DEEP–SEA EELS (TELEOSTEI: ANGUILLIFORMES) OF THE INDIAN EEZ: SYSTEMATICS, DISTRIBUTION AND BIOLOGY

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Ph. D. Thesis in Marine Biology

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Certificate

This is to certify that the thesis entitled **“Deep–sea Eels (Teleostei: Anguilliformes) of the Indian EEZ: Systematics, Distribution and Biology”** is an authentic record of the research work carried out by Mr. Sumod K. S. (Reg. No.: 4326), 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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Declaration

I hereby declare that the thesis entitled "**Deep–sea Eels (Teleostei: Anguilliformes) of the Indian EEZ: Systematics, Distribution and Biology**" 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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Dedicated to

my son Akshath Krishna

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Sumod K. S.

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List of Abbreviations

AMS	Australian Museum, Sydney, Australia
AN	Andaman Sea
ANCOVA	Analysis of covariance
ANOSIM	Analysis of similarity
ANSP	Academy of Natural Sciences, Philadelphia, Pennsylvania, U.S.A.
AS	Arabian Sea
BLAST	Basic Local Alignment Search Tool
BMNH	British Museum (Natural History), London
BoB	Bay of Bengal
BOLD	Barcode of Life Data System
CAS	California Academy of Sciences
CMFRI	Central Marine Fisheries Research Institute
CMLRE	Centre for Marine Living Resources & Ecology
COI	*Cytochrome oxidase I*
CTX	*Ciguatoxin*
DNA	Deoxyribo Nucleic Acid
DOM	Dissolved organic matter
DSL	Deep Scattering Layer
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organisation
FMNH	Field Museum of Natural History, Chicago, Illinois, U.S.A.
FORV	Fishery Oceanographic Research Vessel
FSI	Fishery Survey of India
HOT	High Opening Trawl
HSDT-CV	High Speed Demersal Trawl-Crustacean Version
IKMT	Isaacs-Kid Mid-water trawl
IRI	Index of Relative Importance
IUCN	International Union for Conservation of Nature
K2P	Kimura 2 Parameter
LBZ	Lower bathyal Zone
LS	Lakshadweep Sea

LWRs : Length Weight Relationship
MEGA : Molecular Evolutionary Genetics Analysis
MHNH : Muséum National d’Histoire Naturelle. Paris
MLR : Marine Living Resources
MNHN : National Museum of Natural History, France
MoES : Ministry of Earth Science
MVF : Mean Vertebrae Formula
NCBI : National Center for Biotechnology Information
NEAS : North East Arabian Sea
NJ : Neighbour Joining
NMNZ : National Museum of New Zealand
NWBoB : North West Bay of Bengal
ODV : Ocean Data View
OMZ : Oxygen Minimum Zone
PCR : Polymerase Chain Reaction
POM : Particulate organic matter
PRIMER : Plymouth Routines in Multivariate Ecological Research
R.I.M.S : Royal Indian Marine Survey
RMNH : Rijksmuseum van Natuurlijke Histoire, Leiden, Netherlands
SAIAB : South African Institute for Aquatic Biodiversity
SEAS : South East Arabian Sea
SIMPER : Similarity Percentage
SPSS : Statistical Package for the Social Sciences
SWBoB : South West Bay of Bengal
UBZ : Upper Bathyal Zone
USA : United State of America
USNM : United States National Museum
WoRMS : World Register of Marine Species
ZMB : Zoologisches Museum, Vertebraten, Ichthyologie, Berlin
ZSI : Zoological Survey of India, Kolkata, India

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Chapter 1

GENERAL INTRODUCTION

Contents

1.1 Introduction

Oceans constitute about 70% of Earth's surface. Oceanic autotrophs perform half of the global primary production, and therefore play a major role in the removal of atmospheric carbon dioxide and release of oxygen to the atmosphere. The greatest biodiversity on planet Earth is found in the Oceans, but still about 95% of the Ocean remain unexplored, mostly the deep-sea.

Deep-sea is generally defined as the area starting from the shelf break, which corresponds approximately to the 200 m isobaths in many parts of the world oceans (Thistle 2003). Oceans form the largest ecosystem on our planet, covering an area of 300×10^6 Km^2. The deep-sea had long been thought to be devoid of life until the Challenger expedition (1872–1876) documented the presence of many forms of life from deep ocean floor. Deep oceans are generally considered as the least productive part of the oceans, though in very limited places fish biomass can be very high (Norse et al. 2012). Deep-sea is considered to have the highest biodiversity on Earth, comprising of mega, macro and meiofauana, with high evenness (Ramirez-Llodra et al. 2010). Life in most parts of deep sea is ultimately dependent on surface derived organic matter for energy to fuel growth, metabolism and reproduction. Food support to deep-sea ecosystems descends from the overlaying water column in several forms such as the phytodetritus, macrophyte detritus, fecal pellets, marine snow and carrion (Yeh & Drazen 2009).

Deep-sea is considered as a relatively homogenous environment with stable temperature, no seasonality and no photoperiod. Nevertheless, regular temporal variations are visible in several factors, such as food supply (Lampitt 1985; Rice et al. 1986), temperature (4°C to -1°C), high oxygen concentration [near saturation except in Oxygen Minimum Layer (OMZ)], high pressure (increase of 1 atmospheric pressure for every 10 m depth), absence of light and scarcity of food. Organisms living in deep-sea ecosystems have developed several adaptations such as large and very sensitive eyes, well developed sense organs, black coloration, hydrodynamic shapes, reduced skeleton and muscle mass, bioluminescence (capacity to produce light) and low metabolic rates etc. Deep-water species are considered to be very sensitive to exploitation due to their slow growth rates, low fecundity, delayed maturity, high longevity and low resilience to overfishing. The deep-sea still remain as one of the least explored and understood ecosystems on Earth due to its remoteness and associated technological challenges in investigation. The maintenance of biodiversity is critical to the function and sustainability of deep-sea ecosystems which carries out numerous key ecosystem functions. Hence a better understanding about the deep-sea biodiversity is needed in order to manage this ecosystem effectively. Deep-sea eels of the order Anguilliformes are one of the diverse and abundant group of deep-sea fishes that are least documented.

1.2 Order Anguilliformes

Kingdom : *Animalia*
Phylum : *Chordata*
Subphylum : *Vertebrata*
Superclass : *Gnathostomata*
Class : *Actinopterygii*
Subclass : *Neopterygii*
Division : *Teleostei*
Subdivision : *Elopomorpha*
Order : *Anguilliformes*

The order Anguilliformes belongs to the subdivision Elopomorpha which includes 4 orders Elopiformes (ten-pounders), Albuliformes (bone-fishes), Saccopharyngiformes (sac pharynx fishes) and Anguilliformes (true eels) (Nelson 2006). The relationship between the members of Elopomorphs is largely based on the common occurrence of leptocephalus larvae. Order Anguilliformes is the largest among the subdivision Elopomorpha with 16 families 156 genera and 967 species.

Order Anguilliformes comprises of relatively elongated snake like fishes, called as "Apodes" (footless) due to the absence of pelvic fins. They are designated as "True-eels" to distinguish them from other fishes having similar elongated body shape and burrowing nature such as electric eel, cusk eels, and spiny eels which belong to orders namely Gymnotiformes, Ophidiformes and Notocanthiformes. They are found in almost all marine habitats, from the abyssal plain to coral reefs and distributed throughout the warm and temperate zones of the world (Nelson 2006). They are cryptic in nature, may insinuate themselves into crevices in rock or coral or into the bottom sediment (Castle 1968a). Moray eels are best known for this behavior. Some eels are well adapted for borrowing into the sediments (Ophichthids & Heterenchylids). Few are mesopelagic inhabitants and perform vertical migration from surface to bottom (Nemichthyids, Serrivomerids and Derichthyids) and others are bathypelagic (Synaphobranchids)

1.2.1 General characteristics & classification of Anguilliformes

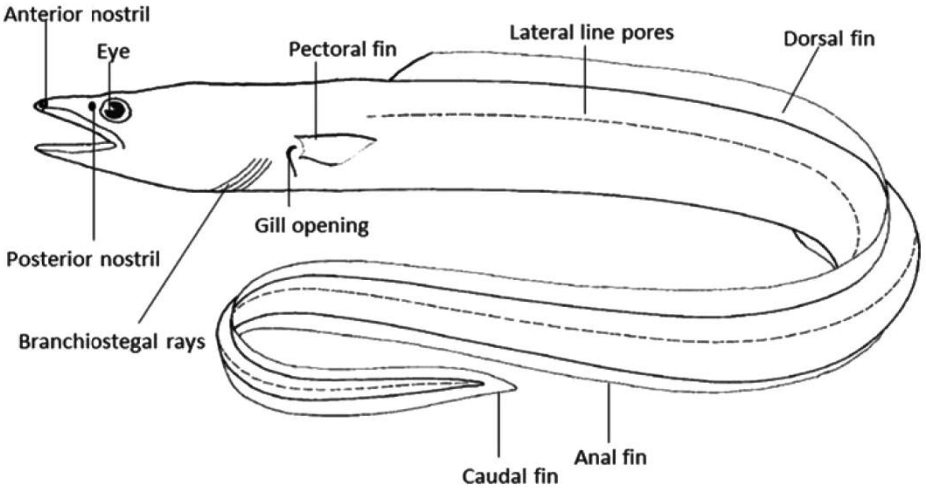

Figure 1.1: General features of Anguilliformes

Eels are long bodied snake like fishes (Figure 1.1) with confluent vertical fins, sometimes reduced or absent especially in burrowing species

(Castle 1968a). Pectoral fins are absent in some eels, but when present are high on the side at least midlateral in position rather than low on the body. Spines are absent on fins. Gill opening restricted to a slit or hole on each side (on or under side of head in some species). The head including the gill region is elongate, the gill apparatus is positioned backwards almost behind the skull rather than below the skull as found in other fishes (Robins 1989a; Tesch & White 2008). Gill rackers absent (except in *Prontanguilla*, Johnson et al. 2012). Pelvic fins and pelvic girdle absent. Nostrils are widely placed except in family Serrivomeridae. Scales usually absent. If present they are small and cycloid and found embedded in the skin. Pectoral girdle is displaced posteriorly and disconnected from the skull. Post-temporal absent. Preopercle, opercle, subopercle and interopercle are present as separate elements but reduced and concealed under the skin. Branchio-stegal rays vary in numbers (6-49) but are usually numerous. Maxilla toothed, bordering mouth; both premaxillae, the vomer, and ethmoid fused into a single bone (except premaxillae autogenous in *Protanguilla*). The skeleton is reduced. The number of vertebrae varies between 79 (Protanguillidae) to more than 300 (Nemichthydae) in deep sea species (Nielson & smith 1978; Johnson et al. 2012). The alimentary tract probably always lacks pyloric appendices (Robins 1989a). Female gonads have no separate outlets (oviducts) and the eggs are expelled through the abdominal pore (Tesch & White 2008). They have retained the swim bladder. They swim by means of typical anguilliform motion using the body and vertical fins (Gray 1933). Another interesting aspect of their swimming behavior is the ability to swim in both directions (D'Août & Aerts 1999) especially in borrowing species which allows them to retreat rapidly into their burrows while still being able to look at any potential enemy (Castle,1968a). Although they can congregate in large numbers under specific situations, both larvae and adults do not generally form schools and thus can be considered to be solitary.

Colouration in Anguilliformes ranges from black or dark gray in deep-sea species to rich colours and complex patterns in tropical reef species. Adult sizes range from 17.9 cm in the shortest eel *Protanguilla palau* Johnson, Ida & Sakaue, 2012 to about 4 m in the longest eel *Strophidon sathete* (Hamilton, 1822).

1.2.2 Systematic classification

Linnaeus (1758) classified eels as *Muraena* and included them in the group; Apodes. Later Regan (1912a) established the modern understanding on Anguilliformes. Regan and successors were not able to define the various families properly due to the scarcity of samples from many families and reluctance to dissect the rare specimens (Robins 1989a). Under the Order Anguilliformes Robins (1989a) recognized 3 suborders (Anguilloidei, Congroidei & Muraenoidei). Nelson (2006) followed this classification. On the basis of several recent molecular studies Nelson et al. (2016) has introduced many changes in relationships among the suborder and families of order Anguilliformes. In the latest classification Nelson et al. (2016) follow the basic arrangement of the phylogenetic study of Inoue et al. (2010) comprising of 4 orders; 8 suborders and 19 families. Order Saccopharyngiformes (Nelson 2006) is shifted in this classification as a suborder of Anguilliformes. Instead a new order Notacanthiformes which include Halosurus and spiny eels is erected. Recently, Poulsen et al. (2018) introduced a new family (Neocymatidae) under order Saccopharingiforms, and therefore the number of families under Anguilliformes should be considered as 20. The details of new classification adopted from Nelson et al. (2016) (Figure 1.2) are as follows.

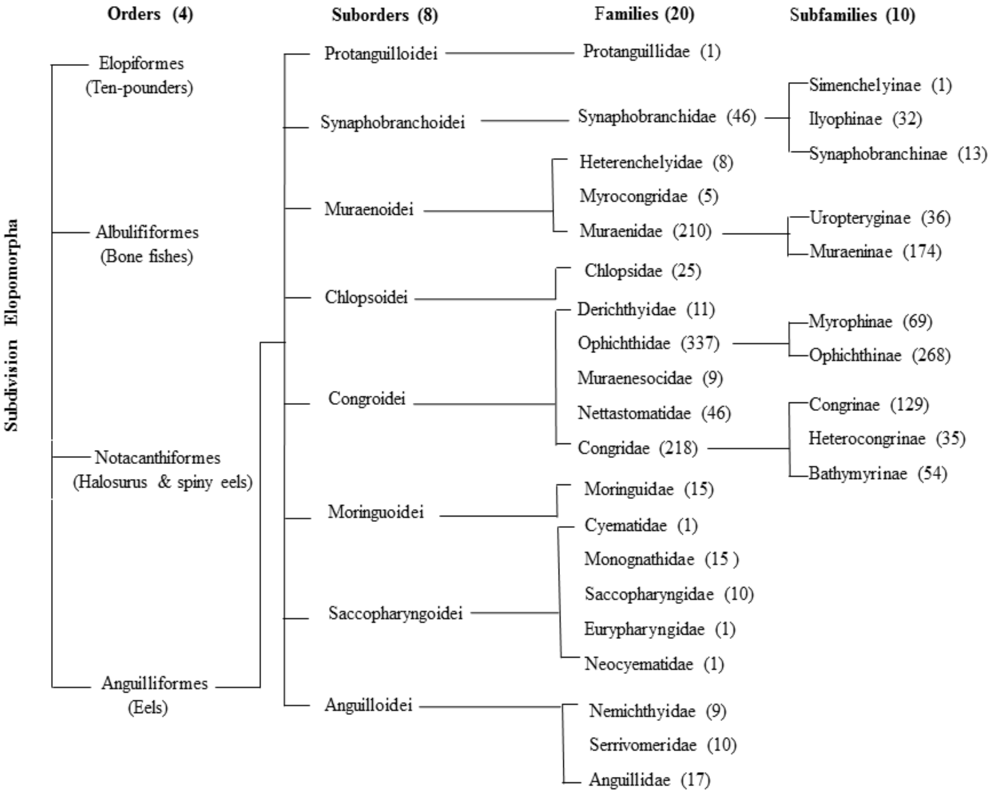

Figure 1.2: Classification of order Anguilliformes. Number in brackets indicates number of orders/ suborders/ families/ sub-families and species.

Nelson (2016) modified the classification system to include family Neocymatidae under Anguilliformes. As per this classification, Anguilliformes include 8 suborders, 20 families, 10 subfamilies and 995 species (Figure 1.2).

I. **Suborder Protanguilloidae**: Comprise single family with a single species. Johnson et al. (2012) considered *Protanguilla* as "living fossil" of true eels but recent molecular studies (Santini et al. 2013; Tang & Fielitz 2013) indicate that *Protanguilla* is a sister group of Synaphobranchoidei. Previous classifications (Nelson 2006) does not include family Protanguillidae, because the family was erected only in 2012.

II. **Suborder Synaphobranchoidei:** Contains single family Synaphobranchidae. In the new classification family Synaphobranchidae is placed in its own suborder. In the previous classification of Nelson (2006) this family was included in the suborder Congroidei. Synaphobranchidae includes 3 subfamilies (Simenchelyinae, Ilyophinae & Synaphobranchinae) with 12 genera and 46 species.

III. **Suborder Muraenoidei**: Includes 3 families (Heterenchelyidae, Myrocongridae and Muraenidae). Johson et al. (2012) and Santini et al. (2013) recover this group as monophyletic and distinct from Anguilliformes. Family Heterenchelyidae include 2 genera and 8 species, and Myrocongridae 1 genus and 5 species. The family Muraenidae includes 2 subfamilies (Uropterygiinae & Muraeninae) with 17 genera and 210 species,

IV. **Suborder Chlopsoidei:** includes a single family Chlopsidae. Previous classification of Nelson (2006) included family Chlopsidae in the suborder Muraenoidei. Family Clopsidae is represented by 8 genera and 25 species.

