reproductive biology are discussed in this chapter. Since simultaneous field observations of WEIO, SEAS and NEAS was not possible due to non-availability of the Research Vessel, data for regional and seasonal comparisons could not be gathered and therefore the biological studies are mostly restricted to specimens obtained in random surveys. Nevertheless, it is expected that the preliminary observations provided in this chapter on biology of myctophids from a data poor region (Western Indian Ocean-WIO) will be a useful contribution.

5.1.1 Length - Weight Relationship (LWR) and Relative Condition Factor (K_n):

Length - Weight Relationship (LWR) and Relative Condition Factor (K_n) of 20 species of myctophids from WIO are described. The species include *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus arabicus, Diaphus brachycephalus, Diaphus coeruleus, Diaphus fulgens, Diaphus garmani, Diaphus jenseni, Diaphus lucidus,, Diaphus perspicillatus, Diaphus thiollierei, Diaphus watasei, Hygophum proximum, Myctophum spinosum, , Lampanyctus turneri, Lampanyctus nobilis* from Eastern Arabian Sea and *Diaphus antonbruuni, Lampanyctus tenuiformis, Diaphus luetkeni* from WEIO. LWR allows estimation of fish weight and biomass based on length and vice versa (Liang *et al*., 2015; Xie 2015). It establishes the mathematical relationship between length and weight of fish (Beyer 1987) and is required to convert length into biomass, for determining fish condition, comparing fish growth in different environments and to complement studies on species-specific reproduction and feeding (Froese 2006). Additionally, knowledge on LWR is essential to assess fish stocks, fisheries, and environmental monitoring programs (Lizama and Ambrósio 2002; Froese *et al.,* 2011; Giarrizzo *et al.,* 2015). In the general parabolic equation $W= aL^b$ (Le Cren 1951), W of fishes is exponentially related to length, where “a” is the intercept and “b” is the log-transformed relation or the growth coefficient. For an ideal fish having isometric growth, growth coefficient (b) is expected to be 3 and is expressed by the Cube Law ($W= aL^3$). However, in nature the growth coefficient most often deviates from 3 as the body forms of fish and their growth patterns changes with sex, season, maturity stages and environmental conditions (Froese 2006). Fishes with “b” values <3 represent hypoallometric growth (Negative allometry) whereas fishes with b>3 represent hyperallometry (Positive allometry). Deviations in observed and estimated weight for length of fish denote the Relative Condition factor (K_n) of the fish (Le Cren 1951), represented by K_n = W/ W^, where W is the observed weight in grams and W^ is the weight calculated from length using the exponential equation.

5.1.2 Gut content analysis (GCA)

Myctophids are important components of marine food webs (Tyler and Pearcy 1975; Shreeve *et al.*, 2009; Cherel *et al.,* 2010), feeding on zooplankton and other pelagic organisms (Gjosaeter 1973b; Kinzer and Schulz 1985; Dalpadado and Gjosaeter 1987, 1988a; Giske *et al.,* 1990; Baliño and Aksnes 1993; Moku *et al.,* 2000; Shreeve *et al.,* 2009), while being a part of the diet of several piscivorous predators such as fish (Hansen and Pethon 1985; Giske *et al.,* 1990; Walker and Nichols 1993), cephalopods (Silas *et al.,* 1985), sea birds (Hedd *et al.,* 2009; Cherel *et al.,* 2010) and marine mammals (Doksaeter *et al.,* 2008). In order to reduce their predation risk from visually foraging piscivores, myctophids can stay in the dark waters of the mesopelagic zone throughout the day (Gartner Jr *et al.*, 1987; Collins *et al.*, 2008 b; Kaartvedt *et al.*, 2009). However, the mesopelagic zone may be inhospitable compared to the epipelagic zone due to abiotic and biotic factors, such as low prey abundance and low oxygen levels (Weikert 1982; Kinzer *et al.,* 1993). Planktivorous organisms, such as myctophids, can solve this trade-off by performing diel vertical migrations (DVM) (Holton 1969; Kinzer and Schulz 1985; Kinzer *et al.,* 1993; Scheuerell and Schindler 2003). Extensive work has been done on DVM in myctophids, mainly in relation to their diet, distribution of prey or swimming behaviour

(Clarke 1978; Kinzer and Schulz 1985; Moku *et al.,* 2000; Kaartvedt *et al.,* 2008; Dypvik *et al.,* 2012a, b).

Myctophid feeding has been mainly studied in adult and juvenile life stages (Tyler and Pearcy 1975; Gorelova 1978; Hopkins and Baird 1985; Young and Blaber 1986; Rissik and Suthers 2000; Watanabe *et al.*, 2002). The feeding habits of myctophids are closely linked to their vertical migratory behavior: (1) migration to the surface for feeding at night (epipelagic migrators; Gorelova 1975, 1983; Hopkins and Baird 1985; Watanabe *et al.,* 2002) and (2) migration and feeding within the mesopelagic depth range- mesopelagic migrators; (Clarke 1978; Kinzer and Schultz 1985; Hopkins and Gartner 1992). These differing behaviours are particularly evident in oligotrophic areas of tropical and subtropical oceanic regions (Clarke 1978; Hopkins and Baird 1985; Kinzer and Schultz 1985), where myctophid species feed in surface strata at night tend to segregate vertically. In productive areas or in high latitudes, the diel feeding cycles are less evident (Tyler and Pearcy 1975; Pearcy *et al.*, 1979; Young and Blaber 1986; Moku *et al.,* 2000). Species-specific migration patterns may reflect adaptations that reduce inter-specific competition when food resources are scarce (Kinzer and Schultz 1985; Hopkins and Gartner 1992). In productive areas (e.g. upwelling systems), a higher degree of overlap in distribution and feeding depth may be expected (Tyler and Pearcy 1975), although temporal segre gation has also been suggested (Young and Blaber 1986).

Previous dietary studies on midwater fishes (Hopkins and Baird 1985; Lancraft *et al.*, 1988; Hopkins *et al.*, 1996; Butler *et al.,* 2001; Pusch *et al.,* 2004) utilized gut content analyses (GCA) to determine trophic relationships. Generally, midwater fishes are divided into three major feeding guilds: zooplanktivores, which consume planktonic organisms such as amphipods, copepods and euphausiids; micronektonivores, which consume fishes and cephalopods; and generalists, which consume a variety of unrelated taxa (Gartner *et al*,. 1997). Unfortunately, as GCA only represents short-term diet (< 24 hours) it has disadvantages like (Hadwen *et al.,* 2007) placement into these feeding guilds could vary and may be inaccurate. Guild placement can be affected by dietary shifts resulting from changes in prey abundance, seasonality and ontogeny (Kawaguchi and Mauchline 1982; Young and Blaber 1986; Hopkins *et al.,* 1996; Beamish *et al.,* 1999; Williams *et al.,* 2001; Butler *et al.,* 2001). Additionally, accurate guild placement is not possible for specimens with empty stomachs which are common in midwater fishes (Gartner *et al.,* 1997). The advantage in GCA is that they provide detailed taxonomic data on consumed prey that is well preserved. GCA documents portion of the trophic structure that are consumed by mesopelagics as their diet (McClain-Counts 2017).

Numerous 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). The volumetric method is the best suited for carnivorous fishes and the gravimetric method for plankton feeders (James 1967a). As the myctophids are planktivorus fish composite index of the volumetric and numerical method gives a better picture of food contents (Sebastine 2014) and the method suggested by Natarajan and Jhingran (1962) known as 'the index of preponderance' is considered to be a good method where in the volume as well as the occurrence of each item found in the stomach is accounted (Sebastine 2014).

In the present study the Gut content analysis of eleven myctophid species collected from Eastern Arabian Sea viz *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus arabicus, D. jenseni, D. garmani, Lampanyctus turneri* and *Symbolophorus evermanni, Diaphus coeruleus, D. perspicillatus, D. watasei* were undertaken with the aim to understand the main diet of myctophids along this region.

5.1.3 Reproductive Biology of Myctophids.

The family myctophidae is diverse and is estimated to contain the greatest biomass of any vertebrate family in the world (Van Noord, 2013). Myctophids play an important role in the transfer of energy in pelagic ecosystems, linking planktonic organisms such as copepods, ostracods, and larvaceans to top predators (Cherel *et al.,* 2010), including fishes (Greer Walker and Nichols 1993), squids (Parry 2006), seabirds (Hedd *et al*., 2009), and marine mammals (Ohizumi *et al.,*2003). In spite of heavy predation pressure, myctophids continue to maintain a high abundance (Lisovenko and Prut'ko 1987) and so it is important to understand the factors that drive their population growth and specifically, the role that reproductive biology plays in this. (Lowerre-Barbieri *et al.,* 2011). The myctophids are dioecious and several genera exhibit sexual dimorphism. In a numerous genera's (e.g. *Benthosema, Hygophum* and *Myctophum*), males possess a supra-caudal luminescent gland just in front of tail on the upper surface of body, while females possess an infra-caudal gland in front of tail on lower surface. In the diverse genus *Diaphus,* most species have enlarged luminescent glands on their heads called supra-orbital glands or "headlights"), which are typically much larger in males. Males and females of the monotypic genus Notolychnus can be distinguished by the noticeably larger eyes of the males. Another pattern of dimorphism is found in some species such as *Ceratoscopelus warmingii* and *Electrona antarctica*, in which males are distinctly smaller than females at maximum size (Gartner 1993).

Myctophids are characterized by rapid growth rates, early sexual maturity, short lifespans and high mortality rates. Females are oviparous and both sexes are non-guarding pelagic spawners. They release eggs and seminal fluid into the water, where fertilization takes place. The tiny eggs 0.70 - 0.90 mm, with a segmented yolk, moderate perivitelline space, single oil globule and delicate chorion are made buoyant by lipid droplets. The fertilized eggs, embryos and the hatched larvae ~2.0 mm, drift at the mercy of the currents until they are developed (Balu and Menon 2006). The females typically produce 100–2000 unfertilized eggs per spawn (Balu and Menon 2006). But there are species with fecundity up to 25,800 per spawn (Flynn and Paxton 2012).Studies on the seasonality of reproduction in the Arabian Sea have found actively spawning individuals during all seasons but an increased spawning activity during the monsoon transition periods March-June and September-November have been reported (FAO 1997a,b; Balu and Menon 2006). Kawaguchi and Mauchline 1982 reported that larger myctophid species have higher fecundities.

Two basic reproductive patterns were noted in myctophids by Gartner (1993). 1) A protracted spawning season of 4 to 6 months duration, with individuals spawning every 1 to 4 days eg: *Benthosema* *suborbitale, Lampanyctus alatus, Lepidophanes guentheri* and *Notolychnus valdiviae*; 2) more restricted spawning periods which primarily occurred once or twice a year eg: Ceratoscopelus species and probably *Diaphus dumerilii*. Protracted spawners shared 1) bimodal oocyte size frequencies among the most advanced oocyte stages with both modes being nearly equivalent in frequency, a linear increase in fecundity with increasing length while 2) batch fecundities in the low hundreds to low thousands and an average life span of 1 year or less. Seasonally restricted spawners also exhibited bimodal oocyte size frequencies but with a greatly reduced frequency in the second mode, an exponential increase in fecundity with increasing size, batch fecundities in the high thousands to low ten thousands, and a life span of less than about 2 years. The energetic cost of maximum reproductive output at the maximum rate of spawning was about 30% of the daily assimilated caloric ration in the protracted spawner eg: *Lepidophanes guentheri*. This suggests that mycto phids are capable of sustaining either reproductive pattern, but growth will most probably slow at larger sizes. As a result, myctophids are able to sustain population sizes equivalent to or larger than larger bodied mesopelagic competitors such as *Gonostoma elongatum* that exhibit high batch fecundities, but which may spawn only once in their lifetime (Gartner 1993).

Generally myctophids in temperate and subtropical waters spawn from late winter to summer (Fast 1960; Odate and Ogawe 1961; Halliday 1970; Smoker and Pearcy 1970; Goodyear *et al.*, 1972; Clarke 1973; Karnella and Gibbs 1977). The reproductive cycles in midwater fishes particularly myctophids are timed to coincide with spring bloom when zooplankton abundance comes to peak (Clarke 1973). In Sub

Arctic and Antarctic waters spawning of myctophids are confined to winter (Smoker and Pearcy 1970; Robertson 1977). Olivar (1987) recorded that spawning is carried out over most of the year except autumn and chiefly takes place in waters where bottom depth is more than 400m (Gjosaeter and Tilseth 1980). Dalpadado (1985) suggested no difference in the proportion of spawning incidents between deep and shallow waters while according to Nafpaktitis (1968) in some Diaphus sp. the ripe female appear to remain in deeper water both during day and night.

The reproductive biology of myctophids were studied by Fast 1960; Odate and Ogawe 1961; Lipskaya 1967; O'Day and Nafpaktitis 1967; Paxton 1967; Nafpakitis 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; Linkowski 1985, Gjosaeter 1981C, 1984; Clarke 1983; Oven 1983; Young *et al.,* 1987; Dalpadado 1985, 1988 b; Gorelova and Prut'ko 1985; Olivar 1987; Gibbs and Krueger 1987; Young *et al.*, 1987; Andrianov and Bekker 1989; Prosch 1991; Gartner 1993; Prosch 1991; Flynn and Paxton 2012; Sassa *et al.,* 2014 and 2016. The studies exclusively on ovarian egg of myctophids were done by Hussain and Alikhan 1988 and Belova 2008. The reproductive biology of myctophids from Indian Ocean were studied by (Hussain and Ali-Khan 1987; Lisovenko and Prut'ko 1987, 1987a; Dalpadado 1988 b; Gjosaeter and Tilseth 1988; Hussain 1992; Sebastine *et al.,* 2013; Sebastine 2014; Vipin 2015; Meera *et al.,* 2018.

5.2 Results

5.2.1 LWRs and K_n of myctophid species.

Length Weight Relationship (LWR) of 20 myctophid species from WEIO and Eastern Arabian Sea are established, based on analysis of 1850 samples. For each species LWR is estimated separately for males, females and also by clubbing both male and female data. Species for which LWR is calculated, the season and area of collection, number of individuals utilized, estimated values of a and b in the exponential equation, the LW equation for male, female and clubbed category and estimated Relative Condition factor for each species (Kn) are given in Table 5.1.

Benthosema fibulatum: A total of 130 numbers of *B. fibulatum* were examined, which included 98 males and 32 females. The Standard Length (SL) ranged from 1.76 to 4.81 cm, with a mean length of 3.14 cm and the weight ranged from 0.2 to 2.45 g with a mean weight of 1.28g. The graphical representations of length-weight relationships of the species are given in Fig 10 (a_1) for male and female and Fig 10 (a_2) for sexes combined. LWRs of *B. fibulatum*, were estimated as: W = 0.0601 $L^{2.388,}$ for females (R^2=0.94); W = 0.0586 $L^{2.393,}$ for males (R^2=0.87); and W = 0.0587 $L^{2.395}$, for males and females combined (R^2=0.90). Stati stically (t-Test), the exponent (b) deviate significantly (P>0.05) from the cube law and therefore, the species show negative allometric growth. However, no significant difference was found in the LWR between male and female fishes (ANCOVA, P< 0.05). The Relative condition factor (Kn) for female, male and sexes pooled was 1.02 indicating overall good condition of the stock in NEAS during WM (Table 5.1, Figure 5.1a1, 5.1a2).

Bolinichthys longipes: LWR is established through the analysis of 197 specimens from NEAS (WM) which include 50 females and 147 males. The SL ranged from 2.45 to 4.46 cm, with a mean of 3.42 cm and the weight ranged from 0.25 to 1.59 g, with a mean of 0.85 g. Regression plots of LWR for females and males and sexes combined are given in Figure 5.1b1 and 5.1b2. The LWR for *Bolinichthys longipes* were estimated as: $W=0.0115\ L^{3.42,}$ for females ($R^2=0.96$); $W= 0.0108\ L^{3.51}$, for males ($R^2=0.92$) and $W= 0.0116\ L^{3.44,}$ for sexes combined ($R^2=0.95$). The exponential value 3.42 for females, 3.51 for males and 3.44 for pooled data differ significantly (t-test, P>0.5) from the cube law which indicates a positive allometric growth in the species. LWR showed no significant difference in the regression of both males and females population (ANCOVA, P< 0.05). Kn for females, males and sexes pooled were 0.97, 0.99 and 0.98 respectively which suggest the good condition of the species in NEAS during WM season.

Ceratoscopelus warmingii : A total of 155 specimens with SL range 2.58 to 6.68 cm and weight range 0.2 to 4.2 g were analysed which included 99 females and 56 males (Table 5.1). The regression plots for females and males (c_1) and sexes combined (c_2) are given in Figure-5.1c1 and 5.1c2. LWR for *Ceratoscopelus warmingii* were estimated as; $W= 0.0156\ L^{2.92}$ for females ($R^2=0.88$) $W=0.0095\ L^{3.19}$ for males ($R^2=0.95$); and $W= 0.0104\ L^{3.15}$ for males and females combined ($R^2=0.94$). In the regre ssion equation the exponent for females, males and sexes combined were 2.92, 3.19 and 3.15 (not statistically significant) which suggests a near allometric growth pattern of the species (*t*-test, P>0.05). The LWR showed no significant difference between males and female population of the species (ANCOVA, P <0.05). Kn was near one, for female (1.02), male (0.95) and sexes combined (0.99) suggesting the good condition of the WM stock in NEAS.

Diaphus antonbruuni: LWR is based on 70 individuals comprising of 22 females and 48 males collected from WEIO during SM season. SL ranged from 2.49 to 6.14 cm and weight ranged from 0.5 to 3.3 g. (Table 5.1). Figure 5.1 provide the regression plot for females and males (5.1d_1) and sexes combined (5.1d_2). The LWR for *Diaphus antonbruuni* were estimated as: W= 0.044 $L^{2.41}$ for females (R^2=0.93); W=0.044 $L^{2.44}$ for males (R^2=0.97) and W= 0.043 $L^{2.45}$, for sexes combined (R^2=0.96). The exponent in the growth equation differ significantly suggesting negative allometry but statically they are significant of isometric value 3 (*t*-test, P<0.05). The LWR showed no significant difference between males and female populations of the species (ANCOVA, P <0.05). The Kn for the species was close to 1 for females, males and sexes combined 0.99, 1.01 and 1.01 respectively).

Diaphus arabicus: A total of 123 individuals (46 females and 77 males) collected from NEAS during WM were analysed to derive LWR. SL ranged from 2.1 to 3.34 cm (mean of 2.8 cm) and the weight ranged from 0.2 to 0.5 g (mean of 0.37 g). Graphical representations of LWR for females and males (e_1) and sexes combined (e_2) for the species are given in Figure 5.1. The L-W equation for *Diaphus arabicus* are W= 0.0172 $L^{2.92}$ for females (R^2=0.70); W=0.0100 $L^{3.33}$ for males (R^2=0.82) and W= 0.0115 $L^{3.24}$ for sexes combined (R^2=0.74). Deviation of the exponent (b) in the regression equation for females (2.92); males, (3.33) and 3.24 for sexes combined were found to be statistically significant (*t*-test, P>0.05) from isometric growth. However there is no significant differences in the exponent value between male and female of the species (ANCOVA, P <0.05). Kn values for female (1.03), male (1.01) and sexes combined (1.02) were close to one for NEAS-WM stocks (Table 5.1).

Diaphus brachycephalus: Total 42 specimens (19 females and 23 males) from WEIO (SM season) were used to derive the LWRs. SL. Regression plot for LWR for females and males (f_1) and sexes pooled (f_2) are given in Figure 5.1. LWR for *Diaphus brachycephalus* were W= 0.005 $L^{3.56}$ for females (R^2=0.75); W=0.0036 $L^{3.65}$ for males (R^2=0.80) and W= 0.0041 $L^{3.66}$ for sexes combined (R^2=0.71). The exponent (*b*) in the regression equation for females (3.56), males (3.65) and sexes combined (3.66) differ significantly (*t*-test, P>0.05) from isometric growth indicating positively allometric growth of the species and is found to be statistically insignificant of isometric value 3. LWR showed significant difference between male and female populations of the species (ANCOVA, P>0.05). Kn values were near one for female, male and sexes combined (Table 5.1).

Diaphus coeruleus: LWR is established by analysing 93 samples from SEAS (SM season) which included 17 females and 76 males. SL ranged from 5.83 to 13.2 cm (mean length of 9.9 cm) and the weight ranged from 2.2 to 23.1 g (mean of 13.7 g). Length-weight regression summaries for *D. coeruleus* males, females and sexes combined are given in the Table 5.1. The graphical representation of length-weight relationships of female and male (g_1) and sexes pooled (g_2) are given in Fig. 5.1. Estimated LWR for *Diaphus coeruleus* were: W= 0.2691 $L^{1.71}$ for females (R^2=0.31); W=0.0094 $L^{3.13}$ for males (R^2=0.94) and W= 0.0107 $L^{3.08}$ for sexes combined (R^2=0.92). The regression fit for females was found insignificant, probably due to the limitation in the samples analysed and therefore the derived exponent (b) of females is doubtful. Males and sexes combined show positive allometric growth close to the cube of the fish length. Kn values 1.00, 1.02 and 1.04 for females, males and sexes combined suggest that the condition of the stock is good.

Diaphus fulgens: LWR is established based on 78 samples (32 females and 46 males) representing the SM season of WEIO. SL ranged from 3.08 to 5.73 cm (mean length of 4.7 cm) and the weight ranged from 0.5 to 2.6 g (mean of 1.81 g). Regression summaries for *D. fulgens* males, females and both sexes combined are given in the Table 5.1. The LWR regression plots for females and males (h_1) and sexes combined (h_2) of the species are given in Figure 5.1. LWR of *Diaphus fulgens* were: W= 0.0269 $L^{2.71}$ for females (R^2=0.92); W=0.011 $L^{3.26}$, for males (R^2=0.71) and W= 0.020 $L^{2.88}$ for sexes combined (R^2=0.97). Exponent in the regression equation do not significantly deviate (*t*-test, $P<0.05$) from the cube of fish length, suggesting an allometric growth pattern of the species during SM season. LWR showed no significant difference in the regression of males and females of the species (ANCOVA, $P<0.05$). The condition of the WEIO (SM) stock appears to be good as Kn is close to one.

Diaphus garmani: A total of 158 specimens (not sorted) from NEAS during WM were used in this study. SL ranged from 2.9 to 4.25 cm (mean length of 3.24 cm) and the weight ranged from 5 to 43 g (mean of 21.9 g). Log transformed LWR for the species (Figure 5.1i) provide the regression equation W= 0.0244 $L^{3.37}$ for the pooled data. However, the exponent (b) do not differ significantly from the cube of fish length (*t*-

test, P<0.05), which suggest allometry in growth. The condition of the species appears good (Kn =1.10) during the WM season of NEAS.