V. **Suborder Congroidei:** As per Nelson, 2006 Suborder Congroidei included 6 families (Derichthyidae, Ophichthidae, Muraenesocidae, Nettastomatidae, Congriadae and Colocongridae). In the new classification (Nelson et al. 2016) the family Colocongridae is merged with family Derichthyidae as both the families belong to a single clade as per evidences from recent molecular analysis (Lo´pez et al. 2007, Johnson et al. 2012 & Tang & Fielitz 2013). Accordingly in the recent classification, Suborder Congroidei include only 5 families (Derichthyidae, Ophichthidae, Muraenesocidae, Nettastomatidae and Congriadae). Familiy Ophichthidae with 64 genera and 337 species is divided into 2 subfamilies Myrophinae and Ophichthinae. Similarly family Congridae with 29 genera and 218 species is divided into 3 subfamilies Congrinae, Heterocongrinae and Bathymyrinae. Familiy Muraenesocidae contains 5 genera and 9 species, Family Nettastomatidae has 6 genera and 46 species and Derichthyidae (Including Colocongridae) is represented by 3genera and 11species.

VI. **Suborder Moringuoidei:** Includes a single family Moringuidae with 2 genera and 15 species.

VII. **Suborder Saccopharyngoidei**: Includes 4 families, Cyematidae, Monognathidae, Saccopharyngidae and Eupharyngidae (present status 5 families including the newly erected family Neocymatidae). Earlier classifications including that of Nelson (2006), treated

Saccopharyngoidei (Swallower & Gulpers) as a separate order (Saccopharyngiformes). However recent molecular studies suggest their relationship to the Anguilloidei and therefore they are now included in the order Anguilliformes. Family Monognathidae includes 1 genus and 15 species, Saccopharyngidae 1 genus and 10 species, Cyematidae, Eurypharyngidae and Neocymatidae contains single species each.

VIII. Suborder Anguilloidei: Includes 3 families (Nemichthyidae, Serrivomeridae and Anguillidae). This grouping is based on the suggestion from molecular studies by Inoue et al. (2010) and morphological characteristics. Family Nemichthyidae contains 3 genera and 9 species, Serrivomeridae 2 genera and 10 species and Anguillidae 1 genus and 17 species.

The works on classification of eels are still in progress. Several relationships and interrelationships between the members of order Anguilliformes have yet not conclusive. In the present study we follow the classification adopted in Catalog of fishes (van der Laan et al. 2018), FishBase (Froese & Pauly 2018), World Register of Marine Species (WoRMS Editorial Board 2018) and recent publications (Ho et al. 2018a) (discussed in chapter 3), treating the Saccopharyngiformes as a separate order from Anguilliformes and retaining the Colocongridae as a separate family without merging with family Derychthyidae to maintain consistency and easy comparisons with earlier reports.

1.2.3 Phylogenetic relationships

The Phylogenetic works on Anguilliformes are still in progress. The phylogenetic relationships of Elopomorpaha have been a subject of debate in the past due to the extensive morphological diversity (Chen et al. 2015). Their monophyly is currently accepted based on the morphological and molecular evidences (Forey et al.1996; Inoue et al. 2004; Nelson 2006; Wiley & Johnson 2010; Chen et al. 2014). Most remarkable among them is the leptocephalus larvae shared by all Elopomorpha (Green wood et al. 1966; Hulet & Robins, 1989).

The most updated phylogenetic studies on Anguilliformes are summarized below (Chen et al. 2014, 2015) (Figure 1.3). The order Saccopharyngiformes (gulper eels) form a monophyletic group with the Anguilliformes (true eels) (Inoue et al. 2004, 2010; Johnson et al. 2012; Tang & Fielitz 2013; Chen et al. 2014). Elopomomorh fishes are accordingly redefined in four orders: Elopiformes, Albuliformes, Notacanthiformes and Anguilliformes (Saccopharyngiformes included in Anguilliformes) (Tang & Fielitz 2013; Santini et al. 2013; Chen et al. 2014). In Anguilliformes four monophyletic groups are included (Protanguilloidei, Muraenoidei, Anguilloidei, and Congroidei) (Chen et al. 2014). Traditionally considered monophyly of some anguilliform families such as, Congridae, Derichthyidae, Nettastomatidae, and Muraenesocidae, are now considered invalid (Tang & Fielitz 2013; Santini et al. 2013; Chen et al. 2014). On the basis of morphological and genetic evidences, it is hypothesized that family Protanguillidae appears to have diverged earlier in evolution than other true eels (Johnson et al. 2012). However, the recent phylogenetic analyses show robust evidence of its sister group relationship to another member of the Protanguilloidei, Synaphobranchidae (Santini et al. 2013; Chen et al. 2014).

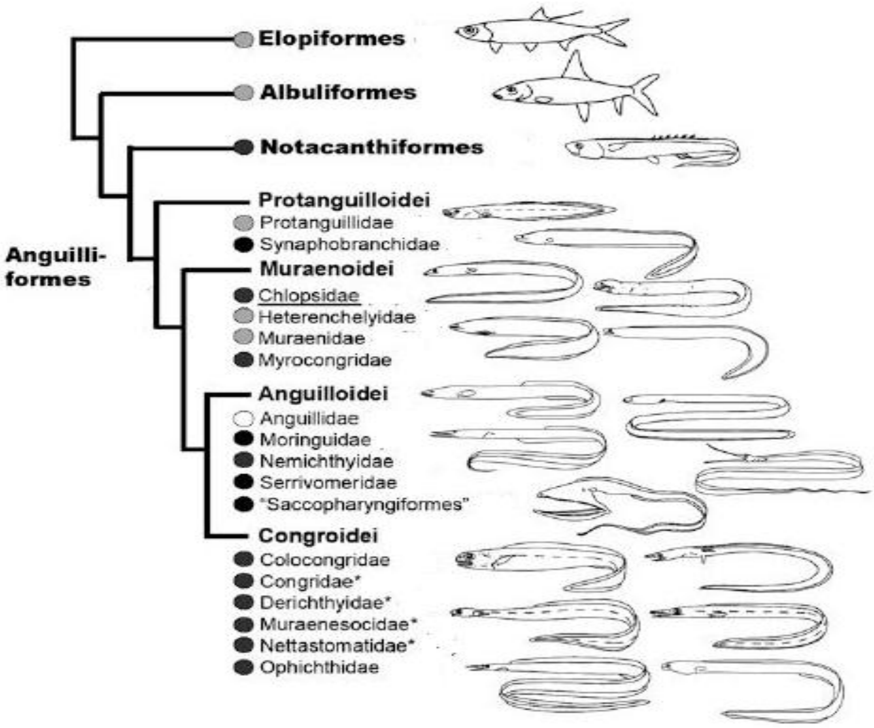

Figure 1.3: Phylogenetic relationships of Anguilliformes adopted from Chen et al. (2015). The taxonomic status of Chlopsidae (underlined) is uncertain; Asterisk shows the families that do not appear to be monophyletic. The order Saccopharyngiformes is nested within the anguilliform suborder Anguilloidei.

Despite the recent efforts by researchers, the sister group relationship among the various species of Anguilliformes still remain unresolved (Tang & Fielitz 2013; Santini et al. 2013; Chen et al. 2014; Dornburg et al. 2015). Recently Poulsen et al. (2018) erected a new family Neocyematidae based on a leptocephalus larvae that has phylogenetic affinity with the Saccopharyngidae (gulpur eels) and

Eurypharyngidae gulpur (swallower eels) by their deep body and mitogenomic DNA sequences and gene orders. As pointed out earlier the classification of eels is still in progress. In the present study we have developed 11 new sequences (details in chapter 3) for deep-sea Anguilliformes which will definitely help in the ongoing phylogenetic studies of this least understood group.

1.2.4 Fossil Anguilliformes

Anguilliformes first appeared as fossils in the upper cretaceous period about 100 million years ago (Belouze et al. 2003), have lost their pelvic and median fins (dorsal, anal and caudal) and became confluent (Robins 1989). Cretaceous eels that may be stem-group taxa include *Abisaadia, Anguillavus, Hayenchelys, Luenchelys, and Urenchelys* (Forey et al. 1996, 2003; Johnson et al. 2012). Cretaceous eels (except for *Anguillavus*) have already lost their pelvic fins and girdle, including the primitive cretaceous eel *Libanechelys* described by Taverne (2004). Johnson et al. (2012) reported a small eel like fish (*Protanguilla palau*) from Republic of Palau in western Pacific which represents an ancient anguilliform linage that dates back to the early Mesozoic (roughly 200 million years ago). Phylogenic analysis based on osteological studies and whole mitogenome sequences clearly depicts that this fish belongs to true eels. They assigned this species as ‘living fossil’ as it closely resembles fossil specimens rather than any living eels. Long, independent evolutionary history dating back to the early Mesozoic and a retention of primitive morphological features (e.g. the presence of a premaxilla, metapterygoid, free symplectic, gill rakers, pseudobranch and distinct caudal fin rays) made them recognize this species as a ‘living fossil’ of the true eels. However recent molecular studies (Santini et al.

2013; Tang & Fielitz 2013) propose *Protanguilla* as a sister group of Synaphobranchoidei.

1.2.5 Diversity & distribution

The order Anguilliformes is the largest among the subdivision Elopomorpha with 16 families 156 genera and 967 species (Fricke et al. 2018a). As stated earlier, throughout this thesis, we are following the old classification (16 families & 967 species of Anguilliformes), instead of the recently erected classification system of Nelson et al. (2016), were Anguilliformes are stated to have 20 families and 995 species. Anguilliformes are cosmopolitan in distribution. Pacific Ocean has the highest diversity with 630 species (65.8% of the extant species) followed by Indian Ocean with 322 species (33.3%) and Atlantic with 248 species (25.6%). The greatest diversity of Anguilliformes in the world is recorded from Taiwan (Pacific Ocean) especially the deep-sea with a diversity of 14 families, 79 genera and 232 species (Ho et al. 2018a). The most speciose families of order Anguilliformes are Ophichthidae with 64 genera and 337 species (35%), Congridae with 29 genera and 218 species (22.5 %) and Muraenidae with 17 genera and 210 species (21.7%). The least speciose families are Protanguillidae (single species) and Derichthyidae (2 genera and 3 species). The 967 species reported here include 76 new species discovered during the last one decade (2008–2018), mostly belonging to the families Ophichthidae, Congridae and Muraenidae (Ho et al. 2018a). This trend indicates that further increase in survey efforts globally can add more species diversity to the fauna of Anguilliformes.

Family wise distribution of order Anguilliformes reveals that families Muraenidae and Ophichthidae are distributed worldwide in tropical and subtropical Seas (Smith 2012), Protanguillidae is restricted to the western Pacific (Johnson et al. 2012), Anguillidae is distributed in tropical and temperate Seas except eastern Pacific & southern Atlantic (Silfvergrip, 2009; Nelson et al. 2016), Heterenchelyidae is distributed in Atlantic and eastern Pacific (Smith 1989a; Eagderi & Adriaens, 2010). The remaining 11 families Colocongridae, Congridae, Chlopsidae, Derichthyidae, Moringuidae, Myrocongridae Muraenesocidae, Nemichthyidae, Nettastomatidae, Serrivomeridae and Synaphobranchidae are distributed in Atlantic, Indian and Pacific Oceans (Nelson 2006).

1.2.6 Reproduction and early life history

Biology and reproductive ecology of most of the eel species are not known (Watanabe et al. 2016) especially that of deep-sea eels. However reproductive biology of few commercially important species belonging to family Anguillidae, Congridae, Muraenesocidae, Muraenidae and Ophichthidae are partly available. Reproductive biology of Family Anguillidae is reported by Yamamoto & Yamauchi 1974; Ohta et al. 1997; Lokman et al. 1998; Kagawa 2003; Dufour et al. 2003; Han et al. 2003; Sato et al. 2003; Tsukamoto 2006; Chow et al. 2009; Endo et al. 2011; Tsukamoto et al. 2011 and Arai & Kadir 2017. Umezawa et al. 1991 and Kobayashi et al. 2015 reported on the reproduction in the family Muraensocidae. Reports on the reproductive biology of family Congridae are from Cau & Maconi 1984; Hood et al. 1988; Okamura et al. 2000; Sbaihi et al. 2001; Utoh et al. 2013; O’Sullivan et al. 2003; Correia et al. 2009; Figueroa et al. 2010; Kurogi et al. 2012); Aspects of reproduction in Muraenidae were reported by Thresher 1984 and Fishelson 1992; that of Ophichthidae by Wenner 1976 and Casadevall et al. 2001 and Nettastomatidae by Porcu et al. 2013. Gonadal morphology of few deep-sea eels has been reported by Fishelson (1994). The fecundity of *Muraenesox bagio*, family Muraenesocidae from Indian waters is reported to range from 17475-144932 eggs (CMFRI 2016–2017 Annual report).

Life cycle of many Anguilliform species are yet to be studied. It is believed that all of them undergo the same complex life cycles regardless of the final habitat they occupy. All eels, even the freshwater species (family Anguillidae), spawn in the ocean. Fertilization among these fishes is external. Most shallow water and continental slope eel species appear to spawn close to their juvenile and adult habitats (Miller 2002). Eggs are relatively large (1–4mm) compared to many other fishes, with large perivitelline space (Castle 1984; Smith 1989b) which allows them to undergo extended development even before being able to feed. The stage immediately after the larval hatch is the preleptocephalus stage (3–7mm). During this stage larvae do not feed externally but rely on their oil globule for nutrition. Some species are born without teeth and some others have rudimentary teeth. After the absorption of oil globule they transform into the leptocephalus stage. Leptocephalus larvae have an elongated, highly compressed, nearly transparent, leaf like body quite unlike their adults (Smith 1989b). Leptocephalus larval forms are characteristic of members belong to the orders Anguilliformes; Notocanthiformes and Elopiformes. Leptocephalus of these orders can be easily distinguished by certain features. Elopiform leptocephali have a large forked fin and non-confluent dorsal and anal fins. Notocanthiform leptocephali are extremely elongate with a single caudal filament rather than a true caudal fin. Anguilliform leptocephali have small, rounded caudal fin confluent with the dorsal and anal fins and also lack pelvic fins in all stages of development (Smith, 1979). Their body shape and head shapes vary widely among the families, though all have similar basic morphological features (Figure1.4). All leptocephali are strongly laterally compressed and transparent, with a small tubular gut along the ventral margin. Dorsal, anal, and pectoral fins are present starting in the euryodontic leptocephalus stage, but the pectoral fin does not have rays until metamorphosis (Smith 1989b). They are found to feed on marine snow and discarded larvacean houses (Miller 2009). Particulate organic material (POM) and dissolved organic matter (DOM) provide an important source of nutrition (Otake 1996; Ozaki et al. 2006). The leptocephali may be the only example of a vertebrate that obtains its nutrition from DOM and POM, hence the leptocephali comprise a unique trophic link in the pelagic food web. Worldwide distribution and basic biology of leptocephali has not been extensively studied due to their strong tendency to avoid standard plankton nets and their fragile transparent bodies (Miller 2009). They grow much larger (50–300 mm) than other typical fish larvae hence they can actively swim both forward and backward. They also have large eyes which increases the vision and helps them avoid small plankton nets (Miller & McCleave 1994; Miller & Tsukamoto 2004). Leptocephali are difficult to collect unless large trawls are fished at night (Miller & Tsukamoto 2004, 2006). Leptocephali undergo metamorphosis in the open ocean after a period that ranges from six months to three years (Castle 1968a; Smith, 1979). After the leptocephali have reached their maximum size, they enter into the glass eel or elver stage. Their laterally compressed bodies tend to become more rounded in this stage. The head thickens, the olfactory organ enlarges, and their teeth will be lost (Miller 2009). In general it can be said that the colder the waters longer the larval stage. The juveniles look like smaller version of adults. These juveniles are the products of many changes that can be summarized as follows. Reduction in total body mass (up to 90% of weight) and body length, making the initial juvenile smaller than the larvae itself. The extended pelagic life of leptocephali allows wide dispersal of the species and this may be the reason for the occurrence of eels throughout the Indo-Pacific (Castle 1986).

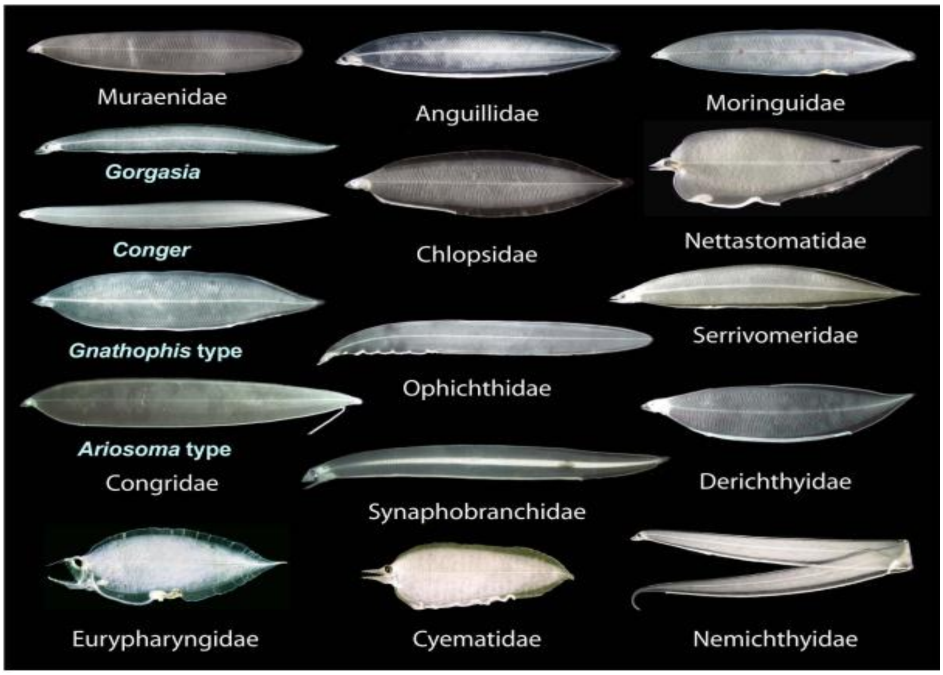

Figure 1.4: Photographs of freshly caught leptocephali showing wide variety of body shapes (Adopted from Miller 2009).

Information on the eggs and early development of eels from Indian waters are mainly from the contributions of Aiyar et al. 1944; Jones & Pantulu 1955; Bapat 1955; Ganapati & Raju 1960 and George 1987. The first report of occurrence of eel eggs in India is by Aiyar et al. (1944) from Madras Coast. Nair & Bhimachar (1950) described three types of eggs and two types of early larvae from off Tuticorin, Gulf of Mannar. Bapat (1955) briefly studied on eel egg and newly-hatched larva from Mandapam area. Descriptions of the early larvae belonging to family Ophichthidae, obtained by rearing the eggs collected from Madras Coast are given by Jones & Pantulu (1955). Ganapati & Raju (1960) described the eggs and early development of *Muraena* sp. and *Ophichthus* sp. off Visakhapattanam Coast. Dharmamba (1960) gave an account of the early development of an Ophichthid egg from the Lawson's Bay, Waltair. Bensam (1966) described the eggs and early development of a Muraenid eel from Indian waters. Dorairaj et al. (1981) conducted induced maturation in *Anguilla bicolor bicolor.*

Nair (1947) stated that most eel species breed in open sea and that there is no seasonality in the occurrence of leptocephali as the eels breed throughout the year. Gopinath (1950) summarized the earlier studies on the leptocephali from the Indo–Pacific region and described few leptocephali from Trivandrum coast. Nair & Mohamed. (1960) recorded congrid eel, *Uroconger lepturus* and described various metamorphosis stages of same from Bombay waters. George (1987) recorded the eggs and early development of an ophichthid and muraenid eels from Vizhinjam waters. James & Prabha devi (1990) reported that the species composition as well as abundance of leptocephali were maximum in the

West Coast, between Goa and Cochin, beyond the 1000 m depth contour of Indian EEZ. They observed that the distribution of larvae coincided very well with the depth of Deep Scattering Layer (DSL) and noted no regular seasonality in larval occurrence. They also pointed out that distribution of leptocephali in Bay of Bengal and the equatorial waters were less compared to Arabian Sea. Gupta et al. 1976 & Menon et al. 1998 also reported the high abundance of leptocephali from Arabian Sea where high salinity water mass existed. Menon et al. (1998) reported leptocephali as one of the major groups among the DSL biocomposition of the mesopelagic zone. James & Prabha devi (1990) reported the leptocephali of 6 families namely, Synaphobranchidae, Nettastomatidae, Ophichthidae, Muraenidae, Nemichthyidae and Congridae from Indian EEZ of which the family Congridae was represented by maximum number of larvae. Balu (2004) reported leptocephalai belonging to five families viz., Congridae, Ophichthidae, Muraenidae, Nemichthyidae and Synaphobranchidae from South West Coast of India.

1.2.7 Food and feeding

Eels are opportunistic feeders, to the point that virtually any animal species they encounter can become a source of food for them, including aquatic insects, crustaceans, fishes and cephalopods. Extreme cases of parasitic diet of fresh water eel (*Anguilla* sp.) with preference on bottom living invertebrates were reported by Frost (1946). The predatory and nocturnal feeding nature of moray eels preying mostly on crustaceans and fishes by the sense of smell have been reported by various authors (Miller 1987, 1989; Sazima 1986; McConnel & Lowe-McConnell 1987; Böhlke

& Chaplin 1993; Randall 1996; Carvalho-Filho 1999; Santos & Castro 2003). Anderson (2005) studied the diet of 5 species of deep-sea eels and reported *Bassanago albescens* and *Gnathophis capensis* as demersal grazers feeding on nekton from water column; *Diastobranchus capensis* and *Synaphobranchus Kaupii* as demersal mesocarnivores but also pick nekton and scavenge and *Simenchelys parasitica* as scavenger. *Nemichthys scolopaceus* diet with crustaceans was reported by various authors (Mead & Earle 1970; Gartner 1981; Appelbaum 1982; Karmovskaya 1982; Hopkins et al. 1996, Bowman et al. 2000; Feagans-Bartow & Sutton 2014). Casadevall et al. (1994) reported the nocturnal feeding habit of *Ophichthus rufus* comprising of benthic organisms (decapodes: *Processa canaliculata* and *Alpheus glaber*) and the teleost fish (*Calliononymus maculates*) and also pointed out that adult males have euryphagic and carnivorous diets, whereas adult females have stenophagic piscivorous diet.

Kagawade (1969) described the food and feeding of *Congresox talabonoides* from Bombay waters. The food analysis revealed that the occurrence of empty stomach is very common in this fish, (83 % of the stomachs examined). A few fishes that had food in their stomachs indicated a carnivorous and predatory habit. The semi-digested food mostly consisted of *Sciaena* spp., *Polynemus heptadactylus*, *Coilia dussumieri*, *Trichiurus* spp., *Lactarius lactarius*, *Harpadon nehereus* and sometimes even young eels. The crustacean food comprised prawns and crabs. Suseelan & Nair (1969) also reported the carnivorous and predatory nature of *C. talabonoides*. Devadoss et al. (1979) reported the largely piscivorous feeding habit in *Muraenesox cinereus*. Kagawade

(1969), Suseelan & Nair (1969) and Devadoss et al. (1979) have reported the lack of feeding activity in eels during spawning period. Reports on food and feeding of deep sea eels from India are scanty. Thankappan et al. (2007) & Hashim (2012) reported the preference of *Nemichthys*, Leptocepalus and shrimps in the diet of *Gavialiceps taeniola.* Viji et al. (2017) reported only digested matter from the stomach of *B. vicinus*.

1.2.8 Commercial importance

Eels are an important source of food in Japan, China, United Kingdom, New Zealand, Italy, Germany, Netherlands, Poland, Denmark and Sweden etc. Eel families Anguillidae, Muraenesocidae, Congridae and Muraenidae are commercially exploited worldwide. *Anguilla* spp. are traded internationally as live eels for farming and consumption as fresh, frozen and smoked/ prepared eels and as skins and leather products for fashion accessories. The IUCN list the European eel *Anguilla anguilla* as a "Critically endangered" species due to the substantial declines (90–95%) in their recruitment during the last 45 years. Recently in 2013 another species *Anguilla japonica,* the Japanese eel has been listed in "Endangered" category based on their substantial decline (50%) over a period of 30 years (Jacoby & Gollock 2014). Overfishing, parasites, barriers to migration (dams), natural climatic changes and pollutions are the major factors contributing to the decline of these species. Earlier days eels were considered as cheaper food in India but the demand for live eels in international market has increased their price. In India species such as *Anguilla bengalensis*, *Anguilla bicolar*, *Congresox talabon*, *Congresox talabonoides*, *Muraenesox bagio*, *Muraenesox cinereus*, *Conger cinereus* and *Strophidon sathete* are used as food. These high value species are mainly caught from the conventional fishing grounds of the northwest and northeast coasts largely as by-catch of trawl nets (70%), and non-mechanized gears (13%) (Menon et al. 1998; Bhathal 2005). Total eel landings in India are estimated as 11,171 (t) (CMFRI Annual report 2016–2017).

Consumption of moray eels (*Gymnothorax* sp) from tropical waters have long been known to be high risk resulting in ciguatera poisoning characterized by prominent neurological problems (Chan 2017). Ciguatera poisoning is caused by the toxic dianoflagellates of the *Gambierdiscus* sp which are the precursors of the ciguatoxin (CTX) and on passing through the food chain it is bioaccumulated in moray eels. As an apex predator they contain greatest and most potent form of CTX which may even cause death to humans during consumption.

Eels of the families Muraenidae and Ophichthidae inhabiting the coral reefs have vibrant colours, body pattern and also thrive well in captivity. Hence they have high demand in marine ornamental fish trade. Similarly *Anguilla* spp. is used in freshwater aquariums. In India collection of marine ornamental fishes from the wild is banned according to the Wildlife Protection Act, 1972 even though illegal collections of eels still exist. In India *Anguilla* sp. is considered to have high medicinal value for the treatment of (arthritis). Another species *Anguilla bengalensis* is considered as a pristine rare ornamental species of Himalayan drainage and being preserved in temple ponds in Nepal for religious purpose (Shrestha 2003).

1.3 Deep-sea Anguilliformes of India: Relevance of the study

Indian deep-sea eels was first documented by the pioneering works of Lt. Col. Alfred William Alcock based on samples collected during the R. I. M. S. *Investigator* surveys (1884–1914) dating back more than a century ago. He described 17 species of deep-sea eels in 13 genera under the family Muraenidae (Alcock 1899), now revalidated as 16 species under 14 genera and 7 families. Most of them (12 species) were new to Science. Followed by Alcock1899, Lloyd (1909) reported two more species from Indian waters based on R. I. M. S. *Investigator* surveys. One species name from Alcock 1899 & Lloyd 1909 is presently treated as invalid. Later Kotthaus (1968) reported 1 more species of deep-sea eel from Indian EEZ during the expedition of research ship *Meteor* in the Indian Ocean. Subsequently Talwar & Mukherjee (1977) reported another new species based on the voyage on fishing trawler, *Red snapper* of the central Institute of Fisheries Operatives. After a long gap the deep-sea eels in Indian EEZ were again documented by Jayaprakash et al. 2006; Sajeevan et al. 2009; Venu 2009; Hashim 2012 & Sudhakar et al. 2013 during the exploratory surveys on board *FORV Sagar Sampada* and *M. F. V. Matsya Varshini* as part of assessment of deep-sea demersal fishes of Indian EEZ under the Marine Living Resource (MLR) programme of CMLRE and Fishery Survey of India (FSI). However, no new discoveries or reliable new records were generated through these studies. The systematics, diversity, biogeographic distribution and biological aspects of deep-sea eels are least known. Hence a clear understanding is necessary on the aspects of systematics, diversity, biogeographic distribution and biology of deep-sea eels of the Indian waters for global records and effective management of our eel resources.

1.4 Objectives

Taking the above facts into account the present study aims to

I. Provide baseline information on the taxonomy and systematics of deep-sea eels of Indian EEZ. Otolith morphology and DNA barcodes of selected species are also done for taxonomic support.

II. Describe biogeographic distribution pattern, abundance and diversity of deep-sea eels in Indian EEZ.

III. Examine the following biological aspects of deep-sea eels

   1) Length-weight relationship
   2) Sex ratio
   3) Fecundity
   4) Food and feeding
   5) Biomass

1.5 Outline of thesis

The thesis is structured as 5 chapters.

Chapter 1: Gives a general introduction to the topic of research. General characteristics, systematic classification, phylogenetic relationship, distribution and diversity, food and feeing, reproduction and early life history and commercial importance of order Anguilliformes are provided. A review of previous status of Indian deep-sea eels, objective and relevance of the present study are discussed.

Chapter 2: Describe the study area, sampling stations, sampling methodology and analytical tools and soft-wares used for the present study.

Chapter 3: Deals with the taxonomy and systematics of deep-sea eels in Indian EEZ. General methodology for taxonomic identification, detailed taxonomic account of all valid species of deep-sea eels in the Indian EEZ., otolith morphology and molecular taxonomy for selected species and an updated checklist of deep-sea eels are provided.

Chapter 4: Deals with biogeographic distribution pattern, abundance and diversity of deep-sea eels in Indian EEZ. Community structure, eel assemblage pattern, diversity indices and K dominance of deep-sea eels in Indian EEZ are provided.

Chapter 5: Investigates the biological aspects of deep-sea eels such as biomass of deep-sea eels from Indian EEZ. Length-weight relationship, sex ratio, fecundity and food and feeding of selected species are discussed.

Ending with summary and conclusions of the study.

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Chapter 2

STUDY AREA, METHODOLOGY & DATA ANALYSIS

Contents

2.1 Study Area

India is endowed with a wide Exclusive Economic Zone (EEZ) of 2.02 million km^2 and having a coast line length of 8129 km. The total marine fish landing from India (excluding Lakshadweep and Andaman & Nicobar) was 3.8 million tonnes in 2017–2018 (CMFRI 2018). Most of our annual marine fishery catches are taken from the continental shelf areas with almost negligible contribution from deep-sea. Also our present knowledge on the deep sea resources, their distribution and abundance are just preliminary and therefore detailed investigations need to be undertaken to assess potential of deep sea resources in promoting the annual yield from the marine capture fishery sector.

Our study area cover the entire Indian EEZ of the Arabian Sea (AS) which lies west to the Indian subcontinent between 7^0N to 24^0 N Latitude and 73^0 E to 78^0 E Longitude having an area of 0.93 million sq. Km; the Bay of Bengal (BoB) which lie east to the Indian subcontinent between 10^0N to 20^0 N and 80^0E to 86^0 E with an area of 0.52 m. sq. Km and the Andaman Sea (AN) which lie South east to Indian subcontinent, oriented in north south direction between 6^0 N to 14^0 N and 92^0 E to 94^0 E. The study area include six distinct ecosystems namely the North East Arabian Sea (NEAS), the South East Arabian Sea (SEAS), the Lakshadweep Sea (LS), the North West Bay of Bengal (NWBoB), the South West Bay of Bengal (SWBoB) and the Andaman Sea (AN). Andaman and Nicobar Islands consists of 572 Islands, are volcanic in origin and located on the Andaman Nicobar Ridge System at the edge of Burma plate. The ridge separates Bay of Bengal from Andaman Sea. The Island arc is divided into groups by transecting channels. These channels, along with other smaller channels connect the Andaman Sea and Bay of Bengal. The Malacca strait connects the Andaman Sea with South China Sea. Andaman Sea shares both the characteristics of Indian Ocean and Western Pacific Ocean. The present study period extended for 8 Years from August 2010 to November 2017 and was carried out exclusively on board the research vessel FORV *Sagar Sampada.*

2.2 Sampling

Deep sea exploratory surveys were carried out from on board the Fishery Oceanographic Research Vessel *Sagar Sampada* (FORV SS) Centre for Marine Living Resources & Ecology (CMLRE) Ministry of Earth Sciences (MoES), Government of India (Figure 2.1) using standard bottom trawls. The vessel is 71.5 m in OAL and equipped with winches for bottom trawl operations up to 1500 m depths. Random samples of deep-sea Anguilliformes were collected from the continental slopes of Arabian Sea, Bay of Bengal & Andaman Sea of the Indian EEZ. A total of 22 cruises and 93 random stations were surveyed at depths ranging from 200 to 1400m categorized as upper bathyal zone (UBZ: 200– 800 m depths) and lower bathyal zone (LBZ: 800–1400 m). Arabian Sea was covered through 13 cruises involving 40 stations, Bay of Bengal through 4 cruises involving 25 stations and Andaman Sea through 5 cruises involving 28 stations. Details of sampling locations are given in figure 2.2 and table 2.1. Prior to the bottom trawl operations, suitability of grounds for bottom trawling were checked by acoustic scanning using a multi-frequency echosounder (SIMRAD EK 60) operated in various frequencies (38, 120 & 200 KHZ frequency) depending on the depth of operations. Duration of trawling operations and depth of operations were noted manually for all stations. Trawl operations were carried out mostly during day time keeping the hauling time to one hour, where ever possible.