Diaphus jenseni: LWR is based on 82 samples from NEAS (WM season) comprising of 18 females and 64 males. The samples *ranged* from 2.97 to 6.17 cm in SL (mean length of 4.63 cm) and the weight ranged from 0.2 to 3.5 g (with a mean of 1.76 g). The graphical representation of length-weight relationships of the species are given in Figure 5.1 j_1 and j_2. Derived LW equations were W= 0.0599 L^{2187} for females (R^2=0.97); W=0.0276 $L^{2.68}$ for males (R^2=0.88); and W= 0.033 $L^{2.56,}$ for sexes combined (R^2=0.89).The exponents in the equations differ significantly (*t*-test, P>0.05) from cube of length which shows statistically significant negative allometry. The length-weight relationship showed no significant difference in the regression of males and female population of the species (ANCOVA, P <0.05). The WM stocks of *D. jenseni* in NEAS appears to be in good condition since Kn values for females, males and sexes combined were 1.02, 1.03 and 1.32 respectively.

Diaphus lucidus: Collections were made (34 samples) from SEAS in SM season.SL ranged from 3.40 to 5.95 cm (mean length of 4.4 cm) and the weight ranged from 0.4 to 2.6 g (mean of 1.12 g). The graphical representation of LWR of the species is given in Figure 5.1K1. LWR was found to be: W= 0.0104 $L^{3.121}$ for the pooled data, which is close to the cube of length and therefore the species shows allometric growth. During SM of SEAS, the species appears to be in good condition since their Kn (1.05) is close to one.

Diaphus luetkeni: A total of 47 samples representing female (15) and male (32) collected during SM season from WEIO were utilized for this study. The range in SL was from 2.63 to 5.23 cm (mean length of 3.9 cm) and the weight range was from 0.2 to 1.8 g (mean of 0.8 g.). The graphical representation of LWR are given in Figure 5.1l1 for female and male and Figure 5.1l2 for the pooled data. The LWR for *Diaphus luetkeni* were estimated as: W= 0.0048 $L^{3.56}$ for females (R^2=0.85) W=0.0054 $L^{3.60}$ for males (R^2=0.86) and W= 0.0044 $L^{3.63}$ for sexes clubbed (R^2=0.85).The exponent (b) of the regression equation deviates (*t*-test, P>0.05) significantly from 3, which implies that the growth in this species is positively allometric for females (3.57), males (3.60) and sexes combined (3.63). The LWR showed no significant difference in the regression of males and female population of the species (ANCOVA, P <0.05). Kn for female, male and sexes pooled where 0.65, 0.91 and 0.83 respectively which indicates the poor condition of females of the species during SM season of WEIO (Table 5.1).

Diaphus perspicillatus: LWR is based on 81 samples from SEAS (SM season) comprising 29 females and 52 males. The SL ranged from 3.02 to 6.83 cm (mean length 4.48cm) and the weight ranged from 0.2 to 5.2 g (mean weight 1.39 g). The graphical representation of LWR are given in Figure 5.1 (m_1) and (m_2). The LWR for *Diaphus perspicillatus* were estimated as; W= 0.0074 $L^{3.43}$ for females (R^2=0.94) W=0.0054 $L^{3.374}$ for males (R^2=0.85; and W= 0.0052 $L^{3.65}$ (R^2=0.89) for sexes combined (Table5.1). Deviations of the exponent (*b)* for females (3.43), males (3.74) and sexes combined (3.65) was found to be statistically not significant from isometric value 3 (*t*-test, P>0.05) which indicates positive allometry of the species. The length-weight relationship showed no significant difference in the regression of males and females of the species (ANCOVA, P <0.05). Kn values were close to one indicating overall good condition of the stock.

Diaphus thiollierei

In all 100 samples from NEAS (WM Season) were analysed to derive the LWR of this species. Samples included 51 females and 49 males in the size range 2.96 to 8.25 cm SL (mean length of 4.81cm) and weight range 0.3 to 8.2 g (mean of 2.05 g). Regression plot for the species are given in Figure 5.1 (n_1 and n_2). The LWR for *D. thiollierei* were estimated as W= 0.0207 $L^{2.85}$ for females (R^2=0.95), W=0.0117 $L^{3.19}$ for males (R^2=0.93) and W= 0.0151 $L^{3.03}$ for sexes combined (R^2=0.95). The exponent (*b)* for females (2.85), males (3.19) and for sexes combined (3.03) was found to be statistically insignificant from isometric growth (*t*-test, P>0.05) which suggest allometric growth in this species. The length-weight relationship showed no significant difference in the regression of males and females of the species (ANCOVA, P <0.05). Kn for female (1.04), male (1.18) and sexes pooled (1.15) indicate the good condition of the stock during the WM of NEAS.

Diaphus watasei

The standard length of *Diaphus watasei* ranged from 9.5 to 14.1 cm, with a mean length of 11.7 cm and the weight ranged from 12.2 to 36 g, with a mean of 22.25 g. Length, weight and length-weight regression summaries for *D. watasei* both sexes combined are given in the Table 5.1. The graphical representation of length-weight relationships of the species are given in Figure 5.1o1. The length-weight relationships of the myctophid fish species *Diaphus watasei* were estimated as: W= 0.0253 $L^{2.73}$, for (pooled data); The exponential value '*b'* for combined data was 2.73, which shows negative allometry and was found to be statistically significant from isometric value 3 (*t*-test, P>0.05). Kn for sexes pooled (1.03) indicate the good condition of the stock during the SM of SEAS.

Hygophum proximum

In all 115 samples from NEAS (WM Season) were analysed to derive the LWR of this species. Samples included 33 females and 82 males in the size range 2.36 to 4.69 cm cm SL (mean length of 3.31cm) and weight range 0.2 to 1.3 g (mean of 1.1 g). Regression plot for the species are given in Figure 5.1 (p_1 and p_2). The LWR for *H. proximum* were estimated as 0.0074 $L^{3.52}$, for females (R^2=0.66) and 0.0197 $L^{2.72}$, for males (R^2= 0.88), 0.0033 $L^{2.78}$ for sexes combined (R^2=0.86). The exponent (*b)* for females (3.52), males (2.72) and for sexes combined (2.78) was found to be statistically significant of isometric growth (*t*-test, P<0.05) for males and pooled data and positively allometric for female species (*t test* P>0.05). The length-weight relationship showed no significant difference in the regression of males and females of the species (ANCOVA, P <0.05). Kn for female (0.85), male (1.12) and sexes pooled (1.14) indicate the good condition of the stock for males and poor condition of stock for females during the WM of NEAS (Table 5.1).

Myctophum spinosum

LWR is based on 91 samples from NEAS (WM season) comprising of 42 females and 49 males. The samples *ranged* from 4.8 to 7.9 cm, with a (mean length of 2.8 cm) and weight ranged from 1.17 to 8.4 g, (with a mean of 2.81 g). The graphical representation of length-weight relationships of the species are given in Figure 5.1 q1 and q2. Derived LW equations were W= 0.0079 $L^{3.36}$, for females (R^2=0.97); W=0.0151 $L^{2.96}$, for males (R^2=0.93); and W= 0.0105 $L^{3.19}$, for sexes combined (R^2=0.96).The exponents in the equations differ significantly (*t*-test, P>0.05) from cube of length which shows statistically significant

Positive allometry. The length-weight relationship showed no significant difference in the regression of males and female population of the species (ANCOVA, P <0.05). The WM stocks of *M. spinosum* in NEAS appears to be in good condition since Kn values for females, males and sexes combined were 1, 1.02 and 1.01 respectively (Table 5.1).

Lampanyctus tenuiformis

A total of 67 individuals (19 females and 48 males) collected from WEIO during SM were analysed to derive LWR. 4.46 to 10.69 cm, (with a mean length of 5cm) and the weight ranged from 0.4 to 3 g, (with a mean of 1.12 g). Graphical representations of LWR for females and males (r_1) and sexes combined (r_2) for the species are given in Figure 5.1. The L-W equation for *Lampanyctus tenuiformis* are W= 0.0138 $L^{2.67}$for females (R^2=0.89); W=0.0266 $L^{2.26}$ for males (R^2=0.71) and W= 0.022 $L^{2.39}$ for sexes combined (R^2=0.78). Deviation of the exponent (b) in the regression equation for females (2.67); males (2.26) and 2.39 for sexes combined were found to be statistically significant (*t*-test, P>0.05) from negative allometric growth. However there is no significant differences in the exponent value between male and female of the species (ANCOVA, P <0.05). Kn values 1.08, 1.06 and 1.0 for females, males and sexes combined suggest that the condition of the stock is good.

Lampanyctus turneri

A total of 82 specimens with SL ranged from 3.11 to 6.87 cm, (with a mean length of 4.96) cm and the weight ranged from 0.4 to 3.2 g, (with a mean of 1.77 g) (Table 5.1). The regression plots for females and males and sexes combined are given in Figure-5.1s1 and 5.1s2. LWR for Lampanyctus turneri were estimated as; W= 0.0282 $L^{2.59}$ for females

($R2=0.77$) W= $W=0.0073\ L^{3.37}$ for males ($R2=0.88$); and $W= 0.0089\ L^{3.26}$ for males and females combined ($R2=0.88$). In the regression equation the exponent for females, males and sexes combined were 2.59, 3.37 and 3.26 (not statistically significant t test $p >0.05$) which suggests a near negative allometric growth pattern of the females and positive allometric pattern in male and pooled species (t-test, $P>0.05$). The LWR showed no significant difference between males and female population of the species (ANCOVA, $P <0.05$). Kn was near one, for female (1.03), male (1.02) and sexes combined (1.02) suggesting the good condition of the WM stock in NEAS (Table 5.1).

Lampanyctus nobilis

LWR is based on 58 samples from WEIO (SM season) comprising of 12 females and 46 males. The samples ranged ranged from 4.46 to 10.67 cm, (with a mean length of 2.41cm) and the weight ranged from 0.7 to 7.5 g, (with a mean of 2.41 g). The graphical representation of length-weight relationships of the species are given in Figure 5.1 t1 and t2. Derived LW equations were $W= 0.0028\ L^{3.61}$, for females ($R2=0.94$); $W=0.0073\ L^{3.03}$, for males ($R2=0.78$); and $W= 0.0061\ L^{3.14}$, for sexes combined ($R2=0.81$).The exponents in the equations differ significantly (t-test, $P>0.05$) from cube of length which shows statistically significant Positive allometry. The length-weight relationship showed no significant difference in the regression of males and female population of the species (ANCOVA, $P <0.05$). The SM stocks of L. nobilis in WEIO appears to be in good condition since Kn values for females, males and sexes combined were 1.01, 1.03 and 1.02 respectively (Table 5.1).

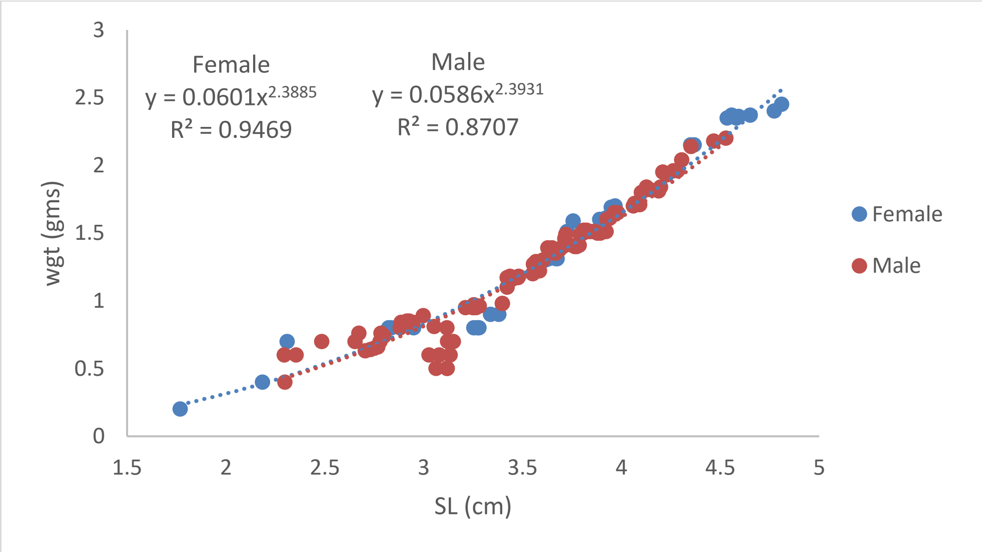


Figure 5.1 a1 : Length-weight relationship of *Benthosema fibulatum* (Female and Male)

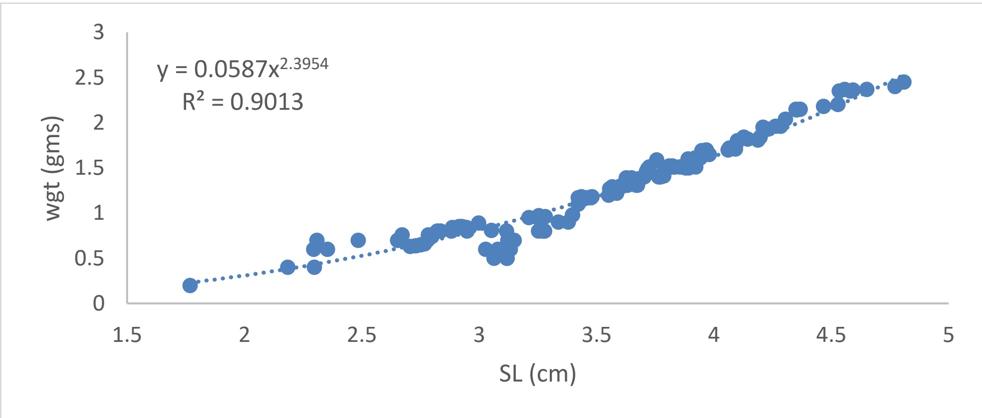


Figure 5.1 a2 : Length-weight relationship of *Benthosema fibulatum* (crude data)

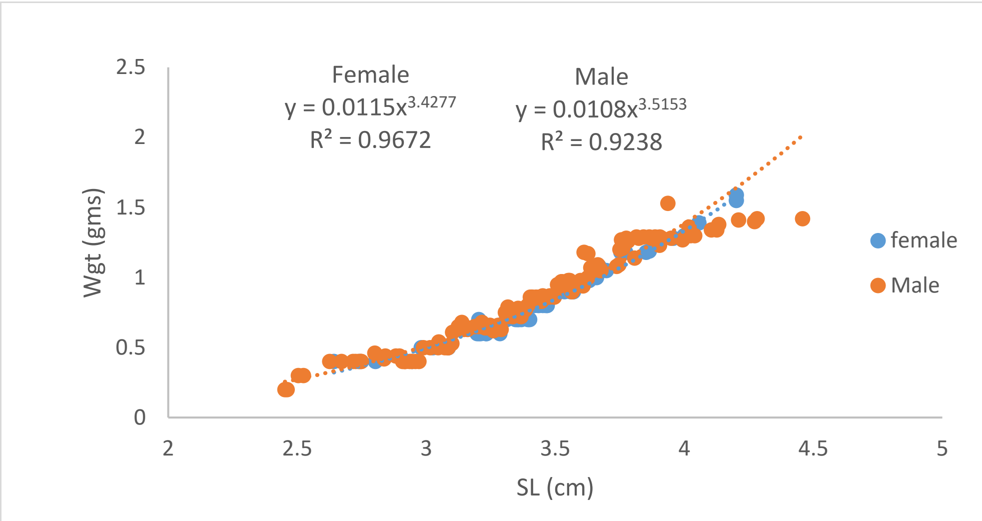


Figure 5.1 b1 : Length-weight relationship of *Bolinichthys longipes* (Female and Male)

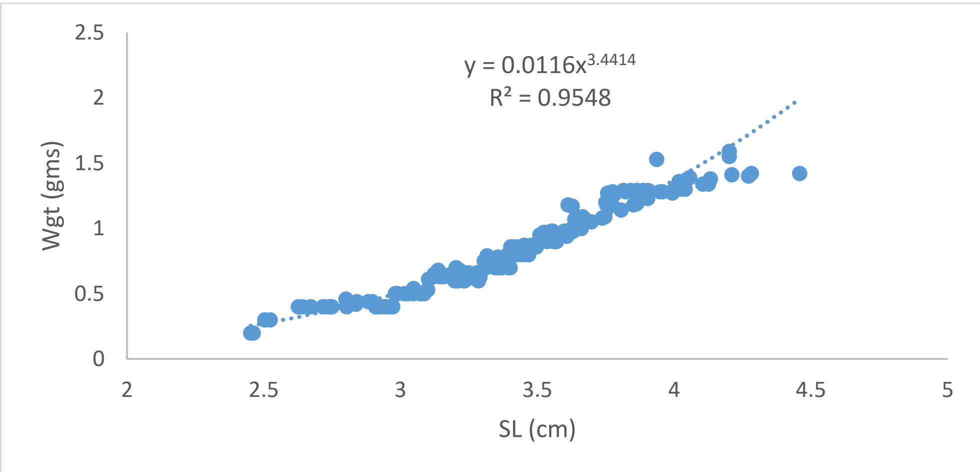


Figure 5.1 b2 : Length-weight relationship of *Bolinichthys longipes* (Crude)

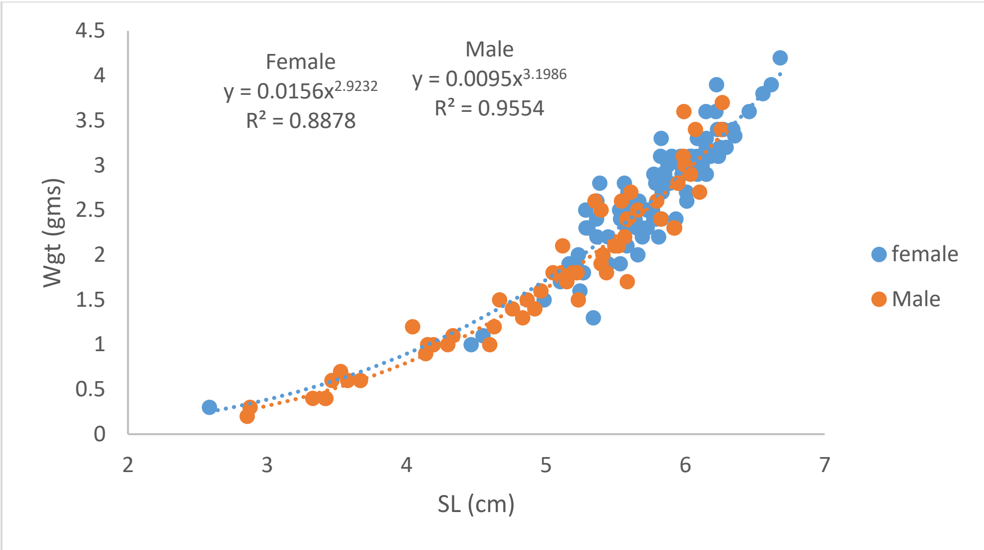


Figure 5.1 c1 : Length-weight relationship of *Ceratoscopelus warmingii* (Female and Male)

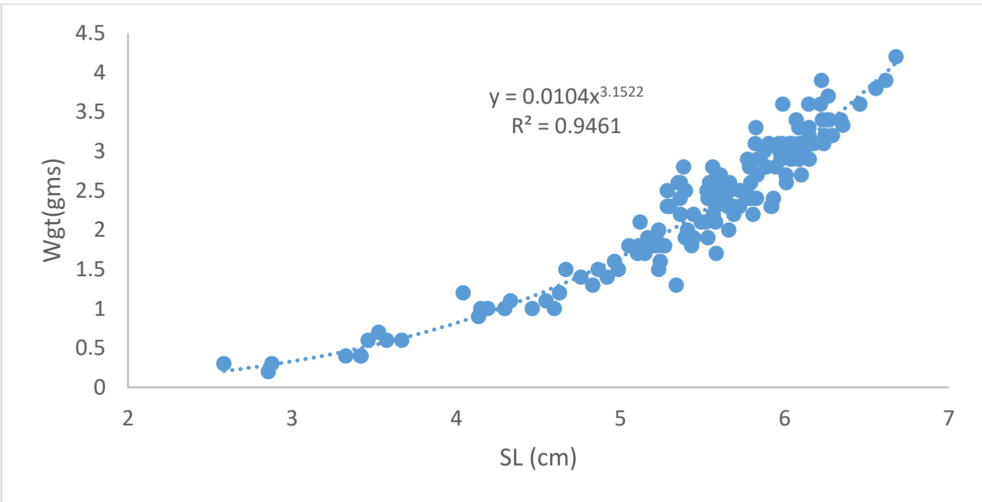


Figure 5.1 c2 : Length-weight relationship of *Ceratoscopelus warmingii* (Crude)

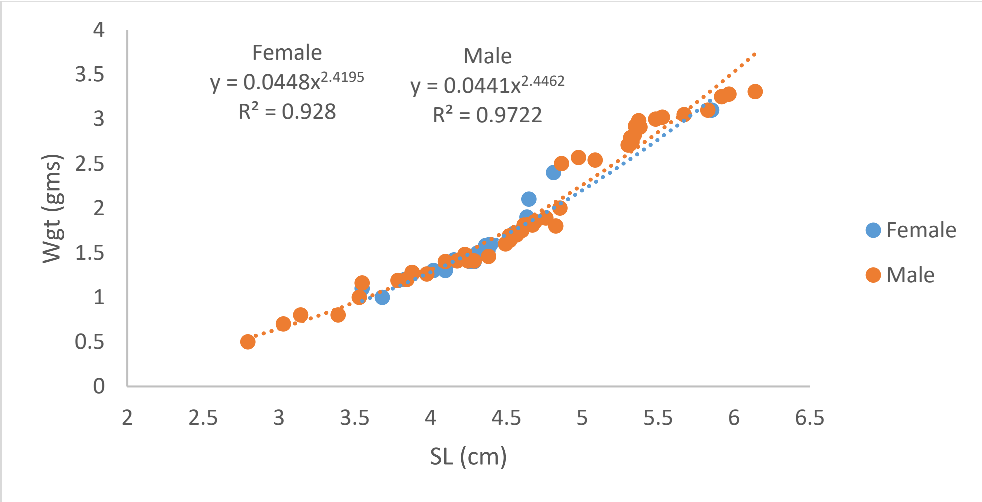


Figure 5.1 d1 : Length-weight relationship of *Diaphus antonbruuni* (Female and Male)