Three types of bottom trawls were employed for deep water fishery surveys in various regions of Indian EEZ. These include High Speed Demersal Trawl –Crustacean Version (HSDT II CV):- A 2-warp twin-otters, bottom trawling net with a total length of 58.6 m, head rope length of 38 m, foot rope of 44.5 m and cod-end with a stretch mesh size of 30 mm, gradually increasing to 130 mm in the front trawl sections; EXPO model trawl;- has a total length of 79.4 m, with a head rope length of 45.6 m, foot rope 55.8 m and cod-end with a stretch mesh size of 30 mm, increasing up to 400 mm in the belly and wing sections of the trawl; HOT I;- has a 50m headline length and foot rope length of 57 m. Mean vertical opening at trawl mouth is 6.1 m. In addition, few samples obtained from deep sea benthic dredge (Naturalist dredge) were also included in this study for taxonomic purpose. Specification of these bottom trawls are given in figure 2.3

Trawling operations were performed in day time. Net behavior during trawl operation such as vertical mouth opening and position at the bottom were observed using remote sensing transducers (SIMRAD FR 500 Trawl-Sonde) connected to the net. For all operations V-shaped otter boards, perfect (Denmark) economy model of 285x126 cm, weighing 2800 kg per set were connected to the mouth of the trawl net using a 50 m wire rope. Warp out (depth to wire rope released) ratio was maintained as 1:3. Ship speed was maintained at 2-3 knots during trawl operations depending up on the wind and direction of water current.

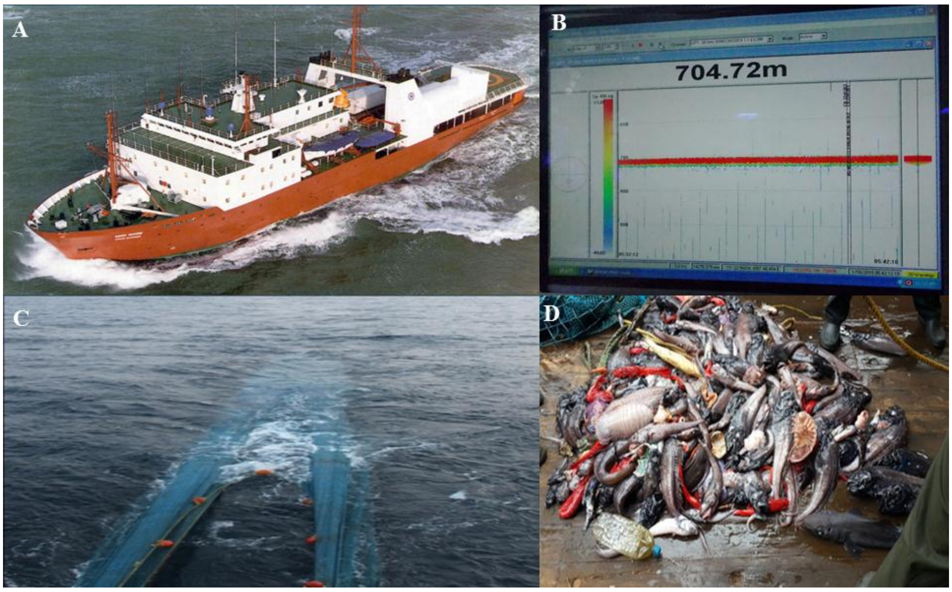

Figure 2.1: A) *FORV Sagar Sampada*; B) Echo sounder output; C) HSDT-CV demersal trawl while trawling; D) Catch onboard.

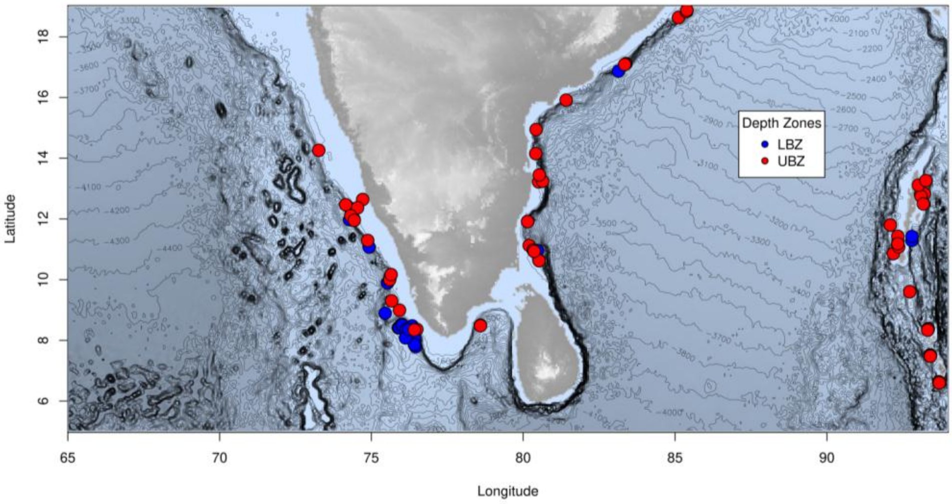

Figure 2.2: Sampling locations; red dots indicate Upper Bathyal Zone (UBZ: 200–800 m) and blue dots indicate Lower Bathyal Zone (LBZ: 800–1400 m).

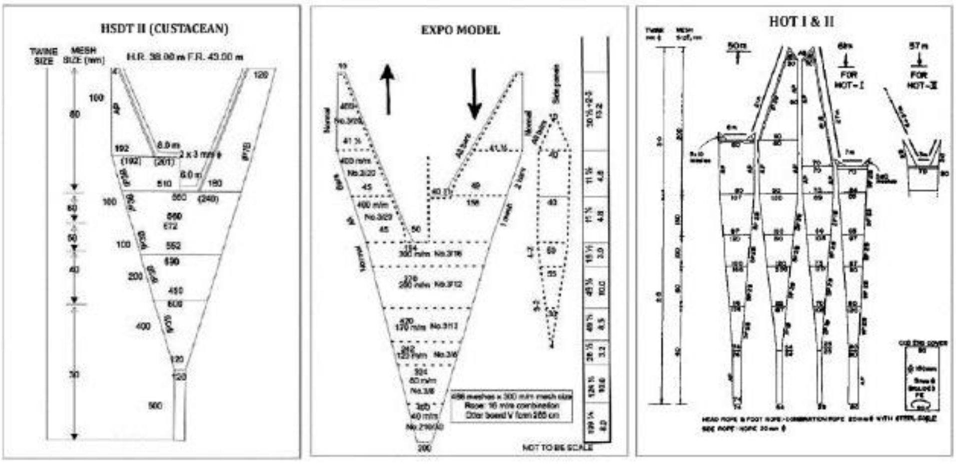

Figure 2.3: Schematic representation of bottom trawls (HSDT- CV, EXPO, HOT)

Table 2.1: Details of sampling locations

Station No.	Date	Area	Latitude (°N)	Longitude (°E)	Depth (m)	Gear
27801	08.08.2010	AS	09°59.575'	75°35.768'	214	HSDT-CV
27802	08.08.2010	AS	09°53.600'	75°31.907'	975	HSDT-CV
27901	26.08.2010	BoB	10°57.946'	80°20.203'	645	HSDT-CV
27905	27.08.2010	BoB	11°07.660'	80°11.840'	540	HSDT-CV
27911	29.08.2010	BoB	13°13.260'	80°30.470'	307	HSDT-CV
27912	29.08.2010	BoB	13°14.502'	80°38.280'	311	HSDT-CV
27923	02.09.2010	BoB	17°07.190'	83°23.121'	567	EXPO
27924	02.09.2010	BoB	17°05.841'	83°21.150'	550	EXPO
27925	02.09.2010	BoB	17°05.310'	83°20.510'	550	EXPO
28015	17.09.2010	AN	12°48.640'	93°05.055'	323	EXPO
28016	17.09.2010	AN	12°49.602'	93°12.782'	441	EXPO
28017	19.09.2010	AN	11°08.920'	92°19.650'	514	EXPO
28037	24.09.2010	AN	06°38.301'	93°41.082'	321	EXPO
28038	24.09.2010	AN	07°31.460'	93°24.091'	567	EXPO
28103	12.10.2010	AS	08°21.601'	76°10.171'	995	HSDT-CV
28109	14.10.2010	AS	10°06.020'	75°37.190'	400	HSDT-CV
28119	15.10.2010	AS	14°15.650'	73°15.970'	214	HSDT-CV
28809	8.08.2011	AS	11°59.455'	74°25.594'	200	EXPO
28817	10.08.2011	AS	09°59.935'	75°36.086'	200	HSDT-CV
29102	28.10.2011	BoB	18°38.260'	85°06.830'	562	EXPO
29103	29.10.2011	BoB	18°50.436'	85°23.119'	644	EXPO
29105	30.10.2011	BoB	18°49.831'	85°22.616'	629	HSDT-CV
29106	30.10.2011	BoB	18°52.681'	85°23.465'	462	HSDT-CV
29110	05.11.2011	BoB	11°55.127'	80°08.838'	634	EXPO
29111	05.11.2011	BoB	11°54.788'	80°08.719'	645	EXPO
29112	06.11.2011	BoB	10°56.270'	80°21.253'	670	EXPO
29113	06.11.2011	BoB	10°58.428'	80°19.779'	652	EXPO
29114	07.11.2011	BoB	10°38.440'	80°31.036'	654	EXPO
29115	07.11.2011	BoB	10°37.411'	80°31.460'	648	EXPO
29116	08.11.2011	BoB	10°55.950'	80°21.519'	650	EXPO
29117	09.11.2011	BoB	11°54.696'	80°08.649'	653	EXPO
29206	22.11.2011	AN	11°08.930'	92°20.210'	526	EXPO
29283	10.12.2011	AN	06°37.814'	93°41.191'	337	HSDT-CV
29289	11.12.2011	AN	07°30.110'	93°24.911'	580	HSDT-CV

29291	14.12.2011	AN	08°21.621'	93°20.065'	574	HSDT-CV
30501	19.08.2012	AS	08°28.550'	76°20.710'	1060	HSDT-CV
30504	20.08.2012	AS	11°98.490'	74°42.770'	210	HSDT-CV
30505	20.08.2012	AS	12°22.150'	74°32.570'	242	HSDT-CV
30506	22.08.2012	AS	12°20.743'	74°19.010'	909	HSDT-CV
31601	14.07.2013	AS	08°17.199'	76°12.341'	1055	HSDT-CV
31602	15.07.2013	AS	07°47.482'	76°27.317'	1338	HSDT-CV
31609	17.07.2013	AS	08°24.837'	75°53.151'	1241	HSDT-CV
31801	24.08.2013	AS	12°28.170'	74°09.142'	445	EXPO
31810	26.08.2013	AS	12°06.221'	74°19.145'	320	EXPO
31818	28.08.2013	AS	11°17.481'	74°52.701'	249	EXPO
31908	09.09.2013	AS	07°53.232'	76°25.780'	1258	EXPO
32116	10.12.2013	AS	08°00.845'	76°25.914'	1152	EXPO
32118	11.12.2013	AS	08°25.107'	75°55.184'	1244	HSDT-CV
32120	12.12.2013	AS	08°31.775'	75°59.743'	1045	HSDT-CV
32201	7.01.2014	AS	10°09.956'	75°38.965'	200	HSDT-CV
32202	8.01.2014	AS	11°04.195'	74°55.430'	1000	HSDT-CV
32204	9.01.2014	AS	11°58.355'	74°16.791'	1000	HSDT-CV
32205	9.01.2014	AS	11°57.317'	74°26.081'	200	HSDT-CV
32207	10.01.2014	AS	08°59.618'	75°55.468'	200	HSDT-CV
32208	11.01.2014	AS	08°53.593'	75°27.288'	1000	HSDT-CV
32209	12.01.2014	AS	08°05.718'	76°25.842'	1000	HSDT-CV
32210	13.01.2014	AS	08°21.750'	76°29.800'	200	HSDT-CV
32212	15.01.2014	AS	08°28.994'	78°35.583'	200	HSDT-CV
32213	15.01.2014	AS	08°29.994'	78°35.583'	1000	HSDT-CV
32701	25.07.2014	AS	08°29.180'	76°01.372'	1080	HSDT-CV
32702	26.07.2014	AS	07°51.476'	76°24.880'	1345	HSDT-CV
32704	31.07.2014	BoB	10°57.418'	80°28.114'	1131	HSDT-CV
32706	3.08.2014	BoB	14°09.197'	80°24.745'	225	HSDT-CV
32707	4.08.2014	BoB	14°56.721'	80°25.473'	230	EXPO
32708	5.08.2014	BoB	15°54.918'	81°24.851'	228	EXPO
32711	7.08.2014	BoB	16°52.178'	83°08.179'	1001	EXPO
33101	2.11.2014	AS	09°17.958'	75°39.942'	392	HSDT-CV
33102	3.11.2014	AS	08°29.844'	76°01.289'	1024	HSDT-CV
33103	4.11.2014	AS	08°04.971'	76°07.555'	1397	HSDT-CV
33401	26.01.2015	AN	10°51.520'	92°11.336'	363	HOT
33403	29.01.2015	AN	08°23.352'	93°20.534'	622	HOT

33404	01.02.2015	AN	06°35.885'	93°42.204'	332	HOT
33405	02.02.2015	AN	07°30.260'	93°25.240'	553	HOT
33410	15.01.2015	AN	11°15.550'	92°20.440'	392	HOT
33411	15.01.2015	AN	11°04.785'	92°21.909'	530	HOT
33412	16.01.2015	AN	11°17.465'	92°47.886'	907	HOT
33413	16.01.2015	AN	11°25.393'	92°48.177'	812	HOT
34901	4.04.2016	AN	11°25.893'	92°20.210'	576	HSDT-CV
34902	4.04.2016	AN	07°28.734'	93°24.510'	650	HSDT-CV
34903	5.04.2016	AN	08°22.401'	93°20.363'	591	HSDT-CV
34904	6.04.2016	AN	09°36.219'	92°43.739'	362	HSDT-CV
34906	10.04.2016	AN	12°44.580'	93°06.302'	332	HSDT-CV
34908	11.04.2016	AN	13°06.78'	93°01.14'	411	HSDT-CV
34910	14.04.2016	AN	11°10.950'	92°20.180'	520	HSDT-CV
35342	30.11.2016	AS	08°20.734'	76°24.887'	544	Dredge
36110	17.06.2017	BoB	13°26.968'	80°31.807'	430	Dredge
36601	20.10.2017	AS	08°21.335'	76°08.562'	1053	HSDT-CV
36602	20.10.2017	AS	08°04.969'	76°07.335'	1400	HSDT-CV
36603	20.10.2017	AS	08°21.520'	76°14.101'	942	HSDT-CV
36704	15.11.2017	AN	08°20.073'	93°19.264'	695	HSDT-CV
36705	25.11.2017	AN	12°29.719'	93°10.732'	314	HSDT-CV
36708	26.11.2017	AN	13°15.902'	93°15.827'	635	HSDT-CV
36715	28.11.2017	AN	11°47.889'	92°05.437'	646	HSDT-CV

2.3 Taxonomic analysis

Catch heaved up on the deck were initially weighed for estimating the total catch. Later samples were sorted into various groups. Weight and number of each group was recorded for further analysis. Deep-sea Anguilliformes samples were sorted to the species level and intact specimens were selected for taking photographs. Most of the specimens were photographed using a digital camera (Nikon D750) in fresh condition (on capture), in order to get their natural coloration. Representative samples of each species were preserved in 8%

formaldehyde solution and transported to the on shore laboratory at CMLRE. Representative samples of specimens of species were deposited with the CMLRE Referral Centre as voucher specimens with unique identification number which includes 5 digit numeric code, in which first 3 digits represents cruise number and later 2 digits represents the station number. Alphabetic letters (A, B, C etc.) followed by the 5 digit code indicates multiple samples of same species.

General methodology and terminology for taxonomic identification (morphometric and meristic characteristics) of deep-sea eels follows Böhlke (1982, 1989) detailed in chapter 3. Taxonomic identification was carried out using standard taxonomic keys of FAO, publications including original descriptions or redescriptions of the species or by using other relevant manuscripts. The validity of the species was checked with Catalog of fishes (Fricke et al. 2018a), World Register of Marine Species (WoRMS Editorial Board 2018), FishBase (Froese & Pauly 2018) and also through discussions with world experts.

2.4 Otolith morphology

Otoliths of 5 selected species were analyzed during the present study. The sagittal otoliths were collected by making an incision on lower part of the cranium. Otoliths extracted were rinsed using distilled water to remove the particulate matter and stored in plastic vials after proper drying. Only the right otoliths were taken for further analysis as both right and left otoliths are considered as mirror images to each other (Stransky & MacLellan, 2005; Bilge & Filiz 2018). Each otolith was photographed using a stereo zoom trinocular microscope (Leica modal No. S8APO camera, Leica DFP-425). Left otolith was placed in such a way that the sulcus acustics orientated towards the observer. Each otolith was weighed to an accuracy of 0.001 g on a digital electronic weighing balance (Metler Toledo, ML 503). The shape parameters of the otoliths such as length (OL, mm), height (OH, mm), perimeter (OP, mm) and area (OA, mm^2) were taken from the photographs using the image analyzing software (Imaje J) following the terminology of Avigliano et al. (2014, 2016). The shape indices: Aspect ratio (OH/OL %), Roundness or Inverse aspect ratio ($4 \times OA/3.14 \times OH^2$) and Circularity ($4\pi \times OA/ OP^2$) were calculated following Leguá et al. (2013). Terminology of describing the morphology of otolith follows (Smale et al. 1995; Tuset et al. 2008).

2.5 Molecular taxonomy

The methodology adopted for molecular taxonomy includes 4 stages.