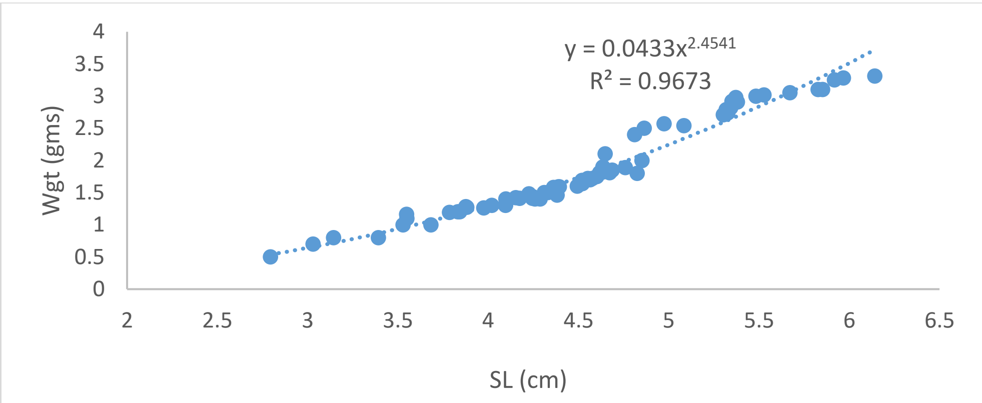


Figure 5.1 d2 : Length-weight relationship of *Diaphus antonbruuni* (Crude)

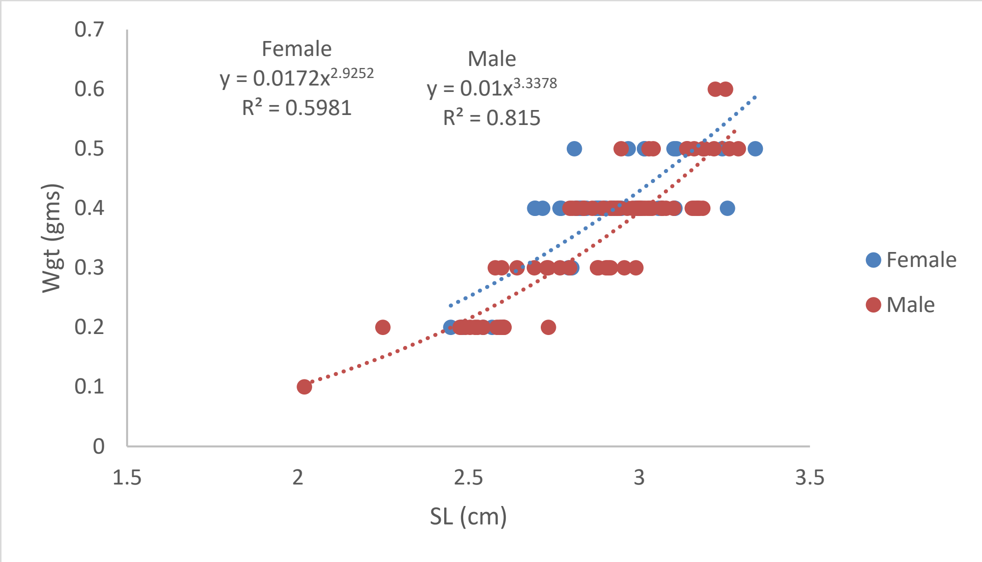


Figure 5.1 e1 : Length-weight relationship of *Diaphus arabicus* (Female and Male)

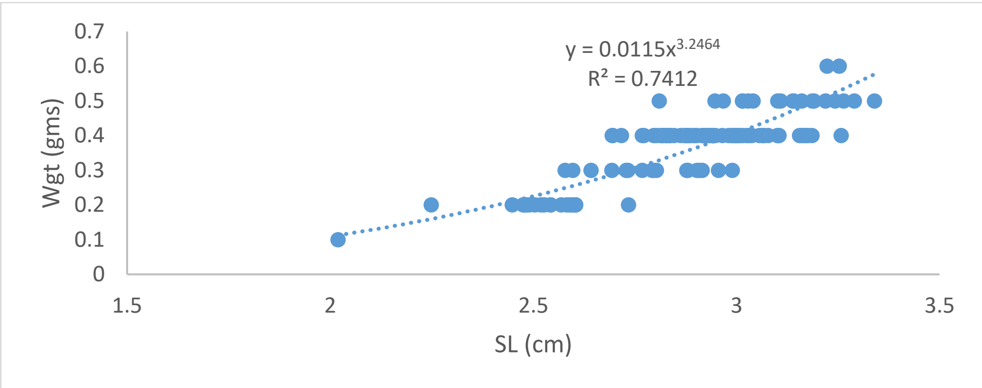


Figure 5.1 e2 : Length-weight relationship of *Diaphus arabicus* (Crude)

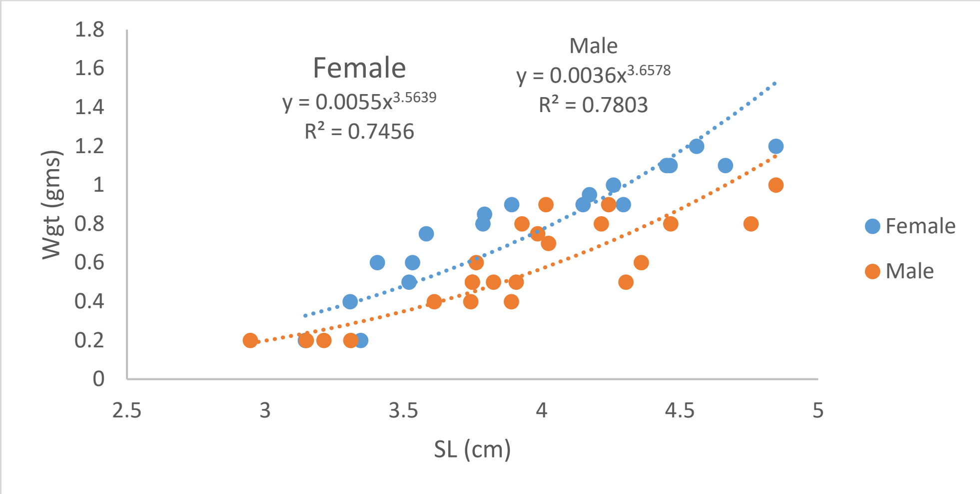


Figure 5.1 f1 : Length-weight relationship of *Diaphus brachycephalus* (Female and Male)

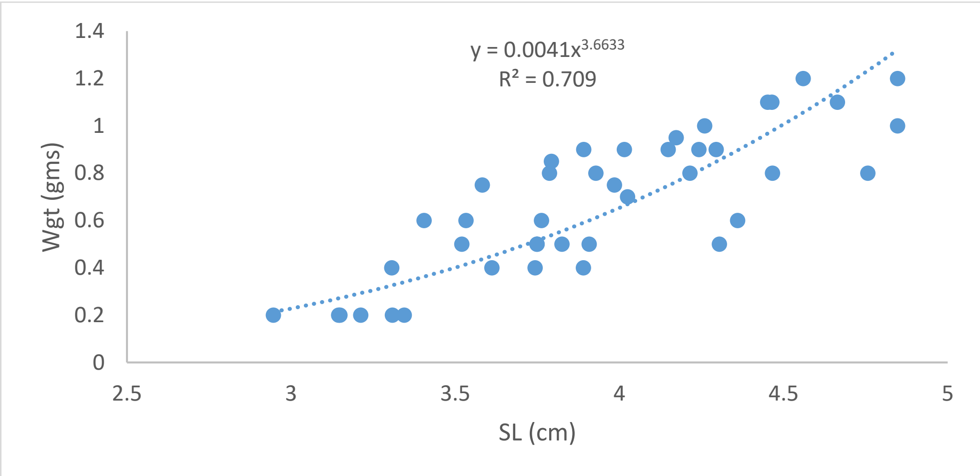


Figure 5.1 f2 **:** Length-weight relationship of *Diaphus brachycephalus* (Crude)

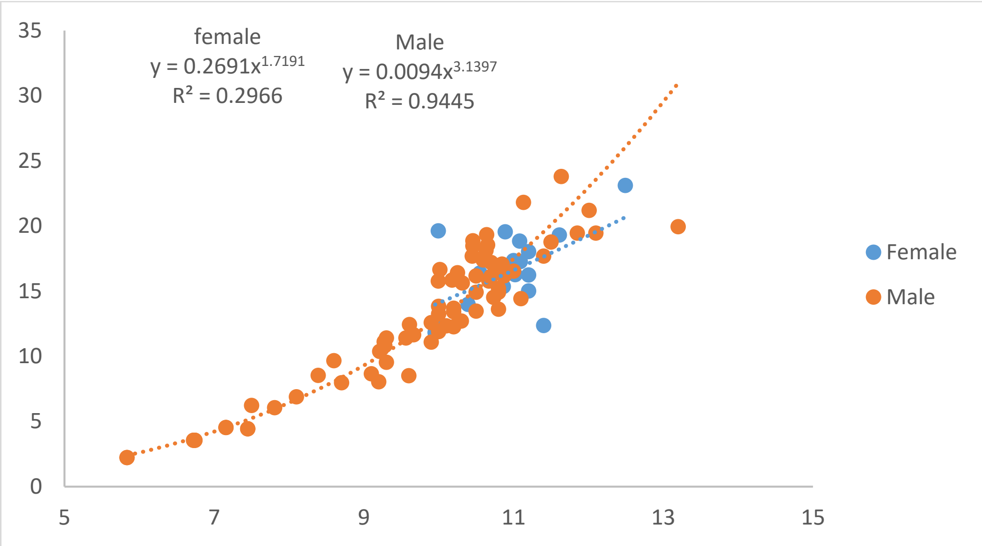


Figure 5.1g1 : Length-weight relationship of *Diaphus coeruleus* (Female and Male)

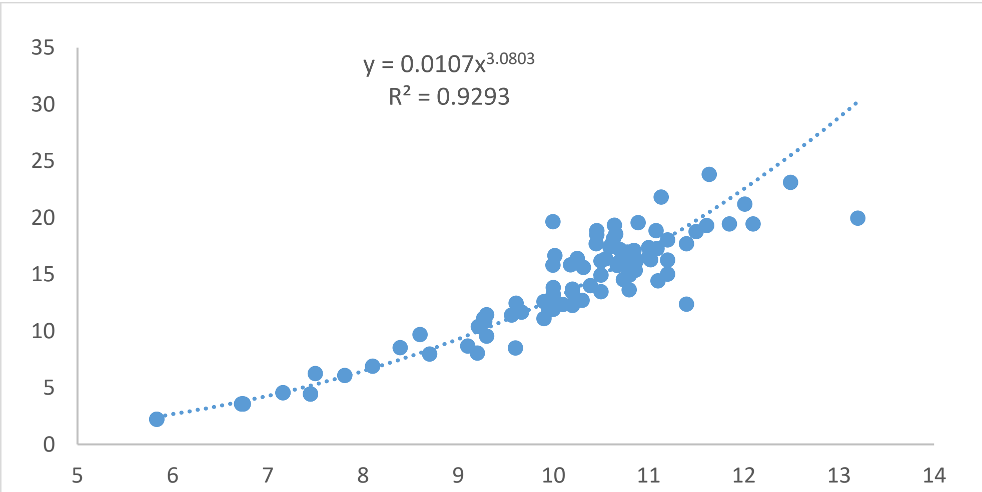


Figure 5.1 g2 : Length-weight relationship of *Diaphus coeruleus* (Crude)

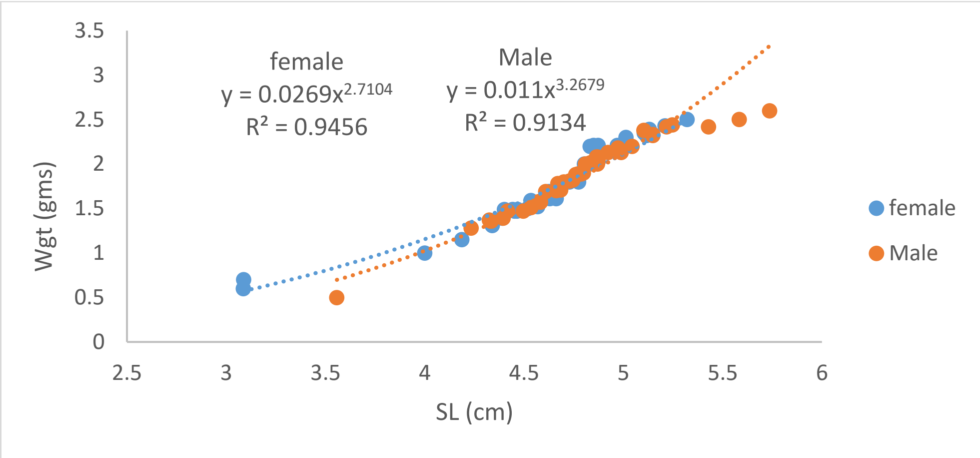


Figure 5.1 h1 : Length-weight relationship of *Diaphus fulgens* (Female and Male)

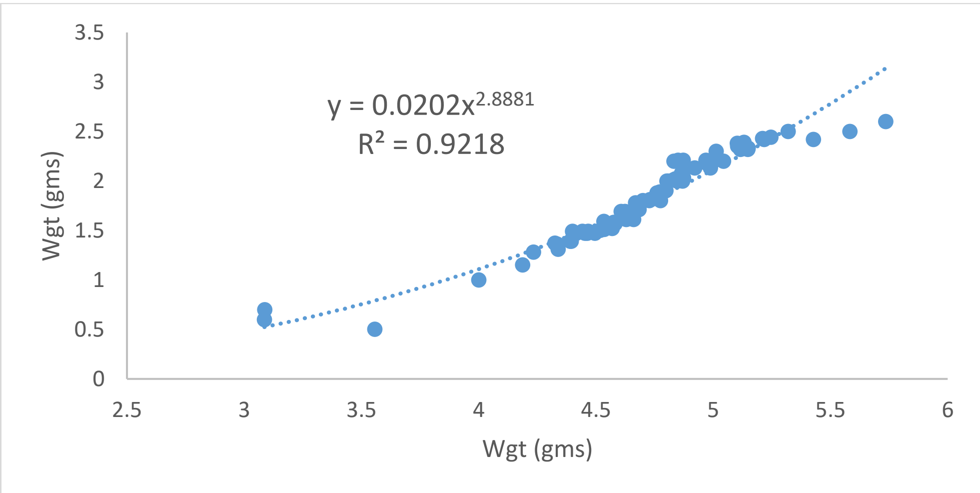


Figure 5.1 h2 : Length-weight relationship of *Diaphus fulgens* (Crude)

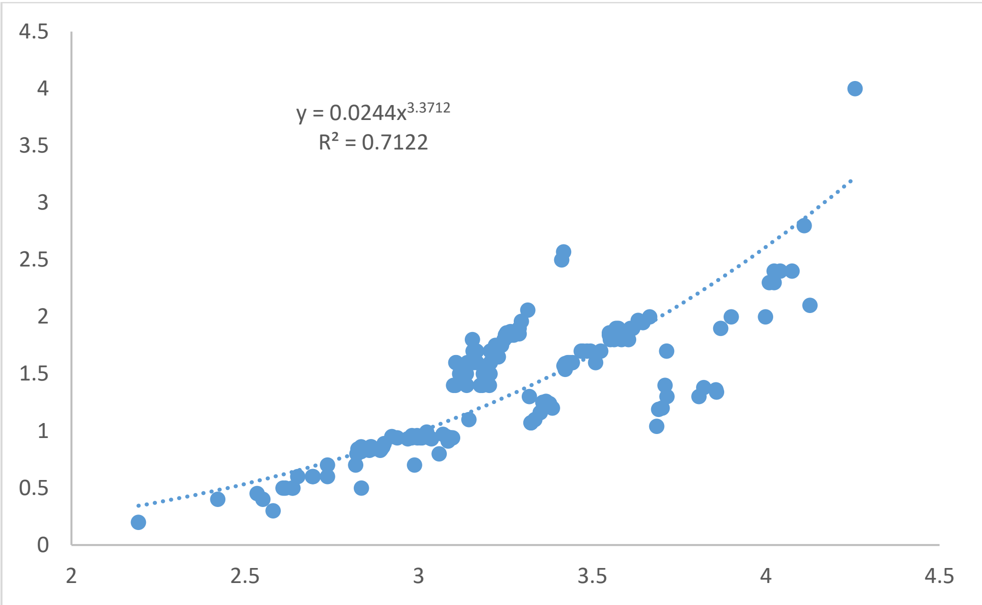


Figure 5.1 i1 : Length-weight relationship of *Diaphus garmani* (crude)

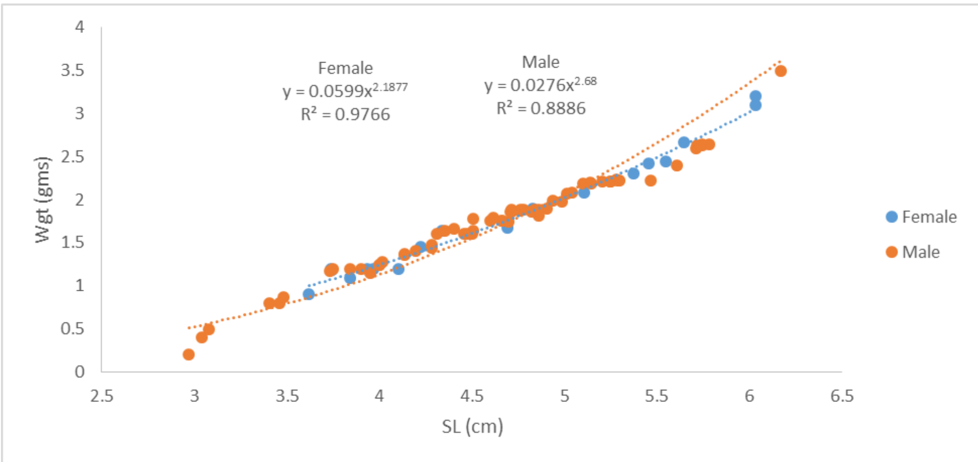


Figure 5.1 j1 : Length-weight relationship of *Diaphus jenseni* (Female and Male)

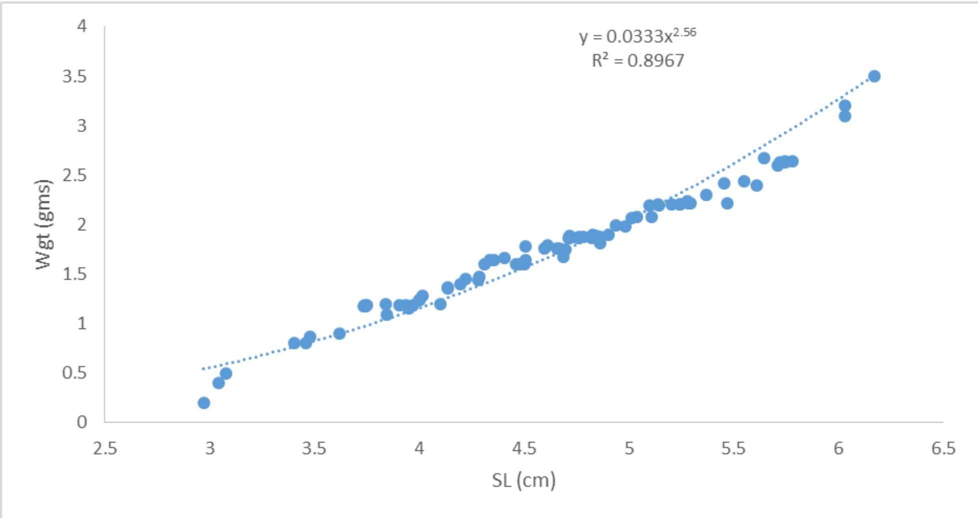


Figure 5.1j2 : Length-weight relationship of *Diaphus jenseni* (Crude)

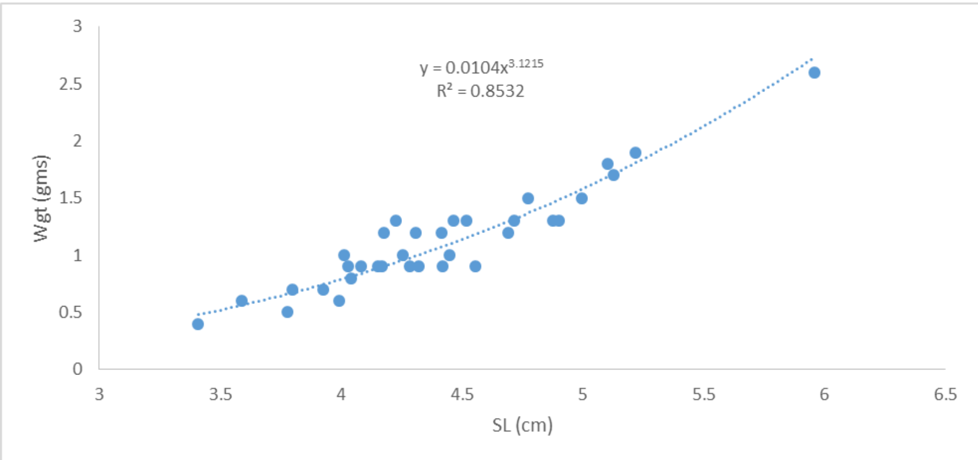


Figure 5.1k1 : Length-weight relationship of *Diaphus lucidus* (crude)

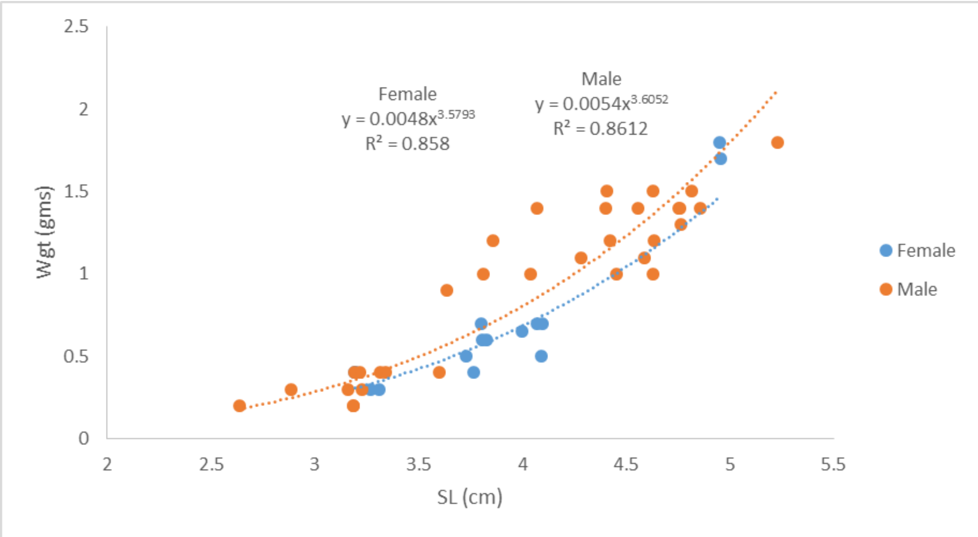


Figure 5.1 l1 : Length-weight relationship of *Diaphus luetkeni* (Female and Male)