1. Sample collection

The samples were thoroughly washed and a portion of muscle was dissected from each species and preserved in 70% ethanol in sterile vials and stored at $^-20\ ^oC$ for further molecular analysis.

2. DNA isolation

Genomic DNA from the samples was isolated following the protocol of Miller et al. (1988). Nucleotide sequencing was performed by the dideoxy chain-termination method (Sanger et al. 1977) using ABI Prism Big Dye Terminator v3.1 Cycle Sequencing kit, (Applied Biosystems, USA).

3. Amplification and sequencing

The fragments of COI were amplified with the following thermo profile: 94 °C for 2 min, 35 cycles at 94 °C for 45 sec, 50 °C for 45 sec, 72 °C for 1 min and with a final extension at 72 °C for 8 min, followed by indefinite hold at 4 °C. Samples with intense bands were selected for sequencing. Sequencing reactions used a BigDye Terminator V.3.1 Cycle sequencing Kit (Applied Biosystems, Inc). All samples were sequenced bidirectionally using an ABI3730 capillary sequencer following the manufacture's protocol.

4. Sequence analysis

The raw DNA sequences were edited and aligned using BioEdit sequence alignment editor version 7.0.5.2 (Hall 1999).

The sequence divergence values within and between species were calculated using Kimura2-parameter (K2P) distance model implemented in MEGA 7 (Tamura et al. 2011) software. The number of polymorphic sites, monomorphic sites, singleton variable sites and parsimony informative sites were calculated using DnaSpver 3 (Rojas et al. 2006). Neighbor-joining (NJ) trees of K2P distance were created to provide graphic representation of divergence with 1000 replications.

2.6 Numerical abundance

The Anguilliform samples collected from bottom trawl were sorted up to species level. The numerical abundance was calculated using the data viz. Cn, the number of Anguilliform fishes and a, swept area. Numerical abundance of Anguilliformes is expressed in Ind/ km^2.

Numerical abundance was calculated as,

Numerical abundance (n) = Cn/a; unit—Individuals/ km^2

Where, Cn= Number of individuals in catch (Individuals);
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) was estimated in units of nautical miles (NM) and calculated using the formula:

$$D=60\times\sqrt{(Lat1-Lat2)2\ +\ (Lon1-Lon2)2\ \times\ \cos2\ (0.5\ \times\ (Lat1+\ Lat2)}$$

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; 38 m for HSDT, 45.6 m for EXPO and 50 m for HOT l
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 etc. 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).

2.7 Length weight relationship

Samples from continental slope of Indian EEZ were collected on board *FORV Sagar sampada* using three different types of bottom trawls discussed earlier. The samples were sorted and preserved in 8% formaldehyde solution for further analysis. The specimens were identified using standard references (Alcock 1899; Talwar 1977; Karmovskaya 1994a). The length (TL) and weight of the Individual specimens were measured to the nearest 0.1 cm and nearest 0.1 gm respectively.

The relationship of length and weight of fish were calculated by the least square regression equation (Le Cren 1951; Ricker 1973; Zar 1999; Froese 2006).

$$W = aL^b$$

$$\text{Log } 10\ W = \text{Log } 10a + b \log 10\ L$$

Where, W = the body weight, L = total length,

a = intercept of the regression curve, b = regression coefficient.

The values of b indicates whether the species is isometric ($b=3$), positively allometric ($b>3$) or negatively allometric ($b<3$). The 95% confidence limit of the constants a & b were calculated. The strength of relationship was evaluated by r^2 (coefficient of determination). The analysis of covariance (ANCOVA) was conducted to find out significant changes in the length-weight relationships between males & females and t-test was performed to examine whether the slope of regression lines deviates from isometry.

2.8 Sex ratio

From the samples collected, males and females of each species were separated by visual examination of gonads after dissection. The sex ratio (M: F) was calculated and the deviation in the sex ratio was assessed by Chi-square (χ^2) test in order to verify whether the population of males and females differed from the expected ratio1:1 (Rao & Yoon 1983).

2.9 Fecundity

Samples collected were dissected and analyzed macroscopically and gonads in mature phase (Maturity stage 4) were sorted out to estimate the fecundity. Ovaries were separated out, washed and weighed using a digital weighing balance after drying on a blotting paper. Random samples were taken, then weighed and evenly spread on a counting slide with few drops of water Number of ova were counted and ova diameters were measured. Fecundity (Venkataramanujam & Ramanathan 1994) was estimated by;

$$F = nG/g$$

Where, F = Fecundity, n= Number of ova in the sub samples,
G = Total weight of the ova, g= Weight of subsamples in the same unit.

2.10 Food and feeding

Samples for the present study were collected using demersal trawls (HSDT, EXPO & HOT) except for one species (*Nemichthys scolopaceus*) which was collected in Isaacs-Kid Midwater Trawl (IKMT) during the exploratory deep-sea fishery surveys. Gut content analysis was done for 8 species of deep-sea eels collected from depths ranging from 200–1338 m. Gut analysis was performed using Index of Relative Importance (IRI) following Pinkas et al. (1971).

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

Where, N = Percentage of particular food content in the gut contents

W = Percentage of food weight

O = Percentage of frequency of occurrence

Fullness of the stomach was also checked to study the feeding intensity by visual examination and stomachs were classified into full, three quarter full, half full, one quarter full and empty.

2.11 Biomass estimation

The Anguilliform samples collected from bottom trawl were sorted up to species level. Catch in weight (Cw) of Anguilliform fishes from each station was recorded using a weighing balance with an accuracy of 0.1 gm.

Biomass is the ratio of catch in weight to the swept area. Biomass estimation is done following Sparre & Venema (1998) using swept area method and expressed in kg/km^2.

$$\text{Biomass (b)} = Cw/a \text{ kg/ km}^2$$

Where, Cw = Catch in weight (kg); a = swept area (km^2)

2.12 Data analysis

Species accumulation curve: represents the cumulative number of species as a function of sampling effort (Colwell & Coddigton 1994). The curve obtained from the plot is concerned with accumulation rates of new species over the sampled area which depends on species abundance (Ugland et al. 2003). The curve rises as the samples are added consistently, till it reaches the asymptote or when further addition of samples does not add additional species. Various Species estimators are used to predict the total number of species that could be encountered in a study area when sampling is unlimited (infinite sampling). In the present study, species accumulation curves were plotted and several estimators like Chaos 1, Jacknife 1 and Bootstrap estimators were calculated using PRIMER (Plymouth Routine in Multivariate Ecological Research; Clarke & Warwick 2001a) software.

Chaos estimator gives significance to the numbers of rare species in the samples. Chaos 1 is the sum of observed number of species plus the ratio of singletons (number of species represented by a single induvidual) and doubletons (number of observed species represented by 2 induvidulas). The Chao 1 estimator calculates the estimated true species diversity of a sample by the equation:

$$S_1 = S_{obs} + \frac{F_1^2}{2F_2}$$

Where, *Sobs* is the number of observed species in the sample, $F1$ is the number of singletons (i.e., the number of species with only a single occurrence in the sample) and $F2$ is the number of doubletons (the number of species with exactly two occurrences in the sample).

Since Chao estimators assume homogeneity among samples, it provides minimum estimates of richness (Magurran, 2004). Hence Chao estimators will not be suitable if there are large compositional difference within the dataset. Jacknife estimators (Heltshe & Forrester, 1983) is used to reduce this bias. The Jacknife estimates are a function of the number of species that occur in one and only one quadrat and are affected by quadrat size, sample size and sampling area (Heltshe & Forrester, 1983). The formula

$$S_{Jack1} = S_{obs} + Q_1 \left(\frac{m-1}{m}\right)$$

represents the first order version of the estimator; the variable m represents the total number of samples.

The bootstrap method differs from the jackknife in the mean of sampling the original sample data. The subsamples (Bootstrap samples) of observed sample used to repeatedly calculate the parameter of interest are each selected at random with replacement from the original sample. The procedure of bootstrap estimates of species richness is described in the following steps.

Step 1: Generate a random sample of size 'n' (observed number of individual) from the sampled individuals with replacement, called bootstrap sample.

Step 2: Find the proportion say, ‘pi’ of the observed individual for i th species in the generated bootstrap sample.

Step 3: Calculate pseudo values from bootstrap sample as

$$S_{\mathrm{boot(i)}} = S_{\mathrm{obs}} + \sum_{i=1}^{S_{obs}} (1 - P_i)^n$$

Step 4: Repeatedly calculate $S_{\mathrm{boot(i)}}$ of step3 a large number of times, usually 20-200 times i.e. calculate for each Bootstrap sample (Bootstrap samples are considering usually 20 to 200 times).

Step 5: Finally calculate the bootstrap estimate of species richness as the average of the pseudo values calculated from the ‘B’ bootstrap samples i.e.

$S^{*}_{boot} = \frac{1}{B} \sum_{i=1}^{B} S_{\mathrm{boot(i)}}$, which gives the true estimate of species richness under bootstrap mechanism.

Cluster analysis: was carried out on Bray-Curtis similarity matrix (PRIMER 6) calculated on square root transformed abundance data, to obtain the samples having similar community composition following the procedure described by Clarke & Warwick (1994~~).~~ Importance of variations among sites, based on factors such as region and depth zones, were tested using Analysis of Similarity (ANOSIM), using the Bray-Curtis similarity matrix. Bray- Curtis coefficient (Bray & Curtis, 1957) was calculated by the following formula:

$$S_{jk} \quad = \quad 100\left\{1 - \frac{\sum_{i=1}^{p} |yij - yik|}{\sum_{i=1}^{p} (yij + yik)}\right\}$$

$$= \quad 100\left\{\frac{\sum_{i=1}^{p} 2\min(yij,\ yik)}{\sum_{i=1}^{p} (yij + yik)}\right\}$$

where, yij represents the entry in the i^{th} row and j^{th} column of the data matrix i.e.

the abundance or biomass for the i^{th} species in the j^{th} sample;

yik is the count for the i^{th} species in the k^{th} sample;

| … | represents the absolute value of the difference;

'min' stands for, the minimum of the two counts and

$\sum$ represents the overall rows in the matrix.

SIMPER tool was used to recognize those species that most characterize the grouping in the cluster analysis

Univariate diversity indices such as species richness (Margalef's index, d), Species equitability (Pielou's index, J'), species diversity (ShannonWiener index, H') and species dominance (Simpson's index, λ') were worked out for Anguilliformes using PRIMER Species richness is the total number of species in a sample. Species evenness express the evenness of individuals that are distributed among the different species and species dominance means the dominance of particular species among a given number of individuals. Species diversity index defines the number of species in a sample and also their relative abundance. The index is high in samples that have less dominance of unique species, or have greater species evenness.

Margalef's species richness (d)

Species richness (Margalef): d = (S-1)/ log (N)

Where, S = Number of species,

N = Number of individual

Shannon – Wiener index

For measuring the variation in Anguilliformes diversity of the region, diversity index (H') was calculated using the Shannon- Wiener's formula (1949)

$$H' = -\sum^{S} Pi \log 2\, Pi\ldots\ldots$$

$$i = 1$$

which can be rewritten as

$$H' = \frac{3.3219\ (N \log N - \sum ni - \log ni)}{N}$$

where, H' = species diversity in bits of information per individual

n_i = proportion of the samples belonging to the i^{th} species (number of individuals of the i^{th} species)

N = total number of individuals in the collection and

$\sum$ = sum.

Pielou's evenness index (J')

The equitability (J') was computed using the following formula of Pielou (1966):

$$J' = \frac{H'}{\log 2S} \quad \text{or} \quad J' = \frac{H'}{\ln S}$$

where, J' = evenness,

H' = species diversity in bits of information per individual and

S = total number of species

Simpson index (λ')

Simpson index assigns to the measure of dominance in a community

$$\lambda' = \mathrm{Sum}(Ni*(Ni-1)/N*(N-1))$$

N is the number of individuals in each sample

Dominance plot are used for abundance, biomass, %cover or other biotic measure representing quantity of each taxon (Clarke & Warwick, 2001b). To compare the biodiversity between the depth zones and regions, dominance plots (in PRIMER 6) were drawn by ranking the species in declining order of their abundance. *K*-dominance curves provides graphical representation of the intrinsic diversity pattern of deep-sea Anguilliformes in which X- axis represents species rank in the order of abundance against their corresponding cumulative dominance on Y-axis. Biodiversity can be compared using these cumulative curves. The ANCOVA, t test and Chi-square (χ^2) test were performed using R software (version 3.4.3). Graphical representations made using Microsoft Excel 2013 and SPSS 20. Station details and geographical distribution of species were plotted using Ocean Data View (ODV 4, Schlitzer 2011).

⁂

Chapter 3

DEEP-SEA ANGUILLIFORMES OF INDIAN EEZ: TAXONOMY ~~& SYSTEMATICS~~

Contents

3.1 Introduction

Deep-sea eels belong to the order Anguilliformes (True eels). Order Anguilliformes is the largest among the subdivision Elopomorpha with 16 families 156 genera and 967 species (Fricke et al. 2018a). They are widely distributed throughout the world oceans. Pacific Ocean has the highest diversity with 630 species, followed by Indian Ocean with 322 species and Atlantic with 248 species (Fricke et al. 2018a; Froese & Pauly 2018).

The general characteristics and systematic classification of Anguilliformes are discussed in Chapter 1. Our understanding on the classification of eels is incomplete and research on these lines is still in progress. The recent classification provided by Nelson et al. (2016) is not followed by most of the global taxonomic experts and popular Fish databases (Froese & Pauly 2018; van der Laan et al. 2018; WoRMS

Editorial Board (2018) & Shao 2018). Britz (2017) reviewed the "Book of Fishes of the World" by Nelson et al. (2016) and opined that the book contains numerous errors and cannot be regarded as a standard work for fish classification. The new edition of Nelson's standard text on fish classification unfortunately does not meet the high standard of Nelson's previous editions: it lacks precision and accuracy (Britz 2017). The reason for this is that Joseph Nelson who had great knowledge on fishes and their classifications had passed away in 2011 after entrusting the legacy to Terry Grande & Mark Wilson. These two authors came up with the revised fifth edition of the book Nelson et al. in 2016. In view of this, in the present study we follow the earlier classification of Nelson (2006).

As per Nelson, 2006 classification (Figure 3.1), order Anguilliformes is divided into 3 suborders (Anguilloidei, Congroidei and Muraenoidei) as suggested by Robins (1989). The Suborder Anguilloidei (Frontals divided) includes 3 families Anguillidae, Heterenchelyidae, and Moringuidae.

Sub order Congroidei (Frontals fused, scales present only in some Synaphobranchids) includes 9 families. The family Congridae is again divided into 3 subfamilies Congrinae, Heterocongrinae and Bathymyrinae. Similarly family Ophichthidae is divided into 2 subfamilies (Myrophinae and Ophichthinae) and family Synaphobranchidae into 3 subfamilies (Simenchelyinae, Ilyophinae and Synaphobranchinae).

The suborder Muraenoidei (Frontals divided, reduction in gill arch elements and lateral line, scales absent) include 3 families; Chlopsidae. Myrocongriade and Muraenidae. Among them Muraenidae is divided into 2 subfamilies (Uropteryginae and Muraeninae). The basis of division of subfamilies is given in the taxonomic account with respect to each family in chapter-1. Family Protanguillidae erected by Johnson et al. (2012) which was not included in the classification of Nelson et al., 2006, is included in the classification system followed here.

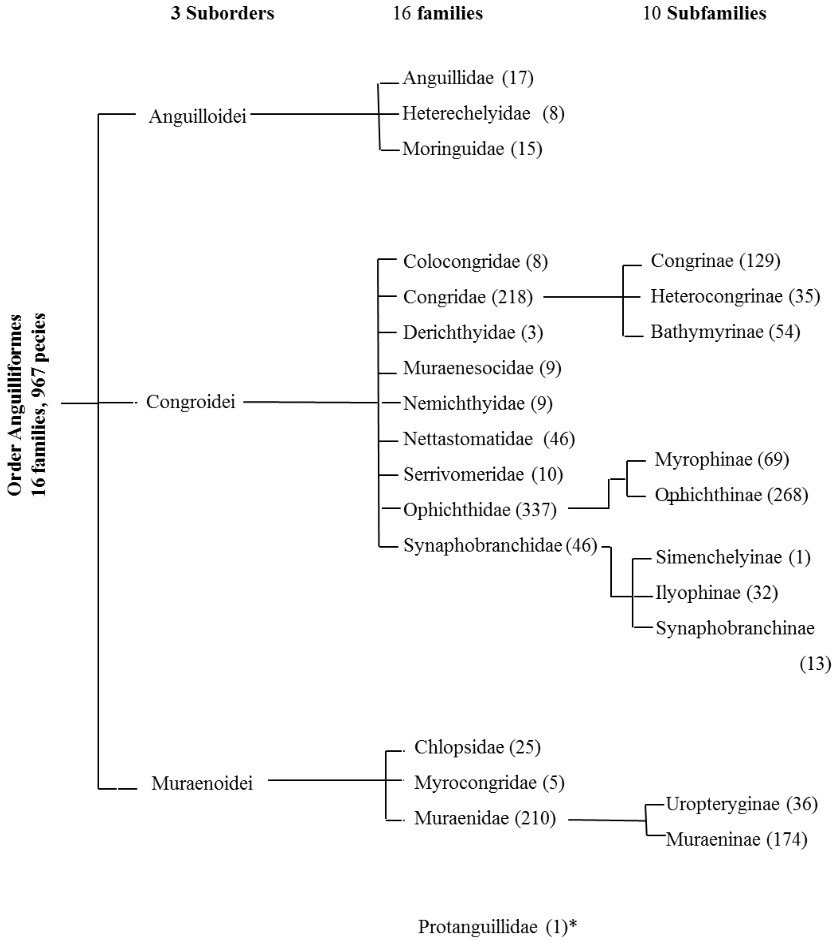

Figure 3.1: Classification of order Anguilliformes based on Nelson 2006. Asterisk indicates the family protanguillidae which was erected recently by Johnson et al. 2012.