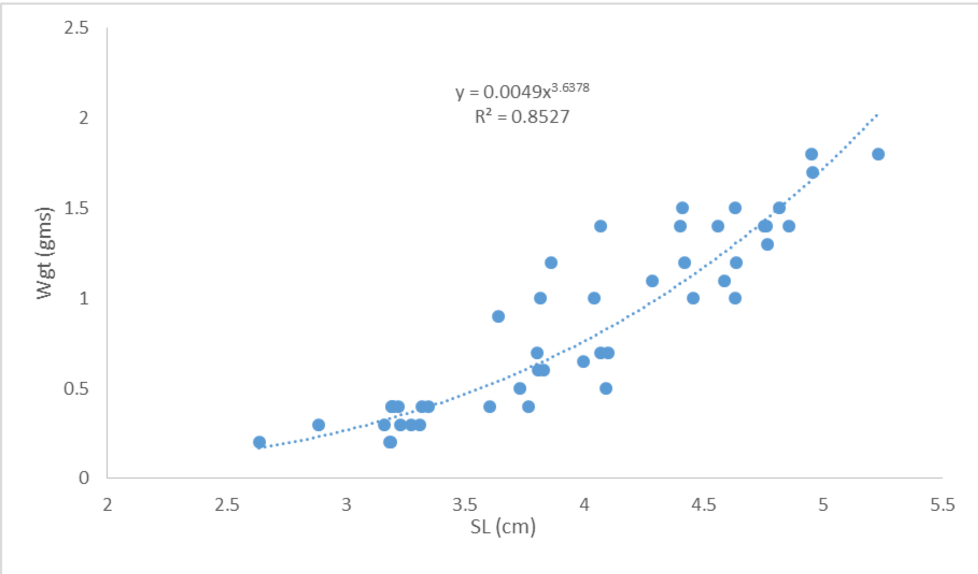


Figure 5.1 l2 : Length-weight relationship of *Diaphus luetkeni* (crude)

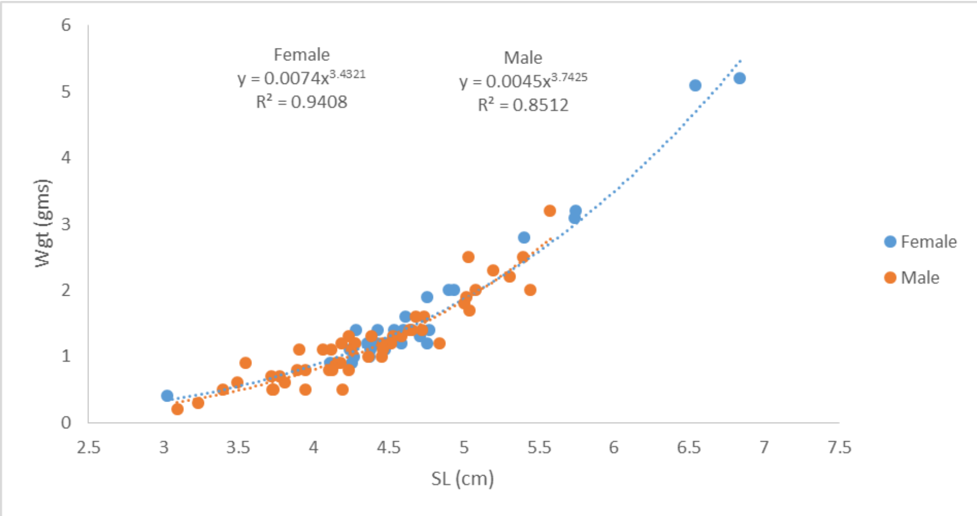


Figure 5.1m1 : Length-weight relationship of *Diaphus perspicillatus* (Female and Male)

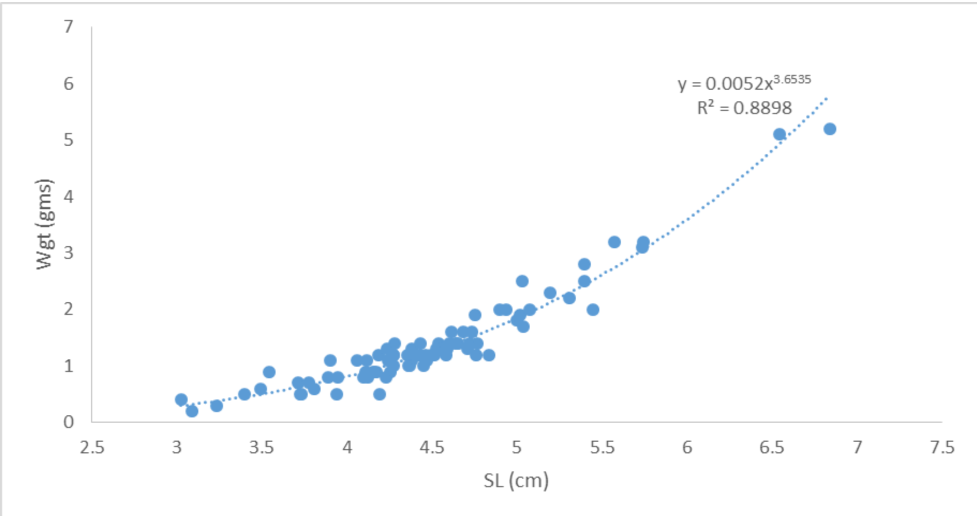


Figure 5.1m2 : Length-weight relationship of *Diaphus perspicillatus* (Crude)

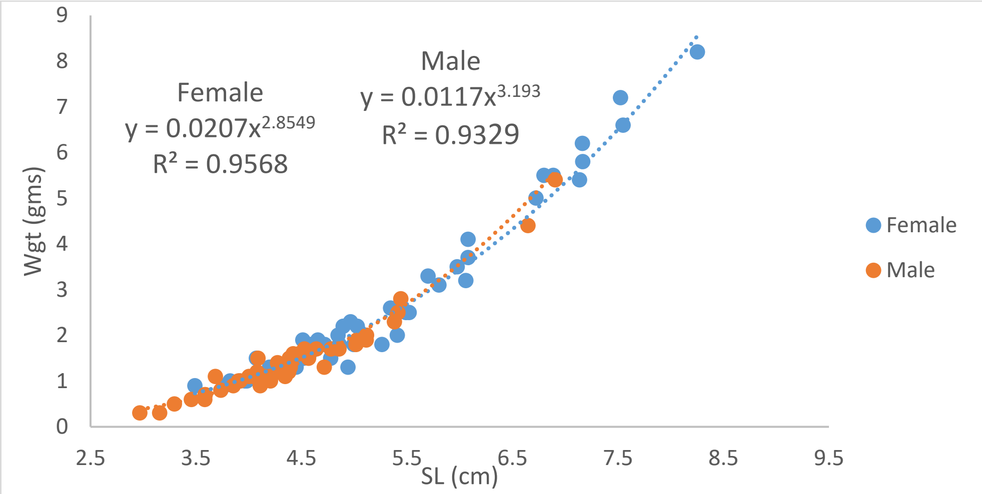


Figure 5.1n1 : Length-weight relationship of *Diaphus thiollierei* (Female and Male)

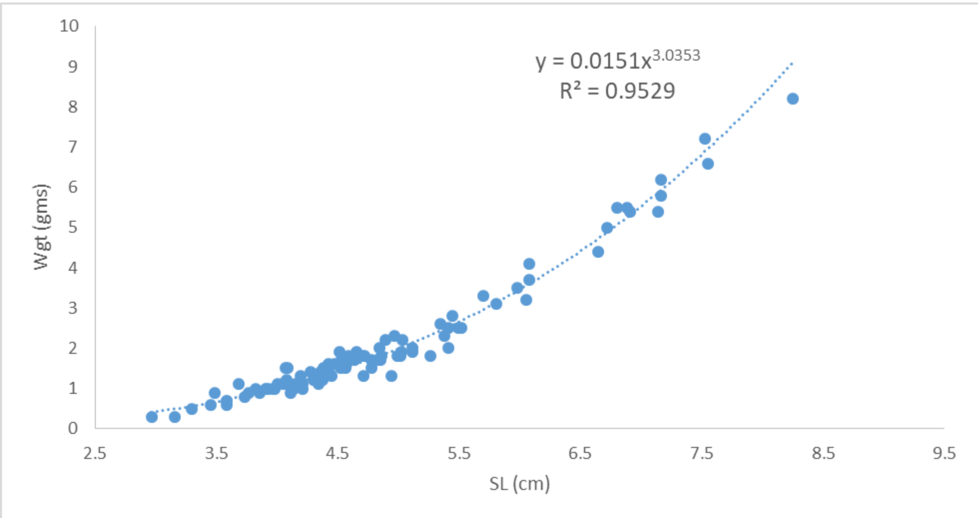


Figure 5.1n2 : Length-weight relationship of *Diaphus thiollierei* (Crude)

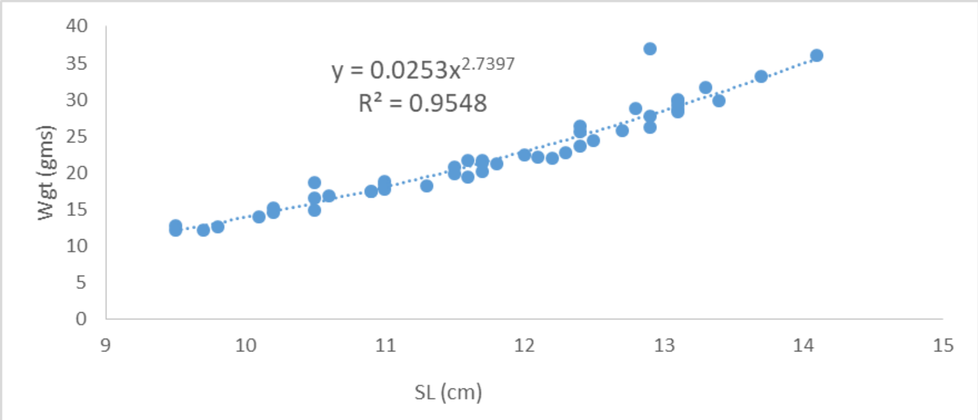


Figure 5.1o1 : Length-weight relationship of *Diaphus watasei* (crude)

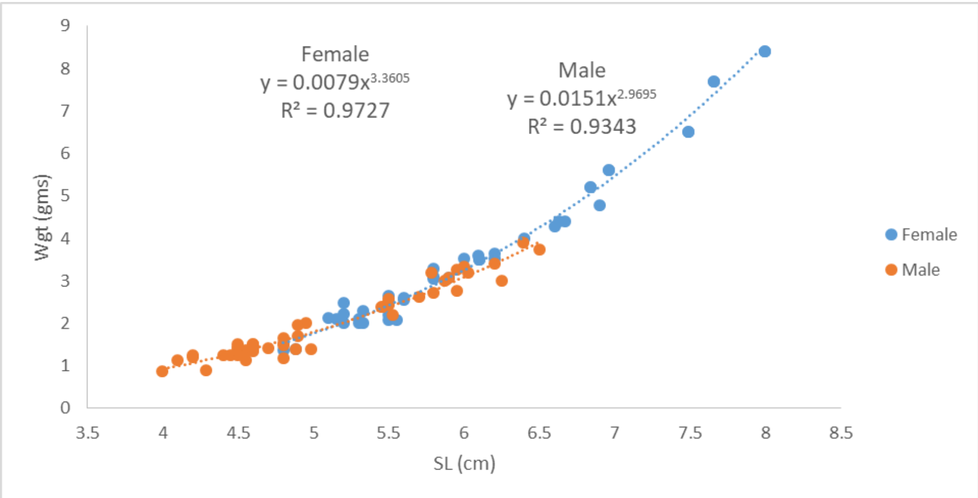


Figure 5.1q1 : Length-weight relationship of *Myctophum spinosum* (Female and Male)

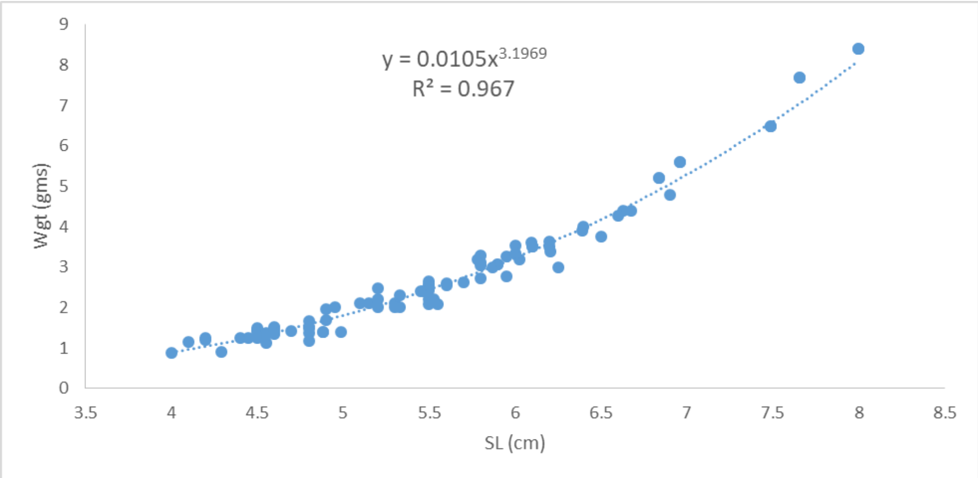


Figure 5.1q2 : Length-weight relationship of *Myctophum spinosum* (Crude)

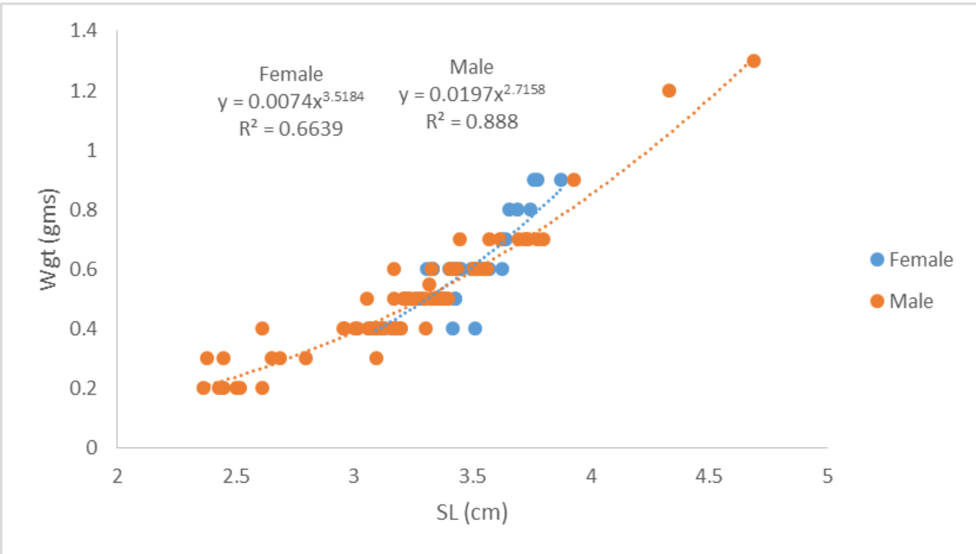


Figure5.1p1 Length-weight relationship of *Hygophum proximum* (Female and Male)

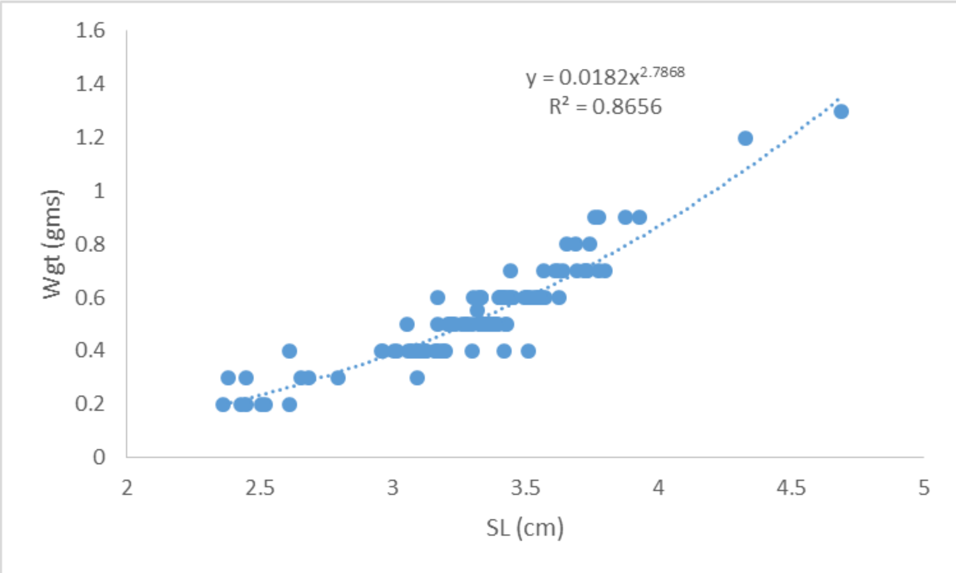


Figure 5.1 o2 : Length-weight relationship of *Hygophum proximum* (Crude)

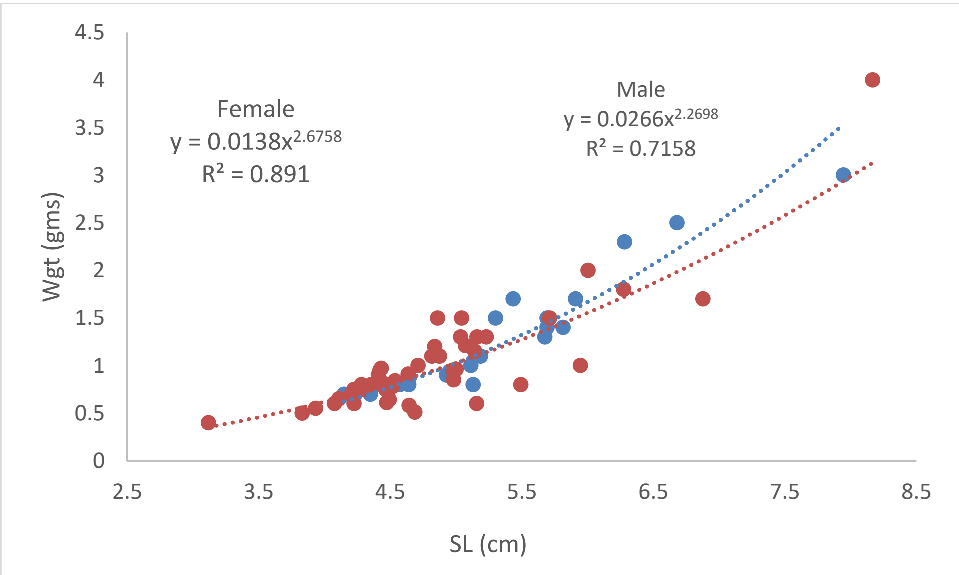


Figure 5.1 o2 : Length-weight relationship of *Lampanyctus tenuiformis* (Crude)

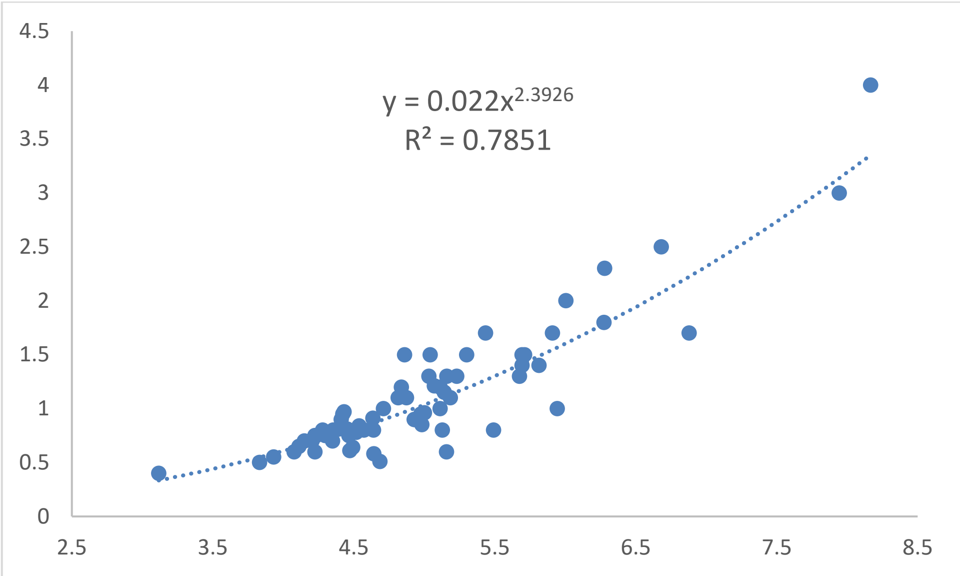


Figure 5.1 o2 : Length-weight relationship of *Lampanyctus tenuiformis* (Crude)

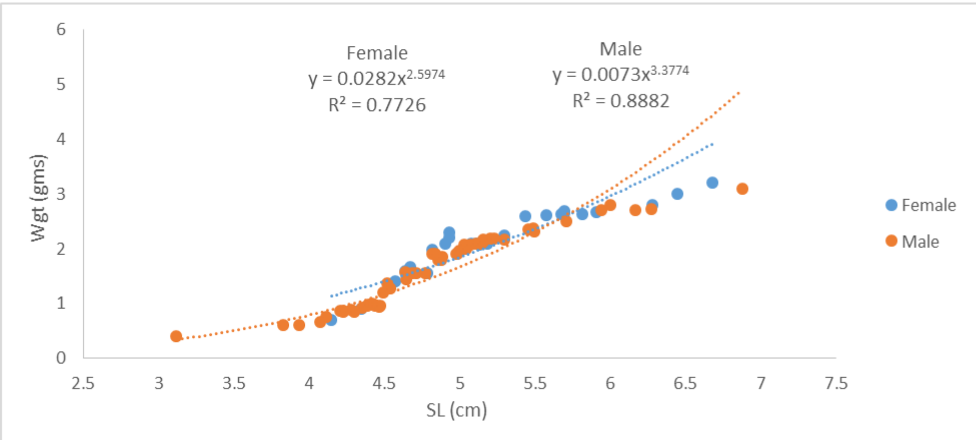


Figure 5.1s1 : Length-weight relationship of *Lampanyctus turneri* (Female and Male)

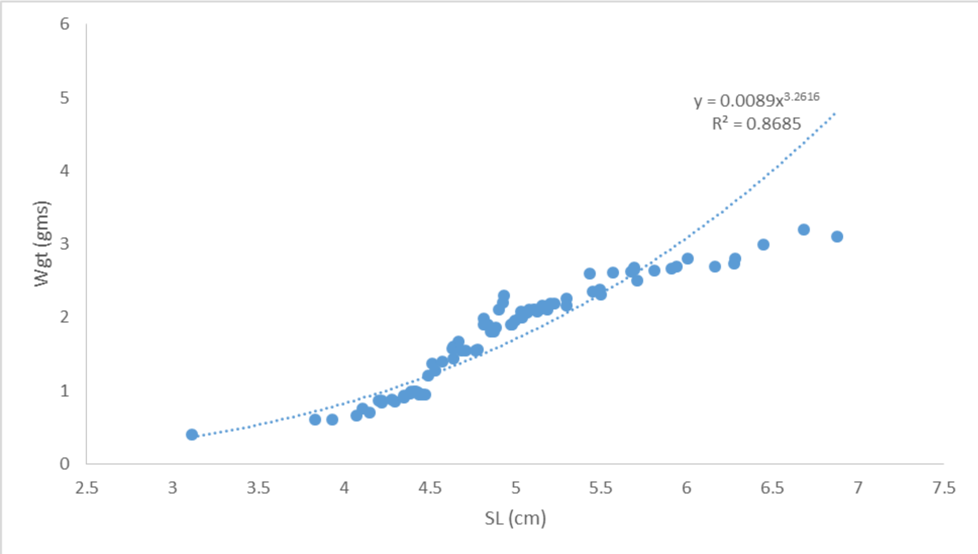


Figure 5.1s2 : Length-weight relationship of *Lampanyctus turneri* (Crude)

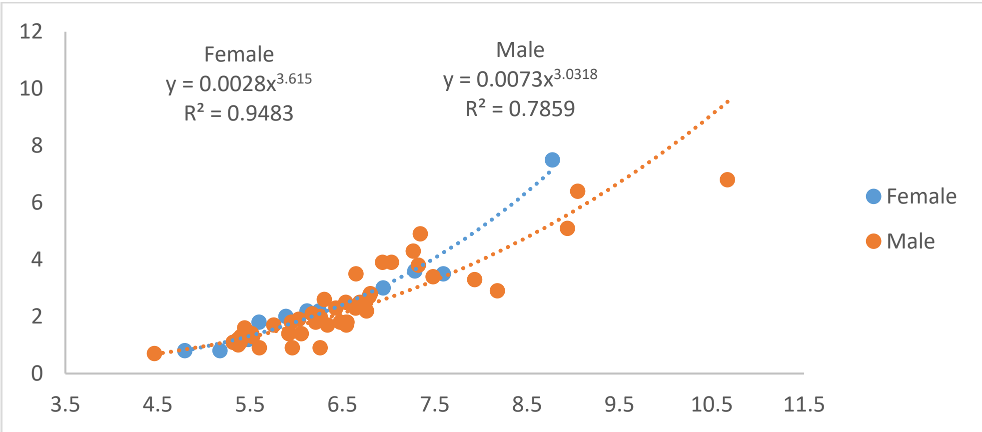


Figure 5.1t1: Length-weight relationship of *Lampanyctus nobilis* (Female and Male)

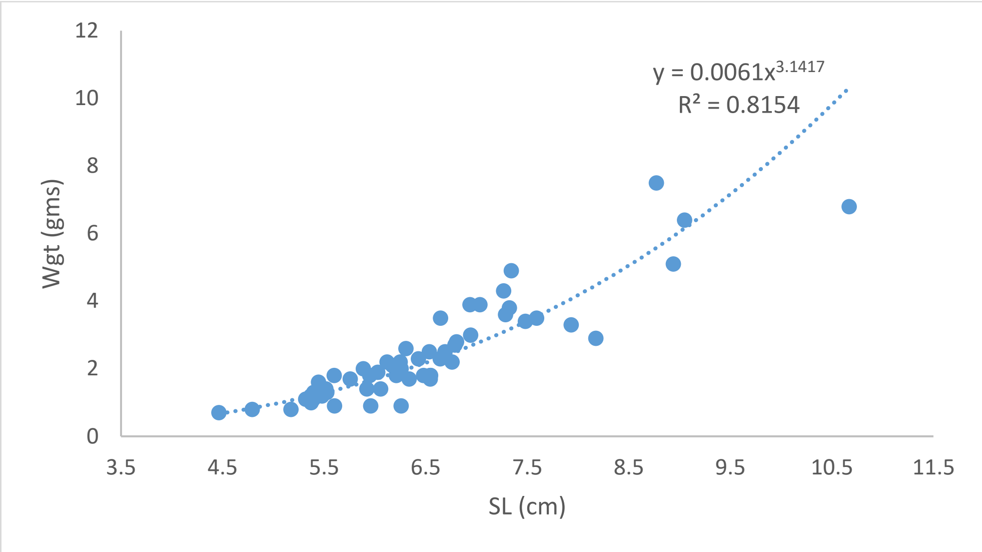


Figure 5.1 t 2 : Length-weight relationship of *Lampanyctus nobilis* (Crude)

5.2.2 Gut content Analysis and feeding condition of Myctophid species.

The stomach fullness and gut content of 11 myctophid species (691 individuals) obtained from Eastern Arabian Sea during Winter Monsoon and Summer Monsoon were analysed. Not much empty stomachs were observed during the analysis. This may be because during night they migrate to upper layers for feeding (Clarke 1978; Kinzer and Schultz 1985; and Hopkins and Gartner 1992). Only 6 specimens of *Lampanyctus turneri* had empty stomachs. They were not considered for the analysis.

Benthosema fibulatum: The stomach fullness and gut contents in 110 specimens of *Benthosema fibulatum* were examined. The percentage of stomach fullness in *B. fibulatum* were; fully filled (8.7%), three-quarters filled (26.2%), half-filled (21.2%) and one-quarter filled (43.7%) respectively. Prey items mainly included crustaceans, cephalopods and fishes. Crustaceans formed the major food item dominated by amphipod (30%), copepod (22%), shrimp (24%) and ostracod (16%). Minor food items included Semi Digested Matter (5%), mesopelagic fish (1.3%), Bregmacerous (0.3%), Squid (0.2%) and Salp (0.19%). A single foraminifera was also obtained from the diet. The percentages of Index of Relative Importance (% IRI) were amphipod (40%), shrimp (25%), copepod (20%), ostracod (12%), digestive matter (1%), mesopelagic fish (0.08%), Bregmacerous (0.01%), and squid (0.005%), Salp (0.005%) (Table 5.2 and 5.3 2, Figure 5.2and 5.3).

Bolinichthys longipes: For *Bolinichthys longipes* stomach fullness and gut contents of 143 specimens were examined. The percentage of stomach fullness obtained for *Bolinichthys longipes* were; fully filled (6%), three-quarters filled (13%), half-filled (50%) and one-quarter filled (30%). Prey items mainly included crustaceans and semi digested particles. Euphasid was the major food item (45%) followed by semi digested particle (44%) and shrimps by (11%) in % IRI (Table 5.2 and 5.3, Figure 5.2and 5.3)

Ceratoscopelus warmingii: The stomach fullness and gut content of 39 specimens were examined. The percentage of stomach fullness in *C. warmingii* were; fully filled (10%), three-quarters filled (5%), half-filled (50%) and one-quarter filled (30%). The main prey items were (in % IRI) shrimp 34.8%, euphasid 14.2%, Copepod 9.41% and fish 0.89% (Table 5.2 and 5.3 2, Figure 5.2and 5.3).

Diaphus arabicus: The stomach fullness of 69 specimens was analysed. The stomach of 93% of *D. arabicus* was three quarter filled and 7% was half filled. Major food items in the diet were (in % IRI) euphasid 37% and Shrimp (18%). Semi digested particles constituted the remaining 44%. (Table 5.2 and 5.3, Figure 5.2and 5.3).

***Diaphus garmani*:** The stomach fullness of 103 specimens of *D. garmani* was examined. No fully filled stomach was observed. 5% of the stomach was three quarter filled, 7% was half filled and 88% was one quarter filled. Major food items obtained from the stomach were (in % IRI) euphasid (40%) and shrimp (17%). Semi digested food formed (43%).(Table 5.2 and 5.3 , Figure 5.2and 5.3).

***Diaphus jenseni*:** The gut content and stomach fullness of 63 specimens of *Diaphus jenseni* was examined. 62% of the stomachs were half filled and 38% were quarter filled. The major food item analysed (in % IRI) was shrimp 7% and semi digested matter constitutes 93 % (Table 5.2 and 5.3, Figure 5.2 and 5.3).

***Lampanyctus turneri*:** The stomach fullness and gut contents of 45 specimens of *Lampanyctus turneri* were examined. The percentage of stomach fullness obtained for *L. turneri* were fully filled (6%), three-quarters filled (3%), half-filled, (3%) and one-quarter filled (88%) respectively. The major food items identified from the stomach (in % IRI) was Ostracod (27%), Shrimp (20%) and Copepod (11%) (Table 5.2 and 5.3, Figure 5.2and 5.3).

Symbolophorus evermanni: The stomach fullness and gut content of 23 specimens were analysed. The percentage of stomach fullness of *S.*

evermanni were as follows; fully filled (10%), three-quarters filled (10%), half-filled (45%) and one-quarter filled (35%) respectively. Shrimp 36%, Euphasid 19% and semi digested food constituted 46% of the gut content expressed in % of IRI (Table 5.2 and 5.3 , Figure 5.2 and 5.3).

***Diaphus coeruleus*:** A total of 83 specimens were examined. The percentage of stomach fullness for *D. coeruleus* were; fully filled (7%), three-quarters filled (13%) half-filled (42%) and one-quarter filled (38%) respectively. Prey items mainly included crustaceans and cephalopods. Cephalopod was the major food item constituted by 86% followed by shrimp 12% and semi digested particle 2% expressed in % of IRI (Table 5.2 and 5.3 , Figure 5.2 and 5.3).

Diaphus perspicillatus: The stomach fullness and gut contents in 32 specimens of *D. perspicillatus* were examined. The percentage of stomach fullness observed in *D. perspillatus* were; fully filled (9%), three-quarters filled (26%), half-filled, (25%) and one-quarter filled (40%) respectively. Prey items mainly included (in % IRI) Copepods (63%), Shrimp (16%) and digested matter (21%) (Table 5.2 and 5.3, Figure 5.2and 5.3).

Diaphus watasei: The stomach fullness and gut contents of 50 specimens of *D. watasei* were examined. The percentage of stomach fullness for *D. watasei* was; fully filled (16%), three-quarters filled (35%), half-filled (21%) and one-quarter filled (8%) respectively. Prey items mainly included crustaceans, cephalopods and fishes. Crustaceans were the major food item constituted by shrimp (64%) followed by cephalopods (squid) 31%, semi digested food (4%) and 0.48% was constituted by fish. (Expressed in % of IRI) (Table 5.2 and 5.3, Figure 5.2 and 5.3).

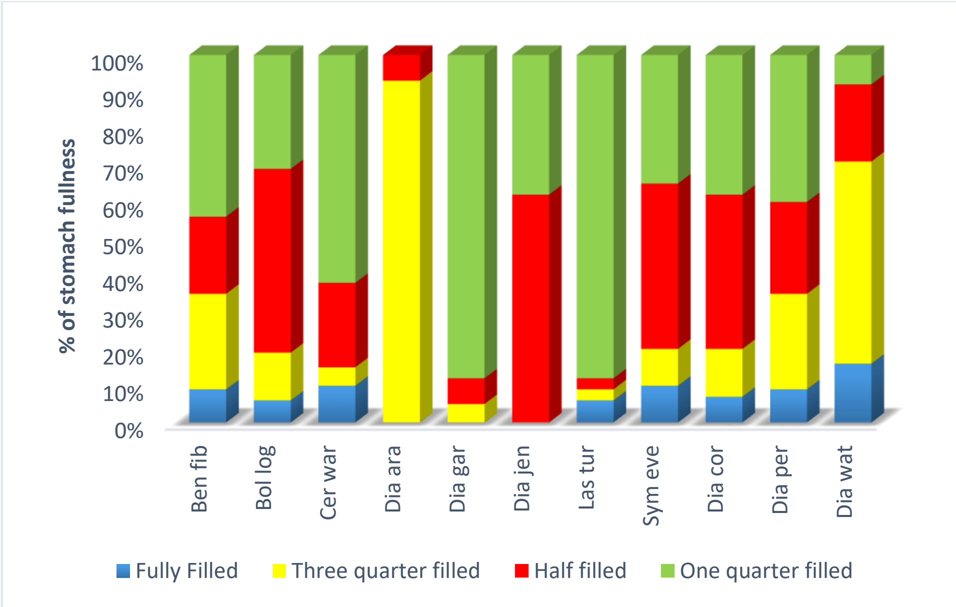


Figure 5.2 : Percentage of Stomach fullness of Myctophids

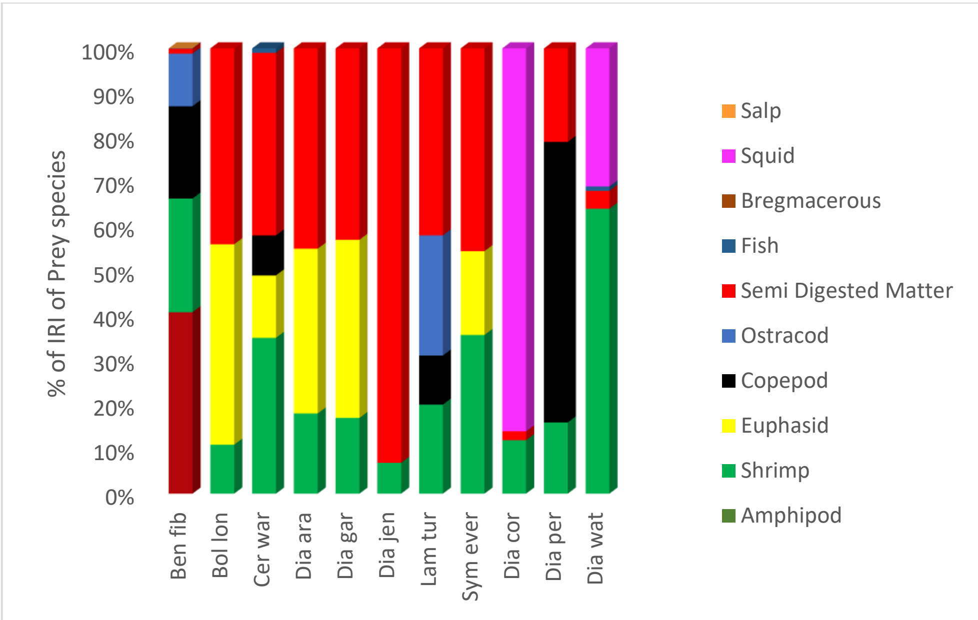


Figure 5.3: Percentage of IRI of prey groups of Myctophid species studied.

Resemblances in food habits: Food contents in the gut of 11 species of myctophids 8 species collected from NEAS during Winter monsoon and 3 species collected from SEAS during summer monsoon were subjected to cluster analysis to evaluate resemblances in food habits of these species. The analysis yielded 4 cluster groups. Group A comprised of *Diaphus coeruleus* and *Diaphus watasei* with 83% similarity in food habits. Group B consisted of *Benthosema fibulatum* and *Diaphus perspicillatus* with 66 % similarity. Group C consisted of 5 species viz *Bolinicthys longipes, Diaphus arabicus, D. garmani, C. warmingii* and *Symbolophorus evermanni* at 79.9% similarity. Within group C first three species formed a sub cluster (C1) with 97% similarity among their food habits and latter species formed a sub cluster (C2) with 93.2% similarity. The last cluster (D) consisting of *Diaphus jenseni* and *Lampanyctus turneri* had 71.36% similarity. Cluster B, C, D were found to have 56% similarity in their food habits. (Figure 5.4)

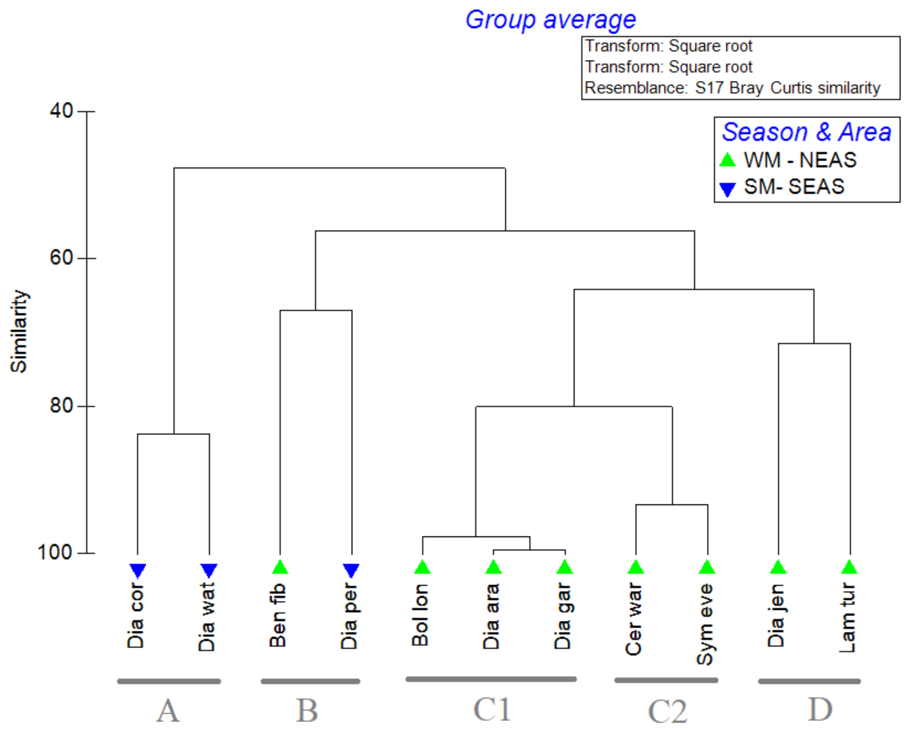


Figure 5.4 : Dendrogram of gut composition of Myctophid species

5.2.3. Reproductive Biology of Myctophids:

Reproductive biological aspects of *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus arabicus, Diaphus jenseni, Diaphus thiollierei, Hygophum proximum* obtained from Eastern Arabian Sea were analysed during the study period. A total of 852 specimens were dissected were and analysed for this purpose.

Sexual dimorphism in Myctophids: The myctophid species *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus arabicus, Diaphus jenseni, Diaphus thiollierei,* and *Hygophum proximum* showed morphological sexual dimorphism. In *Benthosema fibulatum* supracaudal and infracaudal luminous glands are present in the caudal peduncle. The luminous glands begin to appear as fish become mature. In male of *B. fibulatum* both supracaudal and infracaudal luminous glands were observed (Nafpaktitis and Nafpaktitis, 1969). In mature female of *B. fibulatum* single and smaller supracaudal and much smaller infracaudal luminous patch are present. In *Bolinicthys longipes* supracaudal and infracaudal luminous glands are present being longer and denser in males than in females (Hulley and Duhamel 2009). The pattern present in the data for *Ceratoscopelus warmingii* and *Hygophum proximum*, males among smaller mature fish and more females among the large ones (Gartner 1993). In *Hygophum proximum* supracaudal glands of males are large, undivided, filling three-fourths of the supracaudal space while females are having elongate infracaudal gland, consisting of 2 or 3 fused glands. In *Diaphus thiollierei* and *Diaphus jenseni* Dn or Vn enlarged in males when compared to females. But one cannot always depend up on this sexual dimorphic characters because this will be more evident in matured individuals than in immature and maturing individuals.

Sex ratio of Myctophids: Sex ratio between male and female observed during the study period show a dominance of males over the females population of *Benthosema fibulatum (*1 M : 0.3 F)*, Bolinicthys longipes (*1 M :0.3 F)*, Diaphus arabicus (*1 M :0.5 F)*, D. jenseni (*1 M : 0.2 F) and *Hygophum proximum (*1 M :0.4 F) Chi-square analysis show significant difference in the sex ratio (P<0.05). The sex ratio of *C. warmingii* (1 M: 1.7 F) and *Diaphus thiollierei (1 M: 1.4 F)* shows significant dominance of female population over males. No Significance difference in sex ratio was seen in *Diaphus thiollierei* (P>0.05) (Table 5.4).

Table 5.4 : Male and female sex ratios of Myctophids

No	Species	M	F	Chisquare value (X2)	Probability
1	*Benthosema fibulatum*	1	0.3	28.3	P<0.05
2	*Bolinichthys longipes*	1	0.3	47.76	P<0.05
3	*Ceratoscopelus warmingii*	1	1.7	11.929	P<0.05
4	*Diaphus arabicus*	1	0.5	7.7813	P<0.05
5	*Diaphus jenseni*	1	0.2	25.805	P<0.05
6	*Diaphus thiollierei*	1	1.04	0.04	P>0.05
7	*Hygophum Proximum*	1	0.4	20.878	P<0.05

Sexual maturity: Sexual maturity of the fishes were studied both macroscopically and microscopically and as the structures of the gonads of myctophids did not differ, a general description for the species is given below:

Gonads were paired and symmetrical. Fully matured gonad occupied more than 80% of the body cavity. In the immature stages, a small, narrow and filamentous organ with light whitish colour was found in the ovary. Five different maturity stages of gonads were identified and described in the Table 5.5 and Table 5.6. Only a few number of spent specimens were observed during the study period.

Table 5.5 : Description of male gonad developmental stages

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

Table 5.6 : Description of female gonad developmental stages

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

Maturity stages of gonads were classified into six different stages (as detailed in Table 5.5 and 5.6). The first two stages were considered as immature condition. Maturity stages IIIrd, IVth and Vth were considered as matured condition. All maturity stages from Ist to VIth were found in the myctophids species selected for the present study.

In case of *B. fibulatum* majority of individuals were in the ripened stage (V). In females 65% were in ripe stage (V) and in Males 53% were in ripe stage (V). 12 % of females were matured (IV), 9% were mature (III), 9% maturing (II) and 3% were immature (I). In case of males 8% were matured (IV), 23% mature (III), 14% maturing (II) and 1% (I) of the specimens studied were immature individuals. No spend stages were observed in both males and Females.

For *Bolinichthys longipes* immature (stage I), maturing (stage II) and spent stage (stage VI) were absent in females whereas mature (III) 17.7%, matured (IV) 8.8% and ripe (VI) (73%) were present. While for males all six stages were observed wherein immature (I) constituted 2.7%, Maturing (II) 15.9%, Mature (III) 18.7%, matured (IV) 16.6%, Ripe (V) (38%) and spent (VI) 7%.

In *Ceratoscopelus warmingii,* immature females (I) and spent males (VI) were absent. 5% of females were maturing (II), 11% were mature (III), 46% were matured (IV), 35% ripe (V) and 1% were in spent (VI) stage. Among males 1.8% were immature (I), 12.9% was maturing (II), 5.5% was mature (III), 16.6% was matured (IV) and 62.96% was ripe (V).

In *Diaphus arabicus* immature and maturing specimens were absent in both females and males. 8.6% of females were at mature (III) stage, 39% were matured (IV), 43% ripe (V) and 8.6% were in spent stage (VI). In males of 14.6% were mature (III), 16% were matured (IV) and 69% was ripe (V). Spent stage (VI) was absent in both females and males.