Major taxonomic and systematic works on the most abundant Anguilliformes are given below;

Family Congridae: This family has 218 species under 3 sub-families; Congrinae (129 species), Heterocongrinae (35 species) and Bathymyrinae (54 species). In this family the differentiation of species under the genus *Bathycongrus* was found to be difficult earlier due to the similarity in morphometric features and overlapping meristic counts. Presently most of the species in this genus have been differentiated by the efforts of world eel experts, D. G. Smith and Emma Karmovskaya. The other genus *Bathyuroconger* having a species *B. vicinus* with circumglobal distribution was earlier thought to be a genus with single species. Recent studies by Smith et al. (2018a) based on northwestern Pacific specimens have documented the occurrence of 5 species within this genus. Probably, this genus still has more undetermined species except the eastern Pacific (Smith et al. 2018a). Hence worldwide studies need to be undertaken to elucidate the exact diversity of this genus in other areas. Major works in this family have been reported by the following authors.(Jordan & Synder 1901; Castle 1960a, 1968b, 1995; Asano 1962; Smith 1965,1971,2018; Lee & Yang 1966; Rosenblatt 1967; Robins & Robins 1971; Smith & Kanazawa 1977, 2003; Böhlke & Randall 1981; Ben-tuvia 1993; Shen 1998; Casle & Smith 1999; Karmovskaya & Paxton 2000; Karmovskaya 2004, 2009, 2015, 2018; Karmovskaya & smith 2008; Ho et al. 2018b; Smith et al. 2017, 2018a, b, c; Lin et al 2018).

Family Ophichthidae: Ophichthidae is represented by 337 species under sub-families Myrophinae (69 species) and Ophichthinae (268 species). In this family most of the species are known only from single specimens owing to the difficulty in collection as they mostly hide under substrates. Majority of the species in this family have been described by World known ophichthid eel expert, John McCosker. Recently Yusuke Hibino (if it is personnel communication, we need to mention this or we have to give the source of this information) has initiated some works on this family. Major studies on this family were carried out by Böhlke 1960; Rosenblatt & McCosker 1970; McCosker 1972, 1977, 1979,1989,1998, 1995, 1999, 2002, 2006, 2007 2010, 2011, 2014; Leiby & Yerger 1980; McCosker & Böhlke 1982,1984a, b, 1989; McCosker et al. 1982, 1984, 1989, 2007, 2009, 2011, 2012 a, b; Smith & Böhlke 1983; McCosker & Randall 1993, 2005; McCosker & Rosenblatt 1993; Castle 1996; Castle & McCosker 1999; McCosker & chen 2000; Sumida & Machida 2000; McCosker & Lavenberg 2001; Chen 2007; McCosker & Ross 2007; Ji & Kim 2011a, b; Hibino et al. 2012a, b, 2013,2014, 2015a, b, 2016; Ho et al. 2013, 2018c; Fricke et al. 2015; Ho & Loh 2015; McCosker & Hibino 2015; McCosker & Ho 2015; Hibino & Kimura 2016; Tashiro et al. 2016; Chiu et al. 2018.

Family Muraenidae: Has 210 species under sub-families Uropteryginae (36 species) and Muraeninae (174 species). The genus *Gymnothorax* is the most speciose among the Moray eels. More and more species are being reported on the basis of studies carried out worldover. Further intensified surveys in coral reefs as well as deep Sea can add more species to this family in future. Reports on family Muraenidae include Smith 1962, 2002a, 2012; McCosker & Rosenblatt 1975; Böhlke 1997a,b, 1999, 2000; Böhlke & McCosker 1977,1997, 2001; McCosker et al. 1984; Hatooka 1986, 2002; Böhlke et al. 1989; Lavenberg 1992; Chen 1994; Chen & Shao 1995; Randall & Golani 1995; McCosker & Smith 1997; Smith & Böhlke 1997; Böhlke & Randall 1999, 2000; Mccosker &

Stewart 2006; Chen & Loh 2007; Chen et al 2008; Loh et al. 2008, 2011a, 2016; Smith et al. 2008, 2018d; Reece et al. 2010a, b ; Tang & Fielitz 2013; Ray et al. 2015a; Mohapatra et al. 2016, 2017a, b,c, 2018a).

Family Synaphobranchidae: Represented by 46 species under sub-family Simenchelyinae (one species), Ilyophinae (32 species) and Synaphobranchinae (13 species). Within this family the taxonomy of the species belonging to the genus *Synaphobranchus* have some ambiguities. Recently in Taiwan a new species *Synaphobranchus oligolepis* has been described by Ho et al. 2018d. Previously it was considered as *S. affinis*. Similarly previous reports on 2 species (*S. pinnatus* by Alcock 1899 and *S. Pinnatus* var. *brevidorsalis* by Lloyd 1909) are considered invalid due to the lack of specimens and proper description. Major works in this family were done by Castle 1964a, 1968c; Robins & Robins 1975; Saldanha & Merrett 1982; Mok et al. 1991; Chen & Mok 1995, 2001; Karmovskaya, & Merrett 1998; Karmovskaya & Parin 1999; Melo 2007; Svendsen & Byrkjedal 2013; Ho et al. 2015a; Tashiro & Shinohara 2015; Eagderi et al. 2016; Fricke et al. 2018b; Ho et al. 2018d; Tighe et al. 2018).

Family Derichthyiade: The family is represented by only 3 species. Specimens belonging to this family are less reported worldwide. Hence works on this family are very limited. A worldwide review of the genera of this family is still pending. Major works are that of Gosline 1952; Karmovskaya 1985; Merrett & Saldanha 1985; Bauchot 1986a; Robins 1989b.

Family Serrivomeridae: Studies on the various genera of this species is limited. A review of this family is still pending. (Beebe & Crane 1937; Gosline 1952; Bauchot 1986b; Tighe 1989; Smith 2002b).

Family Nemichthyidae: Represented by 10 species. Most of the species in this family are circumglobal. Outstanding work on this family has been carried out by Nielsen & Smith (1978) by comparing world wide specimens.

Family Muraenesocidae: Includes 9 species**.** A recent study by Ho et al. (2018a) has replaced the genus *Gavialiceps* from this family to its proper family congridae. Our phylogenetic study also supports this placement, which has been discussed elsewhere in this chapter. Contributions to this family include Hamilton 1822; Day 1878; Alcock, 1889a; Jang, 1957; Takai 1959; Castle & Williamson 1975; Castle 1977; Gill 1980; Smith 1989c; Karmovskaya 1994; Smith 1999a; Lin et al. 2013.

Family Nettastomatidae: Represented by 46 extant species. The genera *Facciolella* and *Saurenchelys* need to be reviewed on a worldwide basis. Ho et al (2018a) has given information on 3 *Surenchelys* and 2 *Facciolella* spp. which are being described. Major works regarding this family are that of Lane & Stewart 1968; Saldanha & Blache 1968; Smith et al. 1981; Van Utrecht 1983; Smith 1989d; Smith & Castle 1982; Merrett & Saldanha 1985; Saldhanha 1986a; Brito 1989; Karmovskaya 1994b, 2004; Klausewitz 1995,1997; Klausewitz & Zajonz 2000; Hanke & Roias 2013; Lin et al. 2015, Smith et al. 2015.

Major works on the remaining six families are given in parenthesis with respect to family names. **Family Moringuidae:** Represented by 15 species (Hamilton 1822; Gosline 1956; Castle 1968d; Smith & castle 1972; Smith 1989e; Smith 2003). **Family Heterenchelyidae:** Represented by 8 species (Regan 1912b; Ben-Tuvia 1956; Böhlke 1966; Rosenblatt & Rubinoff 1972; Saldanha 1986b; Smith 1989a; Eagderi & Adriaens 2010; Smith et al. 2012). **Family Chlopsidae** Represented by 25 species (Myers & Wade 1941; Böhlke 1956; Robins & Robins 1966, 1967; Smith & Böhlke 1967; Böhlke & Smith 1968; Lavenberg 1988; Smith 1989f, 1999; Tighe 1992, 2000; Tighe & McCosker 2003; Tighe et al. 2015). **Family Myrocongridae:** Represented by 5 species (Günther 1869; Smith1984, 1989g, 1999c; Castle 1991; Castle & Bearez 1995; Karmovskaya 2006a). **Family Colocongridae:** Represented by 8 species (Alcock 1889; Kanazawa 1957, 1961; Castle 1967; Chan 1967; Castle & Raju 1975; Masuda et al. 1984; Smith 1989h; Quéro 2001). **Family Anguillidae:** Represented by 17 species (Bloch & Schneider 1801; Kaup1856a; Playfair & Günther 1867; Ege 1939; Castle 1963; Smith 1989i; Aoyama et al. 2001; Watanabe 2003; Watanabe et al. 2004, 2005, 2008; Lin et al. 2005; Inoue et al. 2010; Arai 2016) and **Family Protanguillidae**: Represented by a single species (Johnson et al. 2012; Springer & Johnson 2015).

Anguilliformes from Indian waters was first reported by the British surgeon and surveyor Hamilton (1822). He recorded 8 species from river Ganges and its tributaries during his survey on the flora and fauna of India. Later, Francis Day (1889) reported 42 species of eels. The British physician and naturalist Alcock (1899) reported 17 species and Lloyd

(1909) 2 species under the R.I.M.S. Investigator surveys in Indian EEZ. Further reports are from Hefford (1922) 2 species, Fowler (1927) 2 species, Sorley (1932) 8 species, and Bal & Mohamed (1957) 14 species from Bombay. Kotthaus (1968) added 6 eels from Indian EEZ during the Indian Ocean expedition; Johnes & Kumaran (1980) reported 38 species of eels from Lakshadweep Archipelago. Subsequent to these, there are only few scattered reports from Indian EEZ; Ramaiyan et al. 1986 reported 12 species from Parangipettai; Ramadevi & Ramachadran (1997) 1 species from Corammandal coast; Jayaprakash et al. (2006); 7 species; Sajeevan et al. (2009) 5 species; Venu (2009) 12 species from South West coast of India. Biswas et al.(2010) added 1 species and Yennawar et al. (2011) 2 species from East Coast of India; Sirajudheen & Bijukumar (2011) added 1 species from Arabian Sea; Biswas et al. (2012), 1 species from Kalpakkam coast; Hashim (2012) reported 10 species from Indian EEZ; Yennawar et al. (2013) 1 species from east coast of India; Sudhakar et al. (2013) 7 species from south west coast of India; Mishra (2013) in his checklist of coastal marine fauna of east coast of India reported 42 species of eel fish. Similarly Rajan et al. (2013) in the check list of fishes of Andaman and Nicobar Islands reported 40 species of Anguilliformes.

Recently ZSI (Zoological Survey of India) has initiated taxonomic studies on Anguilliformes from east coast of India. They have described 7 new species (Ray et al. 2015a; Mohapatra et al. 2016, 2017a, 2017b, 2017c, 2018a, 2018b) and added few new distributional records (Ray et al. 2015b; Mohapatra et al. 2015; Ray & Mohapatra 2015; Ray & Mohapatra 2016; Mohanty et al. 2018)

Majority of the aforementioned studies were based on shallow water species except those reported by Alcock 1899; Lloyd 1909; Kotthaus 1968; Jayaprakash et al. 2006; Sajeevan et al. 2009; Venu 2009; Hashim 2012 and Sudhakar et al. 2013.

Deep-sea eels of Indian EEZ are least explored; the most significant works dating back over a century. The systematics and distribution of deep-sea eels in India is indebted to the outstanding work of Lt. Col. A.W. Alcock on the samples collected during the survey of R.I.M.S. Investigator. Indian off shore waters and adjacent areas were surveyed by Investigator during the period extending from 1884 to 1914. Based on R.I.M.S survey's Alcock (1889-1899) described 17 species of deep-sea eels under 13 genera and 1 family. Now this stands revalidated to 16 species under 14 genera and 7 families. Most of them (12 species) were new to Science. Following Alcock (1899), Lloyd (1909) reported two more species from Indian waters based on *R. I. M. S. Investigator* surveys. One species each from, Alcock 1899 and Lloyd 1909 descriptions are presently considered as invalid. Kotthaus (1968) reported 1 species of deep-sea eel from Indian EEZ during the expedition of research ship *Meteor* in the Indian Ocean. Further, Talwar & Mukherjee (1977) reported a new species based on their study on board the fishing trawler, *Red snapper* of the central Institute of Fisheries Operatives.

After a long gap the deep-sea eels in Indian EEZ were again documented by Jayaprakash et al. 2006; Sajeevan et al. 2009; Venu 2009; Hashim 2012 & Sudhakar et al. 2013 during the exploratory surveys on board *FORV Sagar Sampada* and *M. F. V.Matsya Varshini* as part of assessment of deep-sea demersal fishes of Indian EEZ under the Marine Living Resource (MLR) programme of CMLRE and FSI. There are no new discoveries on deep-waters Anguilliformes from India after the pioneering work of Alcock. Even though few new distributional records were found during the review their authenticity could not be established due to the absence of proper description of the species as well as non-availability of voucher specimens.

The R.I.M.S. Investigator zoological collections deposited in Indian Museum, Calcutta, were later transferred to Zoological Survey of India and continue to be housed in the museum. Type materials of the collections were cataloged by Menon & Yaxzdani (1968) and by Menon & Rao (1970, 1971 & 1976).

Though the earlier descriptions of deep-sea eels were reasonably complete at that time, currently it is impossible to identify the species based on these descriptions alone. Since Alcock's original work, few of these eel species have been studied again [Dysommatin, Synaphobranchidae (Robins & Robins 1976), Muraenesocidae (Talwar 1977) Nettastomatidae (Smith et al. 1981) and Congridae (Castle 1995; Smith et al. 2017)] which provides more information and also help clear the taxonomic ambiguities.

This chapter deals with taxonomy and systematics of deep-sea Anguilliformes from the continental slope (200–1420 m depths) of Indian EEZ. As part of the study about 93 random stations were surveyed onboard *FORV Sagar Sampada* covering the Arabian Sea (AS) Bay of Bengal (BoB) and Andaman Sea (AN) during the years 2010–2018.

Sample collections were carried out using the demersal trawls; High Speed Demersal Trawl- Crustacean Version (HSDT-CV), High Opening Trawl (HOT) and EXPO trawl. Apart from this few samples of deep-sea eels obtained in naturalist dredge (Benthic dredge) operations are also included in the study. The classification of Anguilliformes follows Catalog of Fishes (2018, online version). More details of sampling methodology and analysis are discussed in chapter 2. Status and validity of the species were checked with (WoRMS) World Register of Marine Species; Catalog of Fishes, California Academy of Sciences (CAS) and also through personal discussions/communication with the world eel experts. Institutional abbreviations follow Fricke & Eschmeyer (2018, online version).

3.2 Methodology

General methodology and terminology for taxonomic identification of deep-sea eels follows Böhlke (1982, 1989). Typical measurements adopted in this study are illustrated in (Figure 3.2). All the measurements are expressed in mm. Terminology and abbreviations used for morphometric characters are as follows: Total length (TL); Head length (HL); Trunk (TR); Preanal length (PAL); Tail (T); Predorsal (PD); Snout (S); Eye (E); Upper Jaw (UJ); Lower Jaw (LJ); Interorbital width; Pectoral-fin length (P); Gill opening; Interbrachial width; Depth at gill opening (DGO); Depth at anus (DA).

Meristic characters such as vertebral counts, lateral-line pore counts and head pore counts as well as it arrangement are also used for taxonomic identification of eels. Vertebral count terminology follows Böhlke (1982) and pore counts terminology follows Böhlke 1989 (Figure 3.3). Terminology and abbreviations used for meristic characters are as follows: Predorsal, preanal and total vertebrae; Mean Vertebral Formulae (MVF); Adnasal (AD) pore; Branchial (B) pores; Ethmoid (EM) pore; Frontal pore (F); Infraorbital pores (IO); Mandibular (M); Postorbital pores (PO); Preoperculomandibular pores (POM); Supraorbital pores (SO); Supratemporal pores (ST); Temporal pores (T); Lateral-line (LL) pore counts: Prepectoral, predorsal and preanal LL pore counts

For family Nemichthyidae methodology and terminology follows Nielson & Smith (1978). Artificial standard lengths (SL 200 and SL 100) are measured from the posterior edge of eye to the end of the 200th vertebrae for (*Nemichthys*) and 100th vertebrae for (*Avocettina* and *Labichthys*). In *Nemichthys* each five-pore complex corresponds to one vertebra and in *Avocettina* each pore correspond one vertebra.