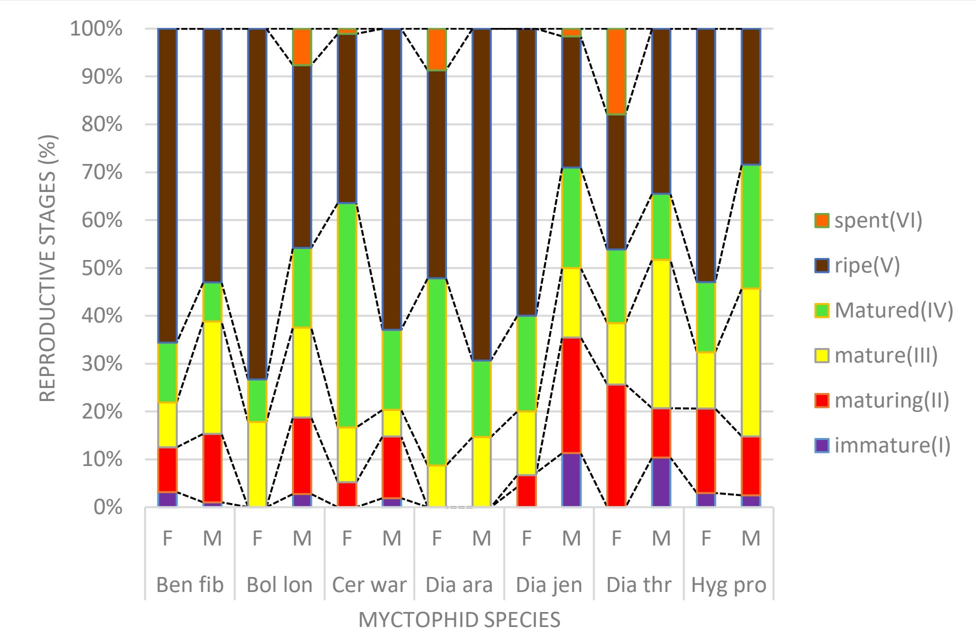
For *Diaphus jenseni* immature (I) and spent females (VI) were absent. 6.6% were maturing (II), 13% were mature (III), 20% were matured (IV) and 60% were ripe (V). In males all the six stages were observed ie; 11% immature (I), 24% maturing (II), 14% mature (III), 20% matured (IV), 27% ripe (V) and 16% spent stage (VI).

For *Diaphus thiollierei,* Immature individual (I) were absent in females and spent stage (VI) was absent in males. In females 25.6% were maturing (II), 12.8% mature (III), 15% matured (IV), 28% ripe (V) and 17% spent (VI). In males 10% each were immature (I) and maturing individuals (II). 31% mature (III), 13.7% matured (IV) and 34.4% ripe (V).

For *Hygophum proximum* spent stage was absent in the both males and females sampled. Ripe stage (V) 52%, matured (VI), 14.7%, mature (III) 11.6% and maturing (II) 17.6% and immature (I) 2% were recorded. In case of males 28% were ripe (V), 26% were matured (IV), 30.8% were mature (III), 12% were maturing (II) and 2% were immature (I) (Figure 5.5).

In all the seven species studied, ripe (V) was the common stage. Immature stages were absent in *D. arabicus*, females of *B. longipes* and *C. warmingii.* Spent (VI) stage was present in *B. longipes*, females of *D.*

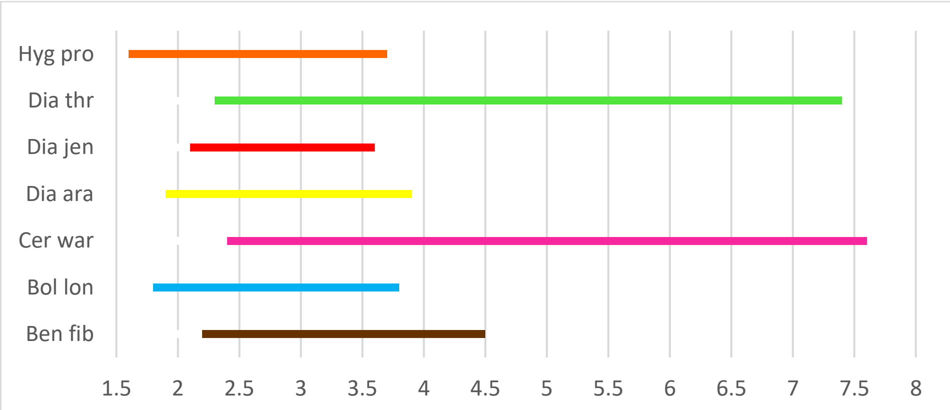
arabicus, *D. thiollierei* and male specimens of *D. jenseni*. Most abundant of all the six stages observed in the specimens was ripe stage followed by matured, mature and maturing stages and least observed were the spent stage and the immature stage (Figure 5.5).



Ben fib *(Benthosema fibulatum)*, Dia thr *(Diaphus thiollierei)*, Bol lon *(Bolinichthys longipes)*, Cer war *(Ceratoscopelus warmingii)*, Dia ara *(Diaphus arabicus)*, Dia jen *(Diaphus jenseni)*, Hyg pro *(Hygophum proximum)*

Figure 5.5: Reproductive stages of Myctophid species

Gonadsomatic Index (GSI): GSI values of the species are plotted in Figure 5.6. Using the data available from NEAS for January to February. The GSI values ranged from 1 to 7.6. Maximum GSI of 7.6 was obtained for *Ceratoscopelus warmingii*. The fluctuation in the GSI values of species plotted in Fig 5.6 almost follow a similar trend obtained in the percentage of maturity for *Diaphus arabicus, D. jenseni, C. warmingii* and *Bolinichthys longipes*. High GSI values were observed for *Diaphus thiollierei* and *Ceratoscopelus warmingii*.



Ben fib *(Benthosema fibulatum)*, Dia thr *(Diaphus thiollierei)*, Bol lon *(Bolinichthys longipes)*, Cer war *(Ceratoscopelus warmingii)*, Dia ara *(Diaphus arabicus)*, Dia jen *(Diaphus jenseni)*, Hyg pro *(Hygophum proximum)*

Fig 5.6: GSI values of the Myctophid species

Fecundity: Fecundity was determined by examining gravid gonads (stage V). Only ripened gonads were used for the estimation of fecundity. Length, weight and fecundity of gonads in the stage V are illustrated in the Table 5.7 Maximum fecundity of 4160- 4425 ± 187.38 ova was observed in *Ceratoscopelus warmingii*. Fecundity was less for *Diaphus jenseni* 1200-1269 ± 48.79 when compared to other species.

Table 5.7: Fecundity of Myctophid species

No	Species	SL(cm)	WGT(gms)	Maturity stage	Fecundity ± Std dev
1	*Benthosema fibulatum*	2.8-4.4	0.8-10.4	V	2800- 3100 ± 212.13
2	*Diaphus thiollierei*	3.5-5.5	1- 4.2	V	2324-2689 ± 258.09
3	*Bolinichthys longipes*	3.5-4.2	0.4-0.8	V	2960- 3248 ± 203.64
4	*Ceratoscopelus warmingii*	5.2-6.0	2.4-3.6	V	4160- 4425 ± 187.38
5	*Diaphus arabicus*	2.6-3.2	0.3-0.6	V	3200- 3654 ± 321.02
6	*Diaphus jenseni*	3.6-4.2	0.8-1.2	V	1200-1269 ± 48.79
7	*Hygophum proximum*	3.0-3.6	0.6-0.8	V	1300- 1359 ± 41.71

OVA diameter study: The ova diameter frequency for *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus arabicus*, *Diaphus jenseni, Diaphus thiollierei, Hygophum Proximum* at stages IV- V are shown in Figs. 5.7 a1, a2 to 5.7 g1, g2. The ova were spherical to oval, translucent and with a prominent oil globule. *Hygophum proximum* and *D. arabicus* had opaque eggs. Ova diameter ranged between 0.2 mm and 1.3 mm with majority of the ova measuring 0.2-0.6 mm. There were different batches of eggs in different sizes in each ovary indicating that they are batch spawners (Figure 5.7).

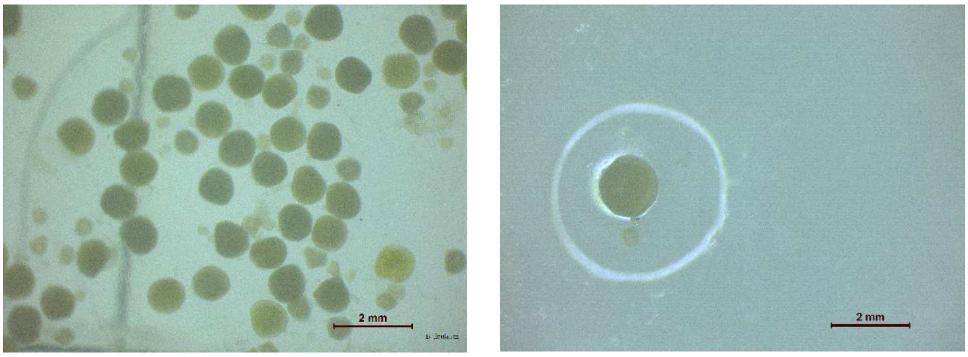


Figure 5.7 : a1 and a2 Maturing Ova of *Benthosema fibulatum*

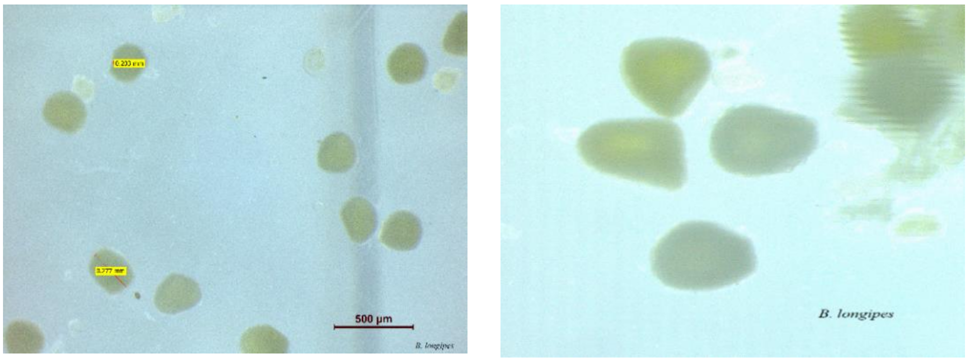


Figure 5.7 : b1 and b2 Maturing Ova of *Bolinicthys longipes*

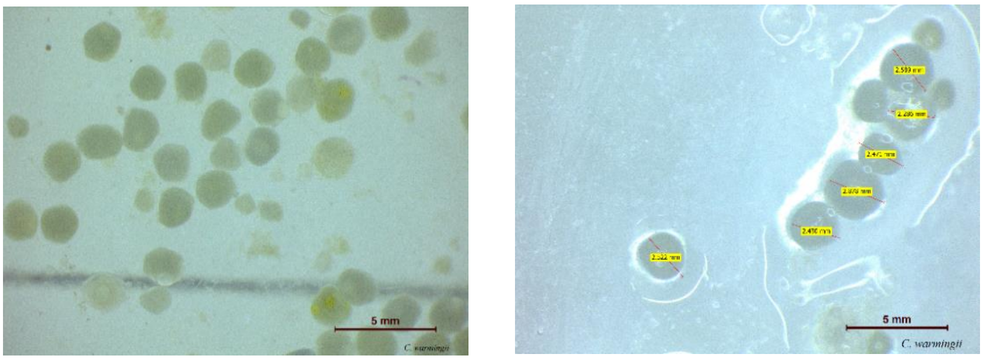


Figure 5.7 : c1 and c2 Maturing Ova of *Ceratoscopelus warmingii*

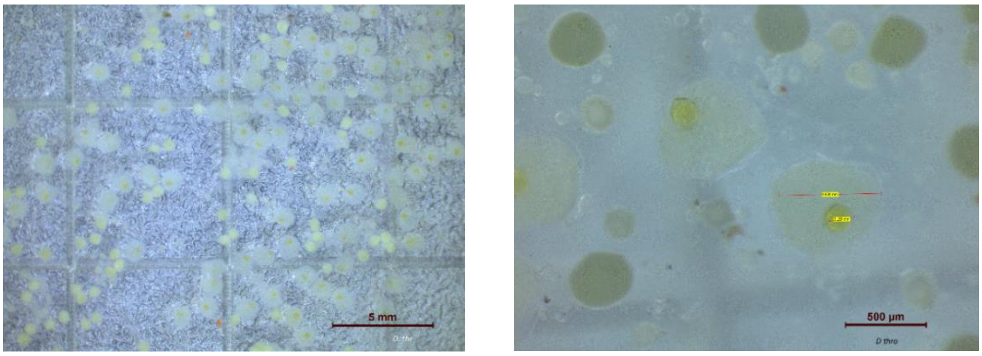


Figure 5.7 : d1 and d2 Maturing Ova of *Diaphus thiollierei*

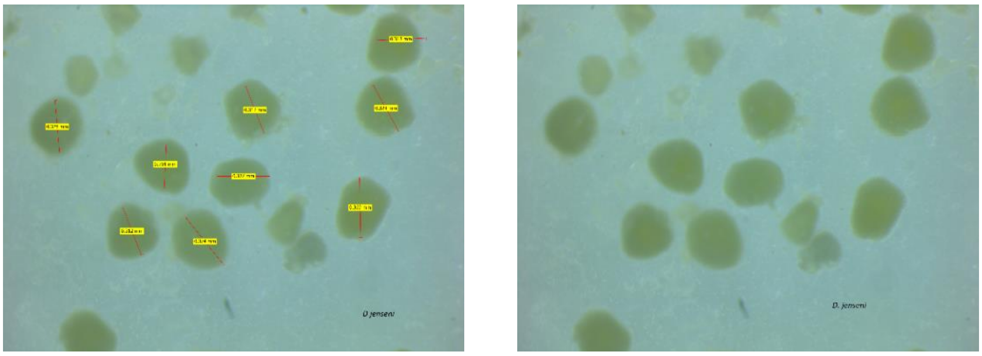
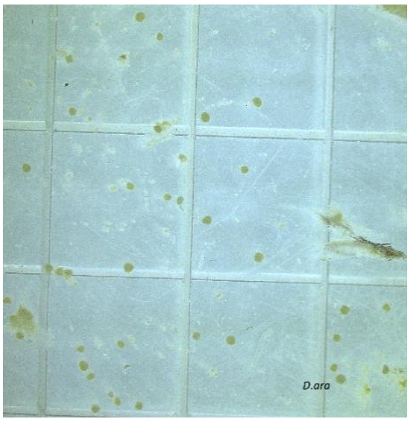


Figure 5. 7 : e1 and e2 Maturing Ova of *Diaphus jenseni*



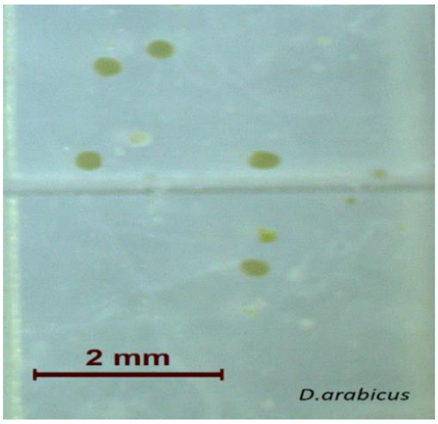
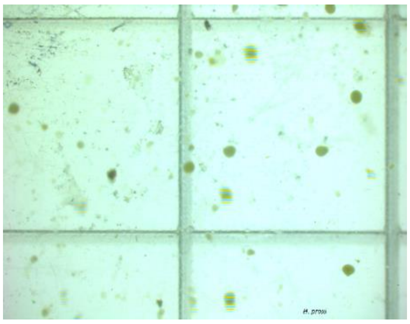


Figure 5.7 : f1 and f2 Maturing Ova of *Diaphus arabicus*



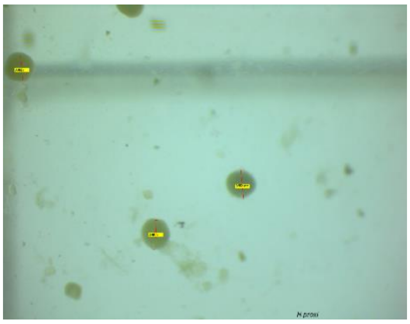


Figure 5.7 : g1 and g2 Maturing Ova of *Hygophum proximum*

5.3. Discussion.

5.3.1 Length-Weight Relationships and Relative Condition Factor.

Studies of the length-weight relationship (LWR) of fishes are an important tool to describe several biological aspects (Le Cren 1951; Froese 2006). LWR studies become relevant due the need to comprehend the fish lifecycle, principally regions where fisheries represent one of the most important economic activities and fish stocks are the main food source for many traditional communities (Froese *et al.,* 2014), The LWRs are regularly applied to fishery work and are used to estimate weight corresponding to a given length (Froese 2006). The anticipated b range was from 2.5 to 3.5 (Froese 2006).

Myctophids are among the most abundant fish in micronekton communities of the mesopelagic layer of all oceans, and are an important link in the food chain of marine ecosystems (Gjøsaeter and Kawaguchi 1980). Although myctophidae is one of the most abundant and varied mesopelagic fish families, biological information of this family is relatively less (Vipin 2016). Studies on the length-weight relationship of myctophid fishes are restricted to the studies of Linkowski 1985; Hussain 1992; Haimovici and Velasco 2000; Karuppasamy *et al.,* 2008 b; Sebastine *et al.,* 2013; Olivar *et al.,* 2013; Vipin *et al.,* 2011, 2015; Vizvari *et al.,* 2017; Jiang *et al.,* 2017 and Meera *et al.,* 2018.

Among the 20 myctophid species for which LWR and Kn have been worked out in the present study, 6 species show isometric growth (b=3) in females, males and sexes combined; in 6 species females, males and combined sexes are positively allometric (b significantly >3) whereas 5 species show negative allometric growth (b significantly <3) in females, males and sexes combined. In *Hygophum proximum* and *Lampanyctus nobilis* females are positively allometric and males are isometric in growth, whereas in *L. turneri* females are negatively allometric and males are isometric in growth.

Species exhibiting isometric growth include *Ceratoscopelus warmingii* (NEAS-WM), *Diaphus fulgens* (WEIO-SM), *Diaphus garmani* (NEAS-WM), *Diaphus lucidus* (SEAS-SM), *Diaphus thiollierei* (NEAS-WM) and *Myctophum spinosum* (NEAS-WM). The relative condition factor of all the above species were one or slightly above one which indicate that stocks of these species thrive well in the areas and seasons mentioned above.

Positive allometric growths were recorded in 6 species, namely; *Bolinichthys longipes* (NEAS-WM), *Diaphus arabicus* (NEAS-WM), *Diaphus brachycephalus* (WEIO-SM), *Diaphus coeruleus* (SEAS-SM), *Diaphus luetkeni* (WEIO-SM) and *D. perspicillatus* (SEAS-SM). Therefore, it is reasonable to state that weight increments of these species are more than length increments. This may be related to the body form of these species viz; *D. brachycephalus* (broad body), *B. longipes* and *D. arabicus* (small body size), *D. coeruleus* (relatively large sized fish) *D. luetkeni* and *D. perspicillatus* (large head) etc. The Kn values for all the above species except females of *D. luetkeni* (kn=0.65) were close to one indicating their relative good condition. The low Kn in females of this species may be due to inadequate sample size (n=15).

Five species recorded negative allometric growths viz; *Benth osema fibulatum* (NEAS-WM), *Diaphus antonbruuni* (WEIO-SM), *Diaphus jenseni* (NEAS-WM), *D. watasei* (SEAS-SM), *Lampanyctus tenuiformis* (WEIO-WM). Since Kn is not biased towards females, negative allometry may be more due to the body shape or increased metabolic activity in these fishes rather than gonad maturity and related stress. All the above species except *D. watasei* are oceanic species known to undertake extensive dial migrations (reaching up to 1000 – 1500 m depths during day and occupying 100 m to 200 m depth strata during night). *D. watasei* is a benthopelagic species and perhaps the reduced export flux associated with the SM season in SEAS may contribute to the decreased body weight of this species during SM.

In species such as *Hygophum proximum* (NEAS-WM) and *Lampanyctus nobilis* (WEIO-SM) females are positively allometric and males are isometric whereas in *Lampanyctus turneri* (NEAS-SM) females are negatively allometric and males are isometric in growth patterns. Positive allometry in females may be associated with gonad maturity where in females tend to gain body weight through fat deposition in the body. In the present study on the reproduction of *Hygophum proximum* from NEAS, the SM collections were dominated (75%) by mature, matured and ripe females, which gives strength to the assumption that weight gain (positive allometry) in females of the above species may be linked with body changes associated with breeding season.

Vipin *et al.,* (2016) worked out LWR for *Benthosema fibulatum, D. watasei, Myctophum obtusirostre* and *Myctophum spinosum* and reported that *Benthosema fibulatum* (b value 2.11-2.18) and *Myctophum obstusirostre* (b value 2.5-2.7) show a negative allometric growth; while *Myctophum spinosum* show an isometric growth for females (b=2.99) and negative allometric growth for males (b=2.48) and *Diaphus watasei* show a positive allometric growth (b = 3.06-3.4). Sebastine (2014) studied LWR of *Diaphus watasei* and *D. garmani* and reported that the species show isometric growth with *D. watasei* having b value of 2.95-3.06 and in *D. garmani* the b values range from 2.6 to 2.86. Hussain *et al.,* (1992) studied LWR relation in *Benthosema fibulatum* and reported an isometric growth pattern for both males and females of the species. Linkowski 1985 studied LWR of *Gymnoscopelus nicholsi* and its b value was found to be 3.36. Jiang *et al.,* (2017) reported LWR for seven myctophid species in South China Sea viz *Myctophum spinosum, Symbolophorus boops, Symbolophorus evermanni, Diaphus chrysorhynchus, Diaphus phillipsi,* *Diaphus watasei,* and stated that the *b*-values of these species were between 2.5-3.5 which was the anticipated b range by Froese (2006). In a study of the LWR of 11 myctophid species of North-Western Mediterranean Olivar *et al.,*(2013) observed positive allometric relationships in *Benthosema glaciale, Ceratoscopelus maderensis, Diaphus holti, Lampanyctus crocodilus, L. pusillus, Lobianchia dofleini, Notoscopelus elongatus* and *Symbolophorus veranyi* and isometric growth *in Hygophum benoiti* and *Myctophum punctatum.* Haimovici and Velasco (2000) studied LWR of marine fishes in southern Brazil and reported that *D. dumerilii* show isometric growth (b= 3.01). Vizvari *et al.,* (2017) study on the LWR and condition factor of female fishes of *Benthosema pterotum established* a negative allometric growth pattern for juveniles and an isometric growth pattern for adult female fishes. Karuppasamy *et al.,* (2008 b) reported b-value of 3.13 for both male and female of *Benthosema pterotum.* In a study on the Length-Weight Relationship of Small Pelagic Fish Species of the Southeast and South Brazilian Exclusive Economic Zone, Bernardes and Wongtschowski (2000) found that b value of seven myctophid fishes ranged from 3.1 to 3.55 viz *Diaphus dumerilii, Diaphus perspicillatus, Hygophum hygomii, Lepidophanes guentheri, Myctophum affine, Notoscopelus caudispinosus, Scolopsis multipunctatus* whereas in *D. garmani* the b value was 2.7. Our study on *Benthosema fibulatum* show negative allometric growth for female (b=2.38) and male (b=2.39) which is consistent with the observations of Vipin (2016). The study of Vipin (2016) show positive allometric growth fo*r D watasei* while the study by *Sebastine* (2014) and Jiang *et al.,* (2017) show isometric growth pattern for the same species. Our study on *D. watasei* indicate b value of this species as 2.7. Sebastine (2014) found allometric growth pattern for *D. garmani* (b= 2.6-2.9) while our study show a positive allometric growth (b=3.33) which is consistent with the report of Bernardes and Wongtschowski, (2000). According to Vipin (2016) *Myctophum spinosum* exhibited a negative allometric growth with females having an isometric growth, whereas results of the present study show a positive allometric growth for *M. spinosum* which is consistent to the observations of Jiang *et al* ., (2017). From the Baseiyan model LW approach by Froese *et al.,* 2014 length weight of eighteen species have been described by Froese and Pauly (2018) in fish base where their b value ranged between 2.8-3.3. No Basiyean model trend was noted for *Benthosema fibulatum* and *Bolinichthys longipes* by Froese and Pauly (2018). Normal LWR given in fish base for *Benthosema fibulatum* and *Bolinichthys longipes* indicate b value of 3- 3.03 for both the species.

The difference in the growth pattern of species may be due to physiological factors such as response to the environmental conditions they come across as a result of their migrations and also of their diurnal changes in growth (Childress *et al.,* 1980). The nature of the population, physiological status of maturity and gonadal development can have profound influence on growth rate of individuals (Tabassum *et al.,* 2013). The higher *b* value may be attributed to relative body plumpness increasing more quickly than body length in adults due to different factors, especially increase in gonadal size and sexual maturation (Froese 2006). Factors such as season, sex, growth phase, gonad maturity, stomach fullness, and local nutrition conditions are known to influence the LWRs (Froese 2006; Liang *et al.,* 2015). The findings of this study, will serve as a baseline for comparison with other stocks of this species in different parts of the Indian Ocean.

5.3.2 Food and Feeding in Myctophids.

Eleven myctophid species belonging to genus *Benthosema, Bolinichthys, Ceratoscopelus, Diaphus, Lampanyctus* and *Symbolophorus* were subjected to study. The study shows that all the species were carnivores. Stomach fullness of species during WM was evaluated and it was found that majority of the stomachs were Half-filled and one quarter filled. Only in *D. arabicus* three fourth filled stomach was prevailing. From the Gut content analysis of species collected during WM it appears that euphasids and shrimps are the main food items followed by semi digested matter. Copepods were also obtained from the stomachs of *Ceratoscopelus warmingii, Lampanyctus turneri* and *Benthosema fibulatum.* Compared to other species, prey diversity of *B. fibulatum* was relatively high and its prey included other mesopelagic fishes as well. All the four stages of stomach were observed in Diaphus samples; dominated by three fourth filled, Half-filled and Quarter filled stomachs. In day time after enough consumption of food myctophids migrate in to deeper layers during day time and will stay there till dusk and undertake leisurely digestion of the swallowed food items. Active feeding take place only during night time after their Diurnal vertical migration is completed (time of completion is species specific). Our sampling time at night was mostly between 16.00-17.30 hrs. And it is the peak time for completion of their migration and to start active foraging at surface layers. In case of *Diaphus coeruleus* and *D. watasei* it is generally believed that larger species of myctophids, do not undertake diurnal vertical migrations (Gjosaeter and Kawaguchi, 1980) which is corroborated by the present study where *D. coeruleus* was collected in bottom trawls both during night and day from almost the same depth (200–300 m). This species appears to be restricted to the waters immediately overlaying the seafloor. The Arabian Sea Oxygen Minimum Zone (OMZ) is reported to impinge on the seafloor at these depths (Karuppasamy *et al.,* 2011; Abdul Jaleel *et al.,* 2014). The affinity of this species is more towards the OMZ rather than to the thermocline depth (Karuppasamy *et al.,* 2011, Meera *et al.,* 2018). These less-migratory species are benefitted by migrating planktivorus organisms from the mid-slope depths (Bulman and Koslow 1992). In the present study gut content of *Diaphus coeruleus* had squid as the major food item followed by shrimps while in *D. watasei* the main food item was shrimps followed by squid. These observations corroborates well with the observations made by others. In *D. perspicillatus* the major food item obtained was copepods followed by shrimps. No squids were observed during the analysis.

Myctophids occupy trophic position as zooplankton consumers (Young and Blaber 1986; Dalpadado and Gjoaseter 1988a; Pakhmovo *et al.,* 1996; Moku *et al.,* 2000) and are therefore consumers of second order constituting the tertiary level of pelagic trophic system (Clarke 1978, 1980; Gordon *et al.,*1985; Duka 1986; Kawamura and Fujii 1988). Though cases of day time feeding has been reported by Legend *et al.,* 1972 and Hopkins and Torres 1989, most of the literature on myctophid feeding chronology strongly suggest that trophic migration occur at night when these fishes are known to reach the epipelagic Zone (Good Year *et al.,* 1972; Nafpaktitis *et al.,* 1977; Gorelova 1975, Hopkins and Baird 1985; Kinzer and shulz 1985; Dalpadado and Gjosaeter 1988a; Watanabe *et al.,* 1999) and their diet composition resembles mostly the zooplankton community (copepods, ostracods, euphasiids, shrimps, amphipods, chaetognaths etc) of the surface waters consisting of both surface and migrating sub surface species. A clear ontogenic dietary shift has been noticed by Dalpadado and Gjosaeter (1988a) that when size of fishes increases the importance of smaller prey items decreases. This is clearly evident in the present study where the food of larger myctophid species like *Diaphus watasei* and *D. coeruleus* consisted of larger shrimps and cephalopods than copepods and other mesozooplanktons.

Cluster Analysis to check the resemblance in food habits of the 11 species studied, show that the species fall under 4 groups with regard to their food habits (Group A, B, C and D). Group A myctophid species indicate 80% similarity, Group B 66%, Group C 79.9% similarity while Group D show 71.3% similarity in their food habits.

Group-A species *Diaphus watasei* and *D. coeruleus* were collected from SEAS during SM. *Diaphus coeruleus* is one of the pseudo-oceanic representatives of the Myctophidae (Hulley, 1985; Kornilova and Tsarin, 1993) and closely related to and difficult to distinguish from the coexisting species, *D. watasei*. The two species have overlapping geographic distribution in the northern Indian Ocean (Andaman Sea, western Arabian Sea etc.), where they are known to occupy the same habitat (Meera *et al.,* 2018). Like other members of the myctophidae both *Diaphus coeruleus* and *D. watase*i are carnivores. Results of the present study indicate that *D. coeruleus* feed predominantly on squids (86%) followed by crustaceans (11%) whereas *D. watasei* feed on shrimp (64%) and squid (30%). The current observations present an example of resource partitioning among myctophids occupying the same region in the SEAS, with *D. coeruleus* preferentially feeding on deep-sea squids, and *D. watasei* showing an affinity to deep-sea shrimps. Observations on the feeding habit of *D. coeruleus* have been reported by Meera *et al.,* (2018) and for *D. watasei* by Sebastine *et al.,* 2013.

Group-B species *Benthosema fibulatum* and *Diaphus perspicillatus* show 66% similarity in their food habits. Both species are highly oceanic and mesopelagic in their habitat occupying surface to 250 m depths during night and migrating up to 1000m during day time. Though they follow same food habit, resource portioning and competition are not significant because of their occurrence at two different trophic niches. Though in the present study the two species are seen to occupy different geographical areas (*D. perspicillatus* in SEAS and *B. fibulatum* in NEAS), which avoids competition for food between them, it is not necessary to occur all the time. If the two species occupy the same habitat probably there will be some sort of resource partitioning among them like in other myctophid species (Hopkins and Gartner 1992). Since D. *perspicillatus* is a bigger fish as compared to *B. fibulatum* their size class of prey may be different, which may help them overcome the competition for food.

Group-C and Group-D comprises of highly Oceanic and mesopelagic species, occupying 300-1000 m during day time and S-200m during night except *Diaphus arabicus* (group C1) which is bathypelagic and seen at 500m during day and S-100m during night. Though all these species depend on crustaceous zooplankton for their food, there is some preference in the food items. *Bolinicthys longipes* and *D. arabicus* are small fishes compared to other species in the group. Since in myctophids trophic competition is reduced through resource-partitioning, considerable overlap are seen at niche boundaries. Niche separation presumably is the result of competition during the evolution of the ecosystem and is maintained presently as "diffuse competition": the effect on a species of the combined competition from all other species at that trophic level. Hopkins and Gartner 1992 hypothesized that this broad niche overlap enables the co-occurrence, i.e., the "packing" of over 50 myctophid species in the epipelagic zone at night, the diel period of maximum potential competition. In the present study, niche similarity > 60% was considered as more than one species occupying the same niche (Figure 5.4). The potential for intense competition would be high and, over time, could result in competitive exclusion and changes in community structure. The fact that niche separation does occur is presumably the result of competition over the course of evolution of the ecosystem and may exist in present time as "diffuse competition" (Hopkins and Gartner 1992). As suggested by Pianka (1974), among the myctophids “diffuse competition" are minimized by niche overlap among the myctophid species.

Mesopelagic fishes seems to partition food among themselves by species and ontogenic variations in depth distribution and feeding time (Clarke 1973; Merett and Roe 1974). In many myctophids, trophic competition is reduced through resource partitioning although with considerable over lap at niche boundaries. Myctophid predation removes a fairly good percentage of zooplankton biomass and this predation is selective in that greatest pressure is on certain size classes and types of prey (Hopkins and Gartner 1992). Menon (2002) reported that the prey spectrum is very narrow in case of *Lampanyctus turneri* which feed only on copepods, euphasids, shrimps and ostracods which is consistent with the results obtained the present study. Myctophids are also found to reduce competition either by changing their feeding intensity or rather by switching their prey preferences (Menon 2002). Results of the present study show that *Diaphus watasei* preferred shrimps, followed by squids, euphausids, detritus, fishes and crabs as their food.

Diaphus garmani which occupy an identical niche preferred euphausids followed by shrimps, squids, detritus and fishes (Sebastine *et al.,* 2014).

5.3.3 Reproductive Biology of Myctophids

Though the details on reproductive biology of few myctophid species from Eastern Arabian Sea have been published, not much information on these aspects are available from the NEAS. Sexual dimorphism, Sex ratio, Sexual maturity, Gonad somatic index, fecundity and ova diameter in the myctophid species *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus arabicus, Diaphus jenseni, Diaphus thiollierei, Hygophum proximum* obtained from NEAS are discussed on the basis of data and information from 852 specimens.

The myctophids are dioecious and a number of genera also exhibit sexual dimorphism. In some of the myctophid genera (e.g. *Benthosema, Hygophum* and *Myctophum),* males possess a supra-caudal luminescent gland (just in front of tail on the upper surface of body), while females possess an infra-caudal gland (in front of tail on lower surface). In the diverse genus *Diaphus,* most species have enlarged luminescent glands on their heads (called supra-orbital glands or "headlights"), which are typically much larger in males. Another pattern of dimorphism is found in some species such as *Ceratoscopelus warmingii* and *Electrona antarctica,* in which males are distinctly smaller than females at maximum size (Gartner, 2008).

Sex ratio is an important population feature as it contributes to the rate of recruitment (Mayank and Dwivedi 2015b; Pathak *et al.,* 2015). The sex ratio in fish populations is usually close to 1:1, however, it sometimes tilts towards one or the other sex (Devlin and Nagahama, 2002; Dwivedi and Nautiyal, 2010). In the present study it was observed that the Male to Female ratios of *Benthosema fibulatum* (1:0.3) *Bolinichthys longipes* (1:0.3) *Diaphus arabicus* (1:0.5), *Diaphus jenseni* (1:0.2) and *Hygophum Proximum* (1:0.4) deviates significantly from the normal 1:1 ratio towards male dominance while in case of *Ceratoscopelus warmingii* (1:1.7), the females dominate over the males in sex ratio ($P<0.05$). For *Diaphus thiollierei* (1:1.04) P values of Chi-Square test ($P>0.05$) suggest that the differences in the sex ratio are not significant and therefore, the species follow the 1:1 Ratio. The occurrence of 1:1 ratio in *Diaphus thiollierei* is in agreement with reports on a number of other tropical-subtropical myctophids (Clarke, 1983; Karnella, 1987; Lisovenko and Prut'ko1987a) where male to females ratios are statistically insignificant. The deviations in sex ratio observed for the remaining 6 species may be attributed to various causes, namely temperature influences on sex determination (Conover and Kynard, 1981), selective mortality by sex through differential predation (Schultz, 1996), and differentiated sexual behavior, growth rate, or longevity expectation (Schultz, 1996).

Size-related differences in sex ratio were observed by Clarke (1983) who demonstrated that significant deviations from parity unrelated to size dimorphism in several myctophid species from the central Pacific Ocean and proposed several hypotheses to account for a sex ratio that significantly differs from 1:1. This is strongly supported by the data of Dalpadado (1988 b). From his study of 66 stations sampled in the Arabian Sea and western Indian Ocean, she reported that sex ratios of *Benthosema pterotum* were 1:1 at 48 stations, male dominated at

4 stations and female dominated at 12 stations. The analysis of seasonal collections of sexually mature individuals of this species collected in the Arabian Sea showed that males dominated during two seasonal collections (mean ratio 1.9: 1 M:F) and females during the other two (mean 0.6: 1 M:F). Such data indicate that sex ratios among most species are highly variable. It is uncertain whether variations in sex ratio are responses to single factors or a complex of causes, although Conover and Kynard (1981) have shown that it is possible for temperature to affect the sex ratio of developing fish embryos. Sampling design, procedure, and behaviour could conceivably affect sex ratios as well, via unequal sampling effort at depths dominated by one sex or the other, or through sex related capabilities in net avoidance.

Zeyl *et al.,* (2014) demonstrated that Gonado somatic index were effective in selecting spawning capable individuals at higher GSI values. In myctophids there is little information on the relationship between GSI and developmental stage of gonads, although this is useful for assessing maturity. In *Lampanyctodes hectoris* on the continental slope of eastern Tasmania, GSI was positively correlated with gonad stage determined by morphological and histological examination in both females and males (Young *et al.,* 1987). From the study of Sassa *et al* (2014, 2016) the GSI value of *B. pterotum*, *D. garmani* and *D. chrysorhynchus* were found between 3.6-3.9. The study of Vipin (2015) from Arabian Sea reports that the GSI value of *B. fibulatum* ranged between 2.6 to 3.26 and the highest value of 3.26 was obtained during month of April. In the present study the GSI values of *B. fibulatum* ranged from 2 to 4.5. Reports on the GSI values of other species are not available in the literature and therefore observations made in this preliminary study on the GSI value of myctophid species assume significance.

In the myctophid gonads examined during the course of the present study, six stages of maturity were identified based on macroscopic and microscopic examinations. Rare occurrences of spawned fishes in the specimens collected may indicate that these fishes spawn just once, die soon-afterwards and sink out of the sampled depth layers after spawning (Dalpadado, 1983, 1985; Hussain 1992). On the other hand there is another possibility that spawners recover extremely rapidly and leave no trace of previous spawning (Dalpadado 1988 b). The ova diameter frequency distribution studies of the myctophids revealed a multimodal or bimodal pattern (Menon 2002). The presence of two modes of developing oocytes in most mature ovaries (Hussain and Alikhan 1987; Dalpadado 1988) may indicate repeated spawning (Clarke 1983). Most myctophids have ovaries which contain oocytes for the next spawning and cells of protoplasmic growth as well as intermediate cells (Alekseeva and Alekseev 1983; Oven 1983; Gjoaster 1981 c and Lisovenko and Prutko1987) and hence these species are expected to have continuous oogenesis and spawning in many batches. Multiple (usually bimodial) oocyte size frequencies in myctophids have been reported by earlier authors (Oven, 1983; Young *et al.*, 1987; Dalpadado 1988b and Gartner 1993). Coupled with length of spawning period and other relevant data they have interpreted multimodial oocycte frequencies as evidence of repeated spawning with in one spawning season. Oven (1986) and Lisovenko and Prutko (1987) used continuous wave oogenesis to describe the continued sequential production of oocyte batches in myctophids which is an apt portrayal of oocyte development processes in these long term spawners.

The majority of myctophid species occupying the tropical zone of world oceans, spawn throughout the year although their intensity differs in different seasons (Pertseva and Ostroumova 1972, 1973; Oven 1983; Gjoaseter 1981c; Lisovenko and Prutko 1987). According to Gjoaseter and Kawaguchi (1980), winter spawning in high latitudes may be an adaptation to low water temperatures, since hatching takes place longer than in low latitudes. In the present study it was found that male and female mature at same size as found in *D. arabicus* and *B. fibulatum* or sometimes females mature at larger size than males as in *D. thiollierei* or males mature faster than females as in *Bolinicthys longipes, Ceratoscopelus warmingii, Diaphus jenseni* and *Hygophum proximum.* There is no clear relationship between fish length and maturity stages as there are larger fishes which were in the initial stage of maturity among sexes. Similar findings were made for several small tropical myctophids (Dalpadado 1988). The sexual differences in size may result from differences either in growth rates prior to maturity or in age at maturity and subsequent growth (Clarke 1983).

Table 5.1: Length, weight, length-weight regression and relative condition factor Kn summaries for males, females and both sexes combined

No	Species/Area/Season	Sex	No of specimens	SL range (cm)	W range (g)	a	b	aL^b	Kn
1	*Benthosema fibulatum/ NEAS/WM*	F	32	1.76-4.81	0.2-2.45	0.06	2.38	$0.0601\ L^{2.388}$	1.02
		M	98	2.29-4.52	0.4-2.2	0.058	2.39	$0.0586\ L^{2.393}$	1.02
		Combined	130	1.76-4.81	0.2-2.45	0.058	2.39	$0.0587\ L^{2.39}$	1.02
2	*Bolinichthys longipes/ NEAS/WM*	F	50	2.64-4.20	0.4-1.59	0.012	3.42	$0.0115\ L^{3.42}$	0.97
		M	147	2.45-4.46	0.2-1.42	0.011	3.5	$0.0108\ L^{3.51}$	0.99
		Combined	197	2.45-4.46	0.2-1.59	0.012	3.4	$0.0116\ L^{3.44}$	0.98
3	*Ceratoscopelus warmingii/ NEAS/WM*	F	99	2.58-6.68	0.3-4.2	0.016	2.9	$0.0156\ L^{2.92}$	1.02
		M	56	2.85-6.26	0.2-3.7	0.01	3.2	$0.0095\ L^{3.19}$	0.95
		Combined	155	2.58-6.68	0.2-4.2	0.01	3.2	$0.0104\ L^{3.15}$	0.99
4	*Diaphus antonbruuni/WEIO/SM*	F	22	3.54-5.85	1-3.1	0.045	2.42	$0.044\ L^{2.41}$	0.99
		M	48	2.79-6.14	0.5-3.31	0.044	2.44	$0.044\ L^{2.44}$	1.01
		Combined	70	2.79-6.14	0.5-3.31	0.043	2.45	$0.043\ L^{2.45}$	1.01
5	*Diaphus arabicus/ NEAS/WM*	F	46	2.44-3.34	0.2-0.5	0.017	2.92	$0.0172\ L^{2.92}$	1.03
		M	77	2.01-3.14	0.1-0.5	0.01	3.34	$0.0100\ L^{3.33}$	1.01
		Combined	123	2.01-3.34	0.1-0.5	0.012	3.24	$0.0115\ L^{3.24}$	1.02
6	*Diaphus brachycephalus/ WEIO/SM*	F	19	3.14-4.87	0.2-1.2	0.0055	3.56	$0.005\ L^{3.56}$	1.04
		M	23	2.94-4.84	0.2-1	0.0036	3.65	$0.0036\ L^{3.65}$	1.03
		Combined	42	2.94-4.84	0.2-1.2	0.0041	3.66	$0.0041\ L^{3.66}$	1.03
7	*Diaphus coeruleus/SEAS/SM*	F	17	10-12.49	12.54-23.11	0.269	1.72	$0.2691\ L^{1.71}$	1.00
		M	76	5.83-12.01	2.22-21.2	0.009	3.14	$0.0094\ L^{3.13}$	1.02

		Combined	93	5.83-12.49	2.22-23.11	0.011	3.1	0.0107 $L^{3.08}$	1.04
		F	32	3.08-5.32	0.7-2.5	0.026	2.71	0.0269 $L^{2.71}$	1.04
8	Diaphus fulgens */WEIO/SM*	M	46	3.55-5.73	0.5-2.6	0.011	3.26	0.011 $L^{3.26}$	1.01
		Combined	78	3.08-5.73	0.5-2.6	0.02	2.88	0.020 $L^{2.88}$	1.03
9	Diaphus garmani*/NEAS/WM*	Combined	158	2.19-4.25	0.2-4	0.025	3.3	0.0244 $L^{3.37}$	1.10
		F	18	3.61-6.03	0.9-3.2	0.059	2.18	0.0599 L^{2187}	1.02
10	Diaphus jenseni/ *NEAS/WM*	M	64	2.97-6.17	0.2-3.5	0.027	2.68	0.0276 $L^{2.68}$	1.03
		Combined	82	2.97-6.17	0.2-3.5	0.03	2.56	0.033 $L^{2.56}$	1.32
11	Diaphus lucidus*/SEAS/SM*	combined	34	3.40-5.95	0.4-2.6	0.01	3.12	0.0104 $L^{3.121}$	1.05
		F	15	3.19-4.95	0.3-1.8	0.0048	3.57	0.0048 $L^{3.56}$	0.65
12	Diaphus luetkeni */WEIO/SM*	M	32	2.63-5.23	0.2-1.8	0.0054	3.6	0.0054 $L^{3.60}$	0.91
		Combined	47	2.63-5.23	0.2-1.8	0.0049	3.63	0.0044 $L^{3.63}$	0.83
		F	29	3.02-6.83	0.4-5.2	0.0074	3.43	0.0074 $L^{3.43}$	1.01
13	Diaphus perspicillatus / */SEAS/SM*	M	52	3.09-5.74	0.2-3.2	0.0045	3.74	0.0054 $L^{3.374}$	1.03
		Combined	81	3.02-6.83	0.2-5.2	0.0052	3.65	0.0052 $L^{3.65}$	1.02
		F	51	3.48-8.25	0.9-8.2	0.02	2.85	0.0207 $L^{2.85}$	1.04
14	Diaphus thiollierei/ *NEAS/WM*	M	49	2.96-8.25	0.3-5.4	0.011	3.19	0.0117 $L^{3.19}$	1.18
		Combined	100	2.96-8.25	0.3-8.2	0.015	3.03	0.0151 $L^{3.03}$	1.15
15	Diaphus watasei*/SEAS/SM*	Combined	47	9.5-14.1	12.2-36	0.025	2.73	0.0253 $L^{2.73}$	1.03
		F	33	3.09-3.87	0.4-0.9	0.028	3.52	0.0074 $L^{3.52}$	0.85
16	Hygophum proximum/ *NEAS/WM*	M	82	2.36-4.69	0.2-1.3	0.0073	2.72	0.0197 $L^{2.72}$	1.12
		Combined	115	2.36-4.69	0.2-1.3	0.01	2.78	0.0033 $L^{2.78}$	1.14
17	Myctophum spinosum/	F	42	4.8-7.9	1.38-8.4	0.0079	3.36	0.0079 $L^{3.36}$	1.00