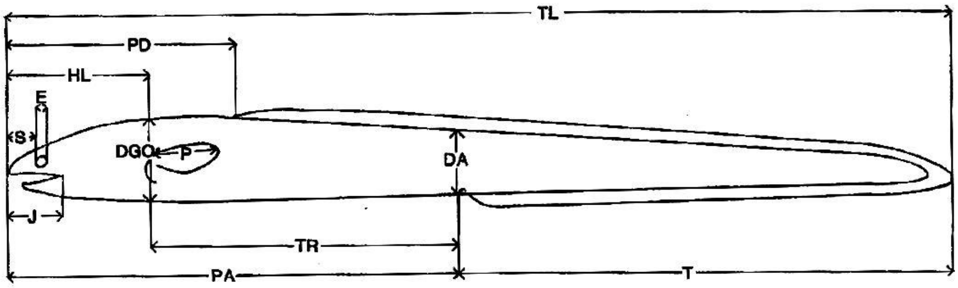

Figure 3.2: Schematic diagram illustrating typical measurements used for eels by Böhlke 1989.

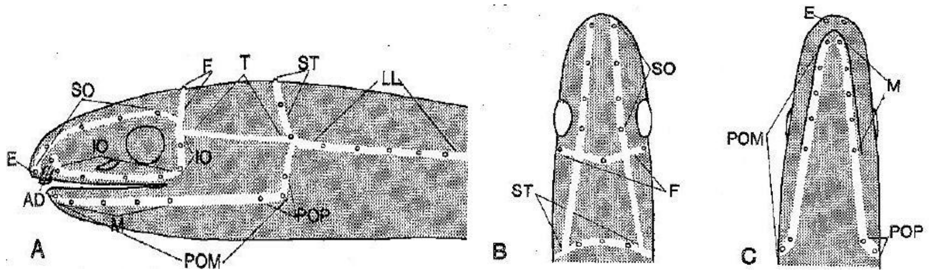

Figure 3.3: Schematic diagrams illustrating lateralis system of cannals and pores for eels by Böhlke 1989, A. Lateral view, B. Dorsal view, C. Ventral view

Other characters used for taxonomic identification of teleosts are frequently subject to variations in eels and thus are of limited usefulness (Böhlke 1989) even though dentition and colouration of specimens are used for taxonomic identification.

3.3 Results

3.3.1 Sampling sufficiency

Sampling sufficiency was tested separately for Arabian Sea (AS), Bay of Bengal (BoB) and Andaman Sea (AN) using species accumulation curves (PRIMER detailed in chapter 2). Species accumulation plots estimates the increasing total number of species observed (Sobs) with increase in sampling effort. Species estimators (Chao1, Jacknife 1 & Bootstrap) attempts to predict the true total number of species that would be observed as the number of samples tends to reach infinity (‘the asymptote’ of the species accumulation curve), assuming that a closed community is being successively sampled (Table 3.1).

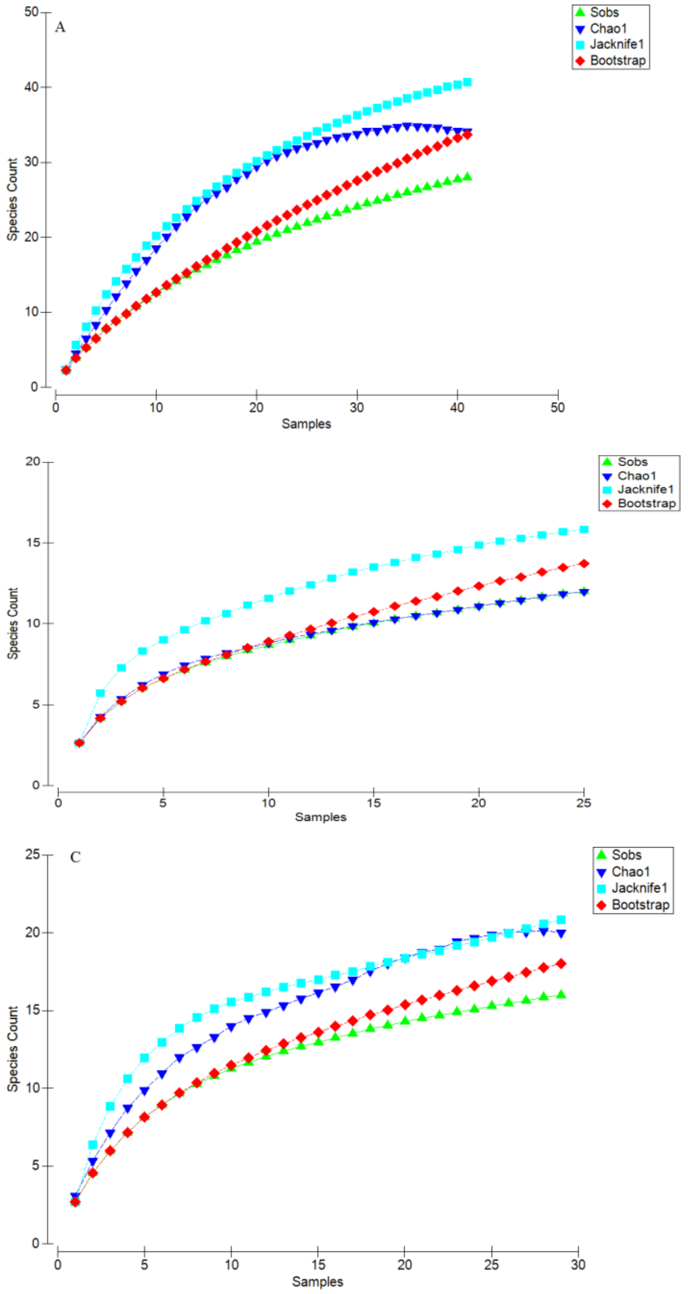

Figure 3.4: Species accumulation plot estimates of sampling sufficiency for Arabian Sea (A), Bay of Bangal (B), Andaman Sea (C)

Figure 3.4 shows that the cumulative number of species-observed (Sobs) increases exponentially with sampling effort but does not reach the asymptote in all the three regions (AS, BoB & AN). The trend of Sobs curves indicate that with more intensified sampling effort more number of species are likely to be obtained. The present sampling intensity provide Sobs values of 28, 12 and 16 from AS, BoB and AN respectively, indicating sampling sufficiency of 73%, 84% and 73% respectively for the three regions. The estimators (Chao1, Jacknife 1 & Bootstrap) from AS predict the expected number of species to reach up to 34±6, 41 and 34 respectively upon more intensified sampling from the area (Figure 3.4A). Thus from the estimator's predictions, the present sampling effort has recorded only 73% of deep-sea Anguilliform species that could be obtained from AS. The estimators (Chao1, Jacknife 1 & Bootstrap) from BoB predict the expected number of species to reach up to 12±1, 16 and 14 respectively upon more intensified sampling from the area (Figure 3.4B). Thus from the estimator's predictions, the present sampling effort for BoB had recorded 84% of deep-sea Anguilliform species that could be obtained from BoB. The estimators (Chao1, Jacknife 1 & Bootstrap) from AN predict the expected number of species to reach up to 20±5, 21 and 18 respectively upon more intensified sampling from the area (Figure 3.4C). Thus from the estimator's predictions, the present sampling effort had recorded only 73% of deep-sea Anguilliform species that could be obtained from AN.

Table 3.1: Values of species estimators

Area	Arabian Sea	Bay of Bengal	Andaman Sea
Species observed (Sobs)	28	12	16
Estimators prediction			
Chao1	34±6 (70%)	12±1 (92%)	20±5 (53%)
Jacknife 1	41(68%)	16 (75%)	21(76%)
Bootstrap	34 (82%)	14 (86%)	18 (89%)
Sampling sufficiency (%)	73%	84%	73%.

3.3.2 Taxonomy of deep-sea Anguiliiformes in Indian EEZ.

A. Suborder CONGROIDEI

I. Family COLOCONGRIDAE Smith, 1971

Short tail eels

Diagnosis: Stubby body; deepest shortly behind the head; blunt snout; short tail; dorsal, anal and pectoral fins well-developed; median fins continuous; dorsal fin origin slightly behind base of pectoral fin; anus well behind mid-body; lateral-line pores in the form of short tubes; presence of dermal papillae on head; large eye; small and conical teeth fully concealed when mouth closed, intermaxillary teeth in two transverse rows, maxillary in one or two rows and mandibular teeth in two to three rows (Smith 1989h).

This family is represented by a single genus *Coloconger* Alcock, 1889. The genus *Coloconger* was rested uncomfortably under the family Congridae for a long period. Matsubara (1955) first questioned the traditional placement of *Coloconger* to Congridae. Further Asano (1962) followed him and excluded *Coloconger* during his treatment of Japanese congrid eels. Later Smith (1971) compared *Coloconger* with other Congrid genera and erected a new family Colocongridae. At first glance it hardly looks like an eel at all, due to its stubby body. These eels prefer open terrain over muddy bottoms and occupy depths of approximately 300–1000 m (Smith 1989h).

Genus *Coloconger* Alcock, 1889a

Type species**:** *Coloconger raniceps* Alcock, 1889a, Andaman Sea

Diagnosis: Same as the family characteristics

Globally, this genus is represented by 8 valid species. *C. cadenati* Kanazawa, 1961; *C. japonicas* Machida, 1984; *C. meadi* Kanazawa, 1957; *C. raniceps* Alcock, 1889a; *C. saldanhai* (Quéro, 2001); *C. scholesi* Chan, 1967 are known from adult specimens and the remaining 2 species *C. canina* (Castle & Raju, 1975) from Indian Ocean and *C. eximia* (Castle, 1967) from Eastern Atlantic are known only from leptocephlus larvae. Both were originally described under the genus *Ascomanai* Castle, 1967 (Fricke et al. 2018a). As explained in Chapter-1, leptocephali have extended pelagic life of 6 moths to 3 years and therefore the mere presence of the larvae cannot be considered a proof for the occurrence of adults of these species in such waters. In view of this, it is fair to conclude that in the Indian EEZ this genus is represented by only a single species *Coloconger raniceps* Alcock, 1889a.

Coloconger raniceps **Alcock, 1889a**

Fig. 3.5, Table 3.2

Froghead eel

Coloconger raniceps Alcock, 1889a (original description based on unspecified number of specimens) 165–267 mm TL; off Ross Island, Andaman Sea, 485–496 m, Investigator Station 13; **Syntypes**: BMNH 1890.7.31.7 (ex ZSI F11777) (1), MNHN 1890-0363 (1), ZSI F11778-79 (1, 1).

Collection locations: AS: 12°06·221'N, 74°19.145'E, 320 m, 26.08.2013, (Cr.318, St.10), EXPO; 08°04·969'N, 76°07.335'E, 1400 m, 20.10.2017, (Cr.366, St.02), HSDT-CV

BoB: 18°50·436'N, 85°23.119'E, 644 m, 29.10.2011, (Cr.291, St.03), EXPO; 18°49·831'N, 85°22.616'E, 629 m, 30.10.2011, (Cr.291, St.05), HSDT-CV; 11°54·788'N, 80°8.719'E, 645 m, 05.11.2011, (Cr.291, St.11), EXPO; 10°58·428'N, 80°19.779'E, 652 m, 06.11.2011, (Cr.291, St.13), EXPO; 10°38·44'N, 80°31.36'E, 654 m, 07.11.2011, (Cr.291, St.14), EXPO; 10°37·411'N, 80°31.460'E, 648 m, 07.11.2011, (Cr.291, St.15), EXPO; 10°55·957'N, 80°21.519'E, 650 m, 08.11.2011, (Cr.291, St.16), EXPO

AN: 12°49·602'N, 93°12.782'E, 441 m, 17.09.2010, (Cr.280, St.16), EXPO; 11°08·920'N, 92°19.650'E, 514 m, 19.09.2010, (Cr.280, St.17), EXPO; 06°38·301'N, 93°41.082'E, 321 m, 24.09.2010, (Cr.280, St.37), EXPO; 07°31·460'N, 93°24.091'E, 567 m, 24.09.2010, (Cr.280, St.38), EXPO; 08°21·621'N, 93°20.065'E, 574 m, 14.12.2011, (Cr.292, St.91), HSDT-CV; 08°23·352’N, 93°20.534’E, 622 m, 29.01.2015, (Cr.334, St.03), HOT; 11°17·465’N, 92°47.886’E, 907 m, 16.01.2015, (Cr.334, St.12), HOT; 11°25·893’N, 92°20.210’E, 576 m, 04.04.2016, (Cr.349, St.01), HSDT-CV; 07°28·734’N, 93°24.510’E, 650 m, 04.04.2016, (Cr.349, St.02), HSDT-CV; 08°22·401’N, 93°20.363’E, 591 m, 05.04.2016, (Cr.349, St.03), HSDT-CV; 09°36·219’N, 92°43.739’E, 362 m, 06.04.2016, (Cr.349, St.04), HSDT-CV; °15.902’N, 93°15.827’E, 635 m, 26.11.2017, (Cr.367, St.08), HSDT-CV; 11°47.889’N, 92°05.437’E, 646 m, 28.11.2017, (Cr.367, St.15), HSDT-CV

Voucher specimen No.: 3490222 (CMLRE)

Diagnosis: Body stubby with large eyes; short and blunt snout, shorter than eye; anus placed well posterior to the mid-body; lateral-line pores open as short tubes; head length 18.2–20.1% TL; dorsal-fin origin slightly behind the base of pectoral fin; numerous papillae on head and body; intermaxillary teeth in 2 transverse rows; SO 6; total vertebrae 144.

Description: Body stubby with a massive head; dorsal and anal fins well developed and confluent with caudal fin; tip of the caudal fin not attenuated; dorsal-fin origin slightly behind the base of pectoral fin, predorsal 20.1–22.9% TL; pectoral fin long and well developed, pectoral-fin length 7.6–10.2% HL; anus well posterior to mid-body; anal fin placed immediately behind anus; preanal 57.5–60.9% TL; head broad 18.2–20.1% TL; snout blunt and short 19.4–24.2% HL; upper jaw slightly overhangs the lower jaw; all teeth are concealed when mouth is closed; tongue free; flanges on upper and lower lip absent; rictus ends below the posterior margin of the pupil; anterior nostril short tube near tip of snout, posterior nostril large slit with a slightly raised rim, at mid-level of eye; eye large spherical in shape, its horizontal diameter 22.7–27.1% HL; interorbital width greater than eye diameter, 27–29.2% HL; gill-opening length small, 12–19.8% HL; depth at gill 9.4–15.3% TL and depth at anus 8.2–10.2% TL; head pore numerous, and tubular difficult to count except few anterior pores: ST 6; small scattered black coloured sensory papillae on head; lateral-line pores conspicuous in the form of short tubes: pectoral 5–6, predorsal 7–8, preanal 67–68; vertebrae: predorsal 8, preanal 68 and total vertebrae 144; teeth small with serrated edge; intermaxillary teeth in 2 transverse rows the inner row continuous with maxillary teeth; maxillary and mandibular teeth uniserial; maxillary teeth less in number than mandibular teeth; vomerine teeth absent; colour when fresh is greyish to black on the body, pectoral, dorsal and anal fins blackish, extreme tip of caudal fin with almost clear margin.

Distribution: Indo-west Pacific: East Africa, Madagascar & Réunion; Southern Japan & Taiwan (Karrer 1883; Quéro & Saldanha 1995; Smith 1989h; Ho et al. 2015b, 2018a; Fricke et al. 2018c); Indian EEZ: Arabian Sea (Alcock 1899; Lloyd 1909; Venu 2009; Sajeevan et al. 2009; Hashim 2012; present study [Figure 3.6]).); Bay of Bengal (Alcock 1889a; 1899; Lloyd 1909; Hashim 2012, Sudhakar et al. 2013; present study[Figure 3.6]).); Andaman Sea (Alcock 1889a; Rajan et al. 2013; present study [Figure 3.6]).

Remarks: This species is widely distributed in Indian EEZ with their presence in Arabian Sea, Bay of Bengal and Andaman Sea.

Table 3.2: Comparison of morphometric and meristic characters of *Coloconger raniceps* Alcock, 1889 with previous study.