	NEAS/WM	M	49	5.5-6.3	1.17-3.9	0.015	2.96	$0.0151\ L^{2.96}$	1.02
		Combined	91	4.8-7.9	1.17-8.4	0.01	3.19	$0.0105\ L^{3.19}$	1.01
18	Lampanyctus tenuiformis/ *WEIO/SM*	F	19	4.14-7.94	0.7-3	0.013	2.67	$0.0138\ L^{2.67}$	1.08
		M	48	3.11-8.16	0.4-4	0.026	2.26	$0.0266\ L^{2.26}$	1.06
		Combined	67	3.11-8.16	0.4-4	0.022	2.39	$0.022\ L^{2.39}$	1.06
19	Lampanyctus turneri/ *NEAS/WM*	F	26	4.14-6.68	0.7-3.2	0.028	2.59	$0.0282\ L^{2.59}$	1.03
		M	56	3.11-6.87	0.4-3.1	0.0073	3.37	$0.0073\ L^{3.37}$	1.02
		Combined	82	3.11-6.87	0.4-3.2	0.0089	3.26	$0.0089\ L^{3.26}$	1.02
20	Lampanyctus nobilis/ *WEIO/SM*	F	12	4.79-8.77	0.8-7.5	0.0028	3.61	$0.0028\ L^{3.61}$	1.01
		M	46	4.46-10.67	0.7-6.8	0.0073	3.03	$0.0073\ L^{3.03}$	1.03
		Combined	58	4.46-10.67	0.7-7.5	0.0061	3.14	$0.0061\ L^{3.14}$	1.02

Table 5.2: Percentage of Stomach fullness of Myctophids

Area	Season	Myctophid Species	% of stomach fullness			
			Fully Filled	Three quarter filled	Half filled	One quarter filled
NEAS	WM	*Benthosema fibulatum (Ben fib)*	9	26	21	44
		Bolinichthys longipes (Bol log)	6	13	50	31
		Ceratoscopelus warmingii(Cer war)	10	5	23	62
		Diaphus arabicus (Dia ara)		93	7	
		Diaphus garmani (Dia gar)		5	7	88
		Diaphus jenseni (Dia jen)			62	38
		Lampanyctus turneri (Las tur)	6	3	3	88
		Symbolophorus evermanni (Sym eve)	10	10	45	35
SEAS	SM	*Diaphus coeruleus (Dia cor)*	7	13	42	38
		Diaphus perspicillatus (Dia per)	9	26	25	40
		Diaphus watasei (Dia wat)	16	55	21	8

Table 5.3: Percentage of IRI of prey groups of Myctophid species studied.

Area	Season	Species	Prey groups	% of IRI
NEAS	WM	*Benthosema fibulatum* (Ben fib)	Amphipod	40.7
			Shrimp	25.5
			Copepod	20.7
			Ostracod	11.8
			Semi Digested Matter	1.1
			Fish	0.07
			Bregmacerous	0.006
			Squid	0.003
			Salp	0.001
		Bolinichthys longipes (Bol lon)	Euphasid	45.1
			Semi Digested Matter	43.8
			Shrimp	11.0
		Ceratoscopelus warmingii (Cer war)	Semi Digested Matter	40.6
			Shrimp	34.8
			Euphasid	14.2
			Copepod	9.4
			Fish	0.89
		Diaphus arabicus (Dia ara)	Semi Digested Matter	44.7
			Euphasid	37.17
			Shrimp	18.12
		Diaphus garmani (Dia gar)	Semi Digested Matter	43.22
			Euphasid	39.52
			Shrimp	17.25
		Diaphus jenseni (Dia jen)	Semi Digested Matter	93.37
			Shrimp	6.62
		Lampanyctus turneri (Lam tur)	Semi Digested Matter	42.45
			Ostracod	27.14
			Shrimp	19.55
			Copepod	10.85
		Symbolophorus evermanni (Sym ever)	Semi Digested Matter	45.60
			Shrimp	35.89
			Euphasid	18.50
SEAS	SM	*Diaphus coeruleus* (Dia cor)	squid	86.13
			Shrimp	11.5
			Semi Digested Matter	2.35
		Diaphus perspillatus (Dia per)	Copepod	62.6
			Semi Digested Matter	21.3
			Shrimp	16.07
		Diaphus watasei (Dia wat)	Shrimp	64.35
			Squid	30.84
			Semi Digested Matter	4.41
			Fish	0.003

Chapter 6

SUMMARY & CONCLUSIONS

- The main study area is the Western Indian Ocean regions NEAS (North Eastern Arabian Sea), SEAS (South Eastern Arabian Sea) and WEIO (Western Equatorial Indian Ocean). For species distribution and biodiversity other regions of WIO namely the Tropical South Western Indian Ocean (TSWIO), Sub-Tropical South Western Indian Ocean (STSWIO), Tropical Western Arabian Sea (TWAS) and Sub-Tropical Northern Arabian Sea (STNAS) are included. Field data collections were made exclusively on board *FORV.Sagar Sampada*, covering a total of 74 stations during the study period (2013 to 2016) involving 6 cruises and 141 days of cruise participation.
- A total of 59 species of myctophids were recorded from WIO in the course of the present study which includes 6 new records of species. The new records include *Bolinichthys nikolayi*, *Diaphus theta*, *Lampanyctus crocodilus*, *Lampanyctus macdonaldi*, *Lampadena urophaos* from WEIO and *Diaphus similis* from SEAS. Based on this and information pooled from secondary data, number of valid myctophid species in the WIO is revalidated to 158 species instead of the 97 species reported by Nafpaktitis, 1982.
- Analysis of presence/ absence data on myctophid species from the Western Indian Ocean north of 15^0S through ANOSIM, PERMANOVA test and nMDS clearly depicts the presence of 3 distinct myctophid assemblages in the study area, representing the eco-regions NEAS, SEAS & WEIO.

- Average dissimilarity between NEAS and SEAS assemblages is 64.58% (SIMPER) and 91.27% of this is explained by 19 species, of which *Bolinichthys longipes*, *Myctophum spinosum*, *Lampanyctus turneri*, *Benthosema pterotum*, *Ceratoscopelus warmingii*, *Diaphus lucidus* and *D. thiollierei* are the principle contributors.
- The dissimilarity between NEAS and WEIO assemblages is 84.52% and is explained by 43 species with *Diaphus arabicus*, *Benthosema fibulatum*, *Bolinichthys longipes*, *Diaphus lucidus* and *D. garmani* as the main contributors to the dissimilarity.
- Species estimators (Chaos & Jacknife 1) predict the occurrence of 66 species in WEIO, 64 in SEAS and 21 in NEAS which may be collected from these regions with more sampling. Sampling sufficiency was found to be 86% for WEIO, 70% for SEAS and 55% for NEAS. The present study, with reports on 16 species from NEAS (from 15 trawl surveys), 45 species from SEAS (from 37 trawl surveys) and 55 species from WEIO (from 9 trawl surveys) has recorded 70-90% of the highest estimated species diversity.
- Among the 59 species recorded from WIO in the present study, 16 species have wide distributional range covering NEAS, SEAS & WEIO. The shared species are; *Benthosema fibulatum, B. pterotum , Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus aliciae, D. arabicus, D. garmani, D. jenseni, D. lucidus, D. signatus, Diaphus thiollierei, Hygophum proximum, Lampanyctus turneri, Myctophum spinosum, Symbolophorus evermanni, Symbolophorus rufinus*. These species therefore are expected to have wide geographical distribution and possibly may have better ability to tolerate wide range of environmental conditions.

- The distributional ranges of 25 species out of the 59 myctophid species recorded from WIO are restricted to the SEAS & WEIO. They are absent in NEAS. The 27 species are; *Taaningichthys minimus, Bolinichthys pyrsobolus, Bolinichthys indicus, Diaphus brachycephalus, D. coeruleus, D. diadematus, D. diademophilus, D. effulgens, D. fulgens, D. lobatus, D. mollis, D. parri, D. perspicillatus, D. problematicus, D. splendidus, D. taaningi, D. aliciae, Hygophum hanseni, Lampanyctus intricarius, L. nobilis, Lampadena luminosa, L. urophaos, L. anomala, Myctophum asperum, M. aurolaternatum, M. nitidulum and M. obtusirostre.* Since these species occupy both SEAS & WEIO, but are not represented in the NEAS, these species may have lesser range of tolerance to environmental changes, as compared to the species occupying all the three eco-regions. It is interesting to note that 13 out of these 25 species fall under the Genus Diaphus.
- Among the species recorded from WIO, 16 species have only narrow distributional range. 14 species are restricted to the WEIO and 2 species are found only in SEAS. The species exclusively found in WEIO are *Bolinichthys supralateralis, Bolinichthys nikolayi, Diaphus antonbruuni, Diaphus luetkeni, Diaphus theta, Electrona risso, Lampadena anomala, Lampadena luminosa, Lampanyctus macdonaldi, Lampanyctus photonotus, Lampanyctus tenuiformis, Lampanyctus crocodiles, Nannobrachium achirus,* and *Nannobrachium atrum.* Species that are found only in SEAS include *Diaphus watasei* and *Diaphus similis.* It is to be expected that these species have only limited tolerance to environmental changes.

- ❖ The number of myctophid species and their regional diversity indices are highest for WEIO followed by SEAS and NEAS. The WEIO recorded 55 species with estimated species richness (9.43), species evenness (0.75) and species diversity (4.33) whereas the SEAS with 45 species had values of 6.006, 0.638 and 3.506 respectively. Species number (16 species) was lowest in NEAS and the corresponding indices of diversity were 1.793, 0.665 and 2.66. It is evident that myctophid species number and diversity show a decreasing trend from equator to the high latitudes of Northern WIO, whereas in the present study the biomass of myctophids showed an opposite trend.
- ❖ Results of Cannonical Correspondence Analysis (CCA) clearly indicate that the observed variations in the 3 species assemblages are closely linked with the DO levels in the intermediate water depths and the water density. CTD measurements show higher DO levels in the 500m depths of WEIO during all seasons, whereas in the SEAS suboxic conditions occur during the SM & FIM seasons. Intermediate depths of NEAS have perennial suboxic conditions.
- ❖ Species assemblages of eco-regions in the present study are best explained by tolerance range of species to low oxygen levels. WEIO assemblages are characterised by species assemblage that need higher DO, whereas the assemblage of SEAS is dominated by species that can tolerate intermediate levels of DO as compared to WEIO & NEAS. NEAS on the other hand is occupied by species that tolerates very low DO levels.
- ❖ Data collected in the course of the present study clearly depict seasonal and regional variations in the environmental variables

especially the DO and density. Sub surface DO levels are high in the WEIO and show a decreasing trend towards north. Water Density is high in the north and decreases towards south. The intermediate waters (500m depth) of WEIO are characterized by the presence of low temperature (9.5^{0}C), low salinity (34.82) and less dense waters (26.98) with higher DO (1.66 ml/L) levels all through the year. Presence of Antarctic Bottom Waters in the WEIO is mainly responsible for these conditions. The sub-surface water characteristics of SEAS vary with seasons. During SM the upsloping of bottom waters enhanced through the upwelling mode of Kelvin make the intermediate depths (500m depth) of SEAS low in oxygen (0.15ml/L) content and high in density (27.03). The oxygen deficiency in the intermediate depths (500m) during FIM & WM are mainly due to the decomposition of organic matter exported from the euphotic zone. However DO levels at 1000m depths are relatively higher. In the NEAS perennial suboxic (DO <0.2 ml/L) conditions persist in the intermediate water columns (500 & 1000m depths) during all the 3 seasons, as these waters are occupied by the dense Arabian Sea High Saline Waters (ASHSW) and Persian Gulf Waters (PGW) that are poor in DO.

- ❖ Species that prefer highly Oxygenated waters with relatively low temperature and salinity and high density (WEIO waters) include *Bolinichthys pyrsobolus, Diaphus aliciae, Diaphus coeruleus, Diaphus diadematus, Diaphus effulgens, Diaphus fragilis, Diaphus jenseni, Diaphus luetkeni, Diaphus splendidus, and Symbolophorus rufinus.* The species associated with intermediate levels of Oxygen, temperature, salinity and density (SEAS) are *Benthosema pterotum,* *Bolinichthys indicus, Diaphus garmani, Diaphus perspicillatus, Diaphus luetkeni, Diaphus perspicillatus, Diaphus problematicus Diaphus similis, Diaphus lobatus, Diaphus lucidus, Diaphus thiollierei, Lampanyctus turneri, Myctophum spinosum and Symbolophorus evermanni.* The species which can thrive under low Oxygenated waters with relatively high temperature and salinity (NEAS) are represented by *Benthosema fibulatum, Bolinichthys longipes, Ceratoscopelus warmingii, Diaphus signatus, Myctophum asperum, Diaphus arabicus, and Hygophum proximum.*

- ❖ Among the 20 myctophid species for which LWR and Kn have been worked out in the present study, 6 species show isometric growth (b=3) in females, males and sexes combined; in 6 species females, males and combined sexes are positively allometric (b significantly >3) whereas 5 species show negative allometric growth (b significantly <3) in females, males and sexes combined. In *Hygophum proximum* and *Lampanyctus nobilis* females are positively allometric and males are isometric in growth, whereas in *L. turneri* females are negatively allometric and males are isometric in growth.
- ❖ Species exhibiting isometric growth include *Ceratoscopelus warmingii* (NEAS-WM), *Diaphus fulgens* (WEIO-SM), *Diaphus garmani* (NEAS-WM), *Diaphus lucidus* (SEAS-SM), *Diaphus thiollierei* (NEAS-WM) and *Myctophum spinosum* (NEAS-WM). The relative condition factor of all the above species were one or slightly above one which indicate that stocks of these species thrive well in the areas and seasons mentioned above.
- ❖ Positive allometric growths were recorded in 6 species, namely; *Bolinichthys longipes* (NEAS-WM), *Diaphus arabicus* (NEAS-WM),

Diaphus brachycephalus (WEIO-SM), *Diaphus coeruleus* (SEAS-SM), *Diaphus luetkeni* (WEIO-SM) and *D. perspicillatus* (SEAS-SM). Therefore, it is reasonable to state that weight increments of these species are more than length increments. This may be related to the body form of these species viz; *D. brachycephalus* (broad body), *B. longipes* and *D. arabicus* (small body size), *D. coeruleus* (relatively large sized fish) *D. luetkeni* and *D. perspicillatus* (large head) etc. The Kn values for all the above species except females of *D. luetkeni* (kn=0.65) were close to one indicating their relative good condition.

- Five species recorded negative allometric growths viz; *Benthosema fibulatum* (NEAS-WM), *Diaphus antonbruuni* (WEIO-SM), *Diaphus jenseni* (NEAS-WM), *D. watasei* (SEAS-SM), *Lampanyctus tenuiformis* (WEIO-WM). Since Kn is not biased towards females, negative allometry may be more due to the body shape or increased metabolic activity in these fishes rather than gonad maturity and related stress. All the above species except *D. watasei* are oceanic species known to undertake extensive dial migrations (reaching up to 1000 – 1500 m depths during day and occupying 100 m to 200 m depth strata during night). *D. watasei* is a benthopelagic species and perhaps the reduced export flux associated with the SM season in SEAS may contribute to the low body weight of this species during SM.
- In species such as *Hygophum proximum* (NEAS-WM) and *Lampanyctus nobilis* (WEIO-SM) females are positively allometric and males are isometric whereas in *Lampanyctus turneri* (NEAS-SM) females are negatively allometric and males are isometric in growth patterns. Positive allometry in females may be associated

with gonad maturity where in females tend to gain body weight through fat deposition in the body. In the present study on the reproduction of *Hygophum proximum* from NEAS, the SM collections were dominated (75%) by mature, matured and ripe females, which gives strength to the assumption that weight gain (positive allometry) in females of the above species may be linked with body changes associated with breeding season.

- ❖ Food and feeding in 11 myctophid species belonging to genus *Benthosema, Bolinichthys, Ceratoscopelus, Diaphus, Lampanyctus* and *Symbolophorus* shows that all the species were carnivores. Majority of the stomachs were Half-filled and one quarter filled except in *D. arabicus* where three fourth filled stomach was prevailing. From the Gut content analysis of species collected during WM it appears that euphasids and shrimps are the main food items followed by semi digested matter. Copepods were also obtained from the stomachs of *Ceratoscopelus warmingii, Lampanyctus turneri and Benthosema fibulatum.* Compared to other species, prey diversity of *B. fibulatum* was relatively high and its prey included other mesopelagic fishes as well. In the present study gut content of *Diaphus coeruleus* had squid as the major food item followed by shrimps while in *D. watasei* the main food item was shrimps followed by squid. These observations corroborates well with the observations made by others. In *D. perspicillatus* the major food item obtained was copepods followed by shrimps. No squids were observed during the analysis.
- ❖ Food and feeding habits of the 11 species were subjected to cluster analysis to evaluate resemblances in food habits. The analysis yielded 4 cluster groups. Group A comprised of *Diaphus*

coeruleus and *Diaphus watasei* with 83% similarity in food habits. Group B consisted of *Benthosema fibulatum* and *Diaphus perspicillatus* with 66 % similarity. Group C consisted of 5 species viz *Bolinicthys longipes, Diaphus arabicus, D. garmani, C. warmingii* and *Symbolophorus evermanni* at 79.9% similarity. The last cluster (D) consisting of *Diaphus jenseni and Lampanyctus turneri* had 71.36% similarity. Cluster B, C, D were found to have 56% similarity in their food habits.

- Group-A species *Diaphus watasei* and *D. coeruleus* were collected from SEAS during SM. The two species have overlapping geographic distribution in the northern Indian Ocean (Andaman Sea, western Arabian Sea etc.), where they are known to occupy the same habitat. Like other members of the myctophidae both *Diaphus coeruleus* and *D. watase*i are carnivores. Results of the present study indicate that *D. coeruleus* feed predominantly on squids (86%) followed by crustaceans (11%) whereas *D. watasei* feed on shrimp (64%) and squid (30%). The current observations present an example of resource partitioning among myctophids occupying the same region in the SEAS, with *D. coeruleus* preferentially feeding on deep-sea squids, and *D. watasei* showing an affinity to deep-sea shrimps.
- Group-B species *Benthosema fibulatum* and *Diaphus perspicillatus* are highly oceanic and mesopelagic in their habitat. Though they follow same food habit, resource portioning and competition are not significant because of their occurrence at two different trophic niches. Though in the present study the two species are seen to occupy different geographical areas (*D. perspicillatus* in SEAS and *B. fibulatum* in NEAS), which avoids competition for food

between them, it is not necessary to occur all the time. If the two species occupy the same habitat probably there will be some sort of resource partitioning among them. Since D. *perspicillatus* is a bigger fish as compared to *B. fibulatum* their size class of prey may be different, which may help them overcome the competition for food.

- Group-C and Group-D comprises of highly Oceanic and mesopelagic species, occupying 300-1000 m during day time and S-200m during night except *Diaphus arabicus* (group C1) which is bathypelagic and seen at 500m during day and S-100m during night. Though all these species depend on crustaceous zooplankton for their food, there is some preference in the food items. *Bolinichthys longipes* and *D. arabicus* are small fishes compared to other species in the group. Since in myctophids trophic competition is reduced through resource-partitioning, considerable overlap are seen at niche boundaries.
- The Male to Female ratios of *Benthosema fibulatum* (1:0.3) *Bolinichthys longipes* (1:0.3) *Diaphus arabicus* (1:0.5)*, Diaphus jenseni* (1:0.2) and *Hygophum Proximum* (1:0.4) deviates significantly from the normal 1:1 ratio towards male dominance while in case of *Ceratoscopelus warmingii* (1:1.7), the females dominate over the males in sex ratio ($P<0.05$). For *Diaphus thiollierei* (1:1.04) P values of Chi-Square test ($P>0.05$) suggest that the differences in the sex ratio are not significant and therefore, the species follow the 1:1 Ratio. The occurrence of 1:1 ratio in *Diaphus thiollierei* is in agreement with reports on a number of other tropical-subtropical myctophids where male to females ratios are statistically insignificant. The deviations in sex ratio observed for

the remaining 6 species may be attributed to various causes, namely temperature influences on sex determination, selective mortality by sex through differential predation, and differentiated sexual behavior, growth rate, or longevity expectation.

- Gonadal maturity was studied in 7 species. In all the seven species, ripe (V) was the common stage. Immature stages were not observed in *D. arabicus*, females of *B. longipes* and *C. warmingii.* Spent (VI) stage was present in *B. longipes*, females of *D. arabicus*, *D. thiollierei* and male specimens of *D. jenseni*. Most abundant of all the six stages observed in the specimens was ripe stage followed by matured, mature and maturing stages and least observed were the spent stage and the immature stage. Rare occurrences of spawned fishes in the specimens collected may indicate that these fishes spawn just once, die soon-afterwards and sink out of the sampled depth layers after spawning or that spawners recover extremely rapidly and leave no trace of previous spawning.
- The total Myctophid biomass obtained from NEAS and SEAS using swept area method was 17903458 tonnes. The abundance of myctophids varied in north and south waters of Eastern Arabian Sea. In NEAS myctophid constituted about 9213048 tonnes and in SEAS the biomass of myctophid was estimated to be 8690410 tonnes.
- The biomass of 9.21 million tons estimated for the NEAS through the present study is contributed by 7 species of Diaphus (40%), 2 species of Benthosema (31%) one species each of Bolinichthys (21%) and Ceratoscopelus (7%). These 11 species account for 99% of the myctophid biomass of NEAS. On the

other hand, the estimated biomass of 8.69 million ton of myctophid in the SEAS is supported by 29 species. The catch per unit area of the most abundant species (*Benthosema fibulatum*) show sharp decrease from 36677 Kg/Km^2 (NEAS) to 29939 kg/Km^2 in SEAS which implies that with increase in species diversity the dominance of any species in the total biomass gets reduced.

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