	Castle 1969	Present study (n=15)		
		Range	Mean	SD
Total length (mm)		271-343		
% TL				
Preanal length	58.6	57.5-60.9	59.1	1.1
Predorsal length	23.4	20.1-22.9	21.1	1.4
Head length	21.9	18.2-20.1	19.2	0.6
Trunk length	_	37.5-41.7	39.9	1.6
Depth at gill-opening	11.4	9.4-15.3	12.2	2.0
Depth at anus	9.6	8.2-10.2	9.0	0.7
Snout length	4.2	3.7-4.6	4.3	0.3
Eye diameter	5.3	4.5-5.2	4.9	0.2
Interorbital width	_	5.1-5.7	5.3	0.5
Upper-jaw length	8.3	7.4-9	8.3	0.5
Lower-jaw length	_	7.0-8.8	7.9	0.6
Gill-opening length	_	2.3-3.8	3.0	0.5
Interbranchial width	_	6-6.6	6.2	0.4
Pectoral-fin length	8.7	7.6-10.2	8.5	0.9
Pectoral-fin base length	_	2.4-2.8	2.6	0.2
Depth at dorsal	_	9.2-12.7	10.9	1.3
Standard length	97	95.5-97.2	96.6	0.6
% HL				
Snout length	_	19.4-24.2	22.2	1.6
Eye diameter	_	22.7-27.1	25.5	1.8
Interorbital width	_	27–29.2	27.6	2.4
Upper-jaw length	_	39.1-47.1	43.4	2.3
Lower-jaw length	_	36.8-46	41.4	2.6
Gill-opening length	_	12.0-19.8	15.8	2.7
Interbranchial width	_	31.3-34.9	32.4	2.0
Pectoral-fin length	_	37.8-54.3	44.6	5.6
Pectoral-fin base length	_	12.9-14.8	13.4	0.6
Meristics				
Lateral-line pores				
Prepectoral	-	5–6		
Predorsal	-	7-8		
Preanal	69.0	67-68		
Vertebrae				
Predorsal	-	8		
Preanal	-	68		
Total	-	144		

Figure 3.5: *Coloconger raniceps***:** A species widely distributed in Indian EEZ

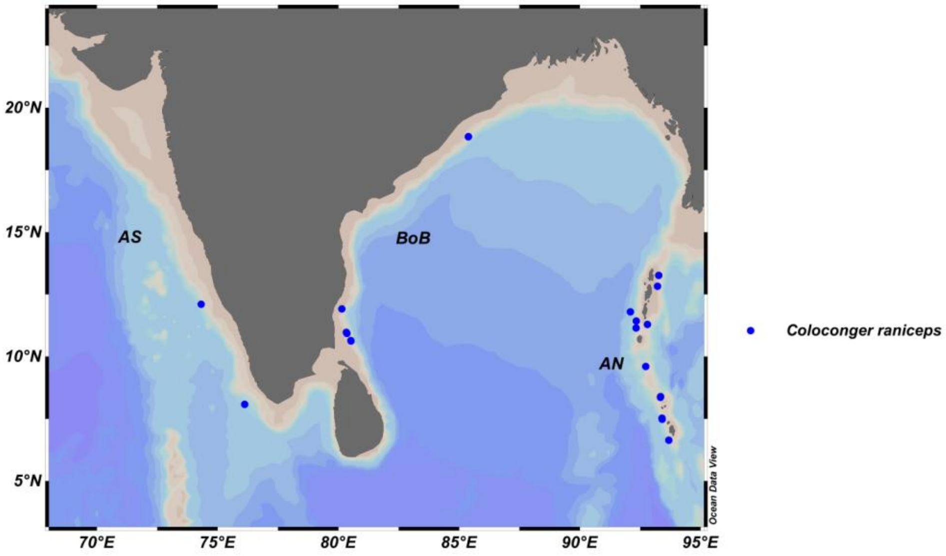

Figure 3.6: Map showing distribution of deep-sea eels of family Colocongridae in the Indian EEZ

II. Family CONGRIDAE Kaup, 1856a

Conger eels

Diagnosis: Body cylindrical anteriorly, with thin delicate tail; lateral line complete; eye well developed; pectoral fin present, dorsal-fin origin closer to pectoral fin than to anus; well developed lips; anterior nostril tubular on tip of snout; posterior nostril oval shape, in front of middle or upper part of eye; presence of median supratemporal pore (absent in *Macrocephenchylus branchialis*) branchiostegal rays 8–22, vertebrae 105–225 (Smith 1999d).

Congridae is a diverse and speciose family with about 218 valid extanct species under 29 genera (Fricke et al. 2018c) whose members inhabit primarily on sandy and muddy bottoms from coastline to depths of 2000 m or more in tropical and subtropical latitudes worldwide (Smith 1989j; Smith 2004). This family comprises 3 subfamilies Bathymyrinae (54 valid species), Congrinae (129 valid species) and Heterocongrinae (35 valid species). The distinguishing characteristics of the sub-families are as follows Bathymyrinae: Fin rays unsegmented; cauadal fin present but short; anus usually near mid-body. Congrinae: Fin rays segmented; caudal fin relatively long; anus usually well before mid-body. Heterocongrinae: Body slender and worm like; mouth very short; pectoral fin reduced or absent (Castle 1968b).

(1) Subfamily Bathymyrinae Böhlke 1949

Genus *Ariosoma* Swainson, 1838

Type species: *Ophisoma acuta* Swainson, 1839 (= *Muraena balearica* Delaroche, 1809 by subsequent designation of Bleeker 1864), Mediterranean Sea.

Diagnosis: Body stout to moderately elongate; dorsal fin originates near pectoral fin base; preanal more than 40% of TL; tail tip stiff and blunt; caudal fin reduced; snout rounded and projects slightly beyond lower jaw; well-developed flanges on upper and lower lips; anterior nostril tubular near tip of the snout, posterior nostril elliptical in front of eye below its mid-level; adnasal pore absent; head pores small, pores along upper jaw located on side of head rather on labial flange; teeth small acute as bands on jaws and vomer, wider anteriorly (Smith 1989j; Shen 1998).

This genus is one of the most abundant and diverse among the congrid genera with 32 valid species (Fricke et al. 2018a). Only one species *Ariosoma gnanadossi* have been reported from deep-waters of Indian EEZ. Present study reports *A. gnanadossi* and added a new species to this genus from Indian EEZ.

Ariosoma gnanadossi Talwar & Mukherjee, 1977

Fig. 3.7, Table 3.3

Holotype*:* ZSI F. 7146/2, 283 mm TL, off Madras coast, India, 250 m.

Collection locationss: BoB: 13°13·260’N, 80°30.470’E, 307 m, 29.08.2010, (Cr.279, St.11), HSDT-CV; 14°09·197’N, 80°24.745’E, 225 m, 03.08.2014, (Cr.327, St.06), HSDT-CV

Voucher specimen No.: 3270601 (CMLRE)

Diagnosis: Dorsal-fin origin slightly before the pectoral-fin base, predorsal 17–17.9% TL; anus positioned anterior to mid-body, preanal 40.3–43.3% TL; large eyes 16.7–18.1% HL; tail tip blunt and stiff; total vertebrae 144.

Description: Body moderately elongated almost cylindrical anteriorly and laterally compressed posteriorly along the tail; tip of the tail blunt and flexible; dorsal and anal fins well developed and continuous with caudal fin; dorsal-fin origin slightly before the pectoral fin base, predorsal 17–17.9% TL; anal fin commences immediately behind anus; pectoral fin moderately elongated and well developed, pectoral-fin length 40–46.9% HL; anus anterior to mid-body, pre-anal 40.3–43.3% TL; head elongated and almost cylindrical, its length 18–18.7% of TL; snout moderately long with a blunt tip, snout length 19.8–22.1% HL; tongue free; upper jaw slightly overhangs the lower jaw; upper and lower lip with well-developed flanges; mouth moderately large and rictus ends at mid eye level; eye large and circular, almost nearer to snout length, its horizontal diameter is 16.7–18.1% HL; anterior nostril tubular and positioned laterally near tip of snout just before the anterior end of the flange; posterior nostril oval in shape without any raised rim, positioned nearer to eye than posterior nostril at mid eye level; gill opening large and its upper edge near the middle of pectoral-fin base, gill-opening length 16.3–18.9% HL; maximum depth at gill opening 5.4–6.1% TL; lateral-line pores small and inconspicuous: lateral-line pores predorsal 9, prepectoral 10, preanal 47; vertebrae: predorsal 10, Preanal 48 and total vertebrae

144; head pores small difficult to count: SO 5 , IO 7, POM 10, ST 3; teeth small and conical in shape; intermaxillary teeth scarcely visible when mouth is closed; maxillary teeth irregular in 4 rows anteriorly and ends in 2 to 3 rows posteriorly; mandibular teeth in 5 rows and ends as 2 rows posteriorly; vomerine teeth in 4 rows and ends as 2 teeth near the level of posterior nostril; colour brown when fresh in dorsal region and paler below, dorsal and anal fins grey with black margin, pectoral fin almost black.

Distribution: Northern Indian Ocean: Pakistan: Arabian Sea (Moazzam & Osmani 2015; Psomadakis et al. 2015).

Indian EEZ: Bay of Bengal (Talwar & Mukherjee 1977; Present study [Figure 3.28B]

Remarks: *Ariosoma gnanadossii* was described by Talwar & Mukherjee (1977) based on a single specimen (283 mm TL) collected from off Madras coast, Bay of Bengal from 250 m. For long time this species was known only from type specimen from Bay of Bengal waters till the recent record of 2 specimens (250–310 mm) from Pakistan, Arabian Sea (Moazaam et al. 2015; Psomadaskis et al. 2015). Present study reports 4 additioal specimens from Bay of Bengal waters. In Indian EEZ this species is reported from depth above 200 m whereas in Pakistan waters they were collected from a much lower depth, 25 m. Hence there is possibility for the presence of this species in shallow waters of India also.

Table 3.3: Comparison of morphometric and meristic characters of *Ariosoma gnanadossi* Talwar & Mukherjee, 1977 with previous study

	Talwar & Mukherjee 1977 (n=1)	Present study (n=4)		
		Range	**Mean**	**SD**
Total length (mm)	283	239-312		
% TL				
Preanal length	39.9	40.3-43.3	41.8	1.4
Predorsal length	16.3	17.0-17.9	17.3	0.4
Head length	17.5	18-18.7	18.4	0.3
Trunk length	22.3	22.1-24.7	23.5	1.4
Depth at gill-opening	6.4	5.4-6.1	5.7	0.3
Depth at anus	6.9	4.3-4.6	4.5	0.1
% HL				
Snout length	19.2	19.8-22.1	21.0	1.0
Eye diameter	19.2	16.7-18.1	17.4	0.6
Interorbital width	-	8.4-15.1	10.7	3.5
Upper-jaw length	-	28.9-31.9	30.5	1.2
Lower-jaw length	-	26.2-26.8	26.4	0.3
Gill-opening length	19.2	16.3-18.9	17.8	1.1
Interbranchial width	-	8.3-11.7	8.9	1.9
Pectoral-fin length	42.4	40-46.9	44.4	3.1
Pectoral-fin base length	-	6.6-8.2	7.4	0.8
Meristics				
Lateral-line pores				
Prepectoral	-	10		
Predorsal	-	9		
Preanal	44	47		
Head pores				
Supraorbital	-	5		
Infraorbital	-	7		
Preoperculomandubular	-	10		
Supratemporal	-	3		
Vertebrae				
Predorsal	-	10		
Preanal	-	48		
Total	-	144		

Ariosoma sp. A (New species)

Fig. 3.8, Table 3.4

Arabian Sea blunttooth conger

Collection locations: AS: 09°59·575'N, 75°35.768'E, 214 m, 08.08.2010, (Cr.278, St.01), HSDT-CV; 11°59·455'N, 74°25.594'E, 200 m, 08.08.2011, (Cr.288, St.09), EXPO; 09°59·935'N, 75°36.086'E, 200 m, 10.08.2011, (Cr.288, St.17), HSDT-CV; 10°09·956'N, 75°38.965'E, 200 m, 07.01.2014, (Cr.322, St.01), HSDT-CV; 08°59·618'N, 75°55.468'E, 200 m, 10.01.2014, (Cr.322, St.07), HSDT-CV; 08°21·750'N, 76°29.800'E, 200 m, 13.01.2014, (Cr.322, St.10), HSDT-CV

Voucher specimen No.: 3220704 (CMLRE)

Diagnosis: Dorsal-fin origin slightly before or above the pectoral fin base, predorsal 20–22.2% TL; anus positioned before mid-body, preanal 44.4–46.9% TL; snout longer than eye; lateral-line pores: predorsal 10–11; prepectoral 11–12 and preanal 45–48; head pores: POM 11, IO 7, SO 6; ST 3 and total vertebrae 139–141.

Description: Body moderately elongated almost cylindrical anteriorly and laterally compressed posteriorly along the tail; tip of the tail blunt and flexible; dorsal-fin origin slightly before to or just above the pectoral fin base, predorsal 20–22.2% TL; anal fin commences immediately behind anus; pectoral fin moderately elongated and well developed, pectoral-fin length 27.4–33.6% HL; anus positioned before mid-body, preanal 44.4–46.9% TL; head broad and moderately elongated, head length 21.1–23%

TL; snout moderate with blunt tip, snout length 18.1–22.6% HL; tongue free; flanges present on both upper and lower lips; mouth moderately large and rictus ends at level with posterior end of the pupil of eye. upper jaw slightly overhangs the lower jaw; eye large and circular in shape, its horizontal diameter 15.6–18.2% HL; anterior nostril tubular positioned laterally near tip of snout, posterior nostril oval slit at the level with the lower margin of eye; gill opening large and its upper edge at the middle of pectoral-fin base, gill-opening length 17.7–22.7% of HL; maximum depth at gill opening 5.6–9.5% of TL; lateral-line pores small but conspicuous: predorsal 10–11, prepectoral 11–12 and preanal 45–48; vertebrae predorsal 11, preanal 47–48 and total vertebrae 139–141 ; head pores small: SO 6 , IO 7, POM 11, ST 3; teeth small and conical in shape; intermaxillary teeth scarcely visible when mouth is closed; maxillary teeth irregular in 4 rows anteriorly and ends as uniserial posteriorly; mandibular teeth in 4 rows and ends as 2 rows posteriorly; vomerine teeth in 5 rows and ends as 3 teeth’s near the level of posterior margin of eye; colour (formaldehyde preserved) is light brown with pale ventral region, median fins with black margin and pale pectoral fin, body with numerous small black pigmented spots, and are more evident under microscopic view.

Distribution: Known only from Arabian Sea through the present study [Figure 3.28B].

Discussion: In deep-waters of India only one species *A. gnanadossi* have been reported. This is the second species representing the genus *Ariosoma* from deep-sea. This species is closely similar to *Ariosoma sokotranum*

Karmovskaya, 1991 described from off Socotra Island, Eastern Arabian Sea in total vertebral counts, cephalic pore counts and in some morphometric proportions. But the present new species differes from *A. sokotranum* in having; slightly longer head and snout (21.1–23% vs. 20.2–20.6% TL) and (18.1–22.6% vs. 17.9–19.2% HL) respectively; dorsal-fin origin further back (20–22.2% vs. 18.8–18.9% TL) and shorter pectoral fin (27.4–33.6% vs. 34.3–38.5% TL). *Ariosoma* sp. A also shows slightly higher lateral-line pore counts than *A. sokotranum* (prepectoral 11–12 vs. 9–11, predorsal 10–11 vs. 9–10 and preanal 45–48 vs. 45–46). *Ariosoma* sp. A is also different from another similar species *A. somalianse* (kotthaus, 1968) described from shallower region of Somali Coast in having higher number of total vertebrae (139–141 vs. 126–130) and higher number of head pores in supraorbital (6 vs. 5) and preoperculomandibular region (11 vs. 8). There is no other species similar to present described species.

Remarks: New species to science

Table 3.4: Morphometric and meristic characters of *Ariosoma* sp. A (New species)

	Present study (n=9)		
	Range	**Mean**	**SD**
Total length (mm)	234-431		
% TL			
Preanal length	44.4-46.9	45.6	0.8
Predorsal length	20-22.2	20.8	0.7
Head length	21.1-23	22.0	0.7
Trunk length	21.5-24.9	23.6	1.2
Depth at gill-opening	5.6-9.5	7.8	1.0
Depth at anus	4.4-7.6	6.3	0.9
% HL			
Snout length	18.1-22.6	20.7	1.4
Eye diameter	15.6-18.2	16.4	0.8
Interorbital width	13.9-17.5	16.0	1.4
Upper-jaw length	28.3-34.7	30.1	2.0
Lower-jaw length	25.2-29.1	26.8	1.2
Gill-opening length	17.7-22.7	20.5	1.9
Interbranchial width	6.5-13.1	9.1	2.0
Pectoral-fin length	27.4-33.6	30.9	1.8
Pectoral-fin base length	5.2-8.2	7.2	1.0
Meristics			
Lateral-line pores			
prepectoral	11-12		
predorsal	10-11		
Preanal	45-48		
Head pores			
Supraorbital	6		
Infraorbital	7		
Preoperculomandubular	11		
Supratemporal	3		
Interorbital	2		
Vertebrae			
Predorsal	11		
Preanal	47-48		
Total	139-141		

Genus *Bathymyrus* Alcock, 1889b

Type species: *Bathymyrus echinorhynchus* Alcock, 1889b; Bay of Bengal India.

Diagnosis: Body stout to moderately elongate; well developed median fins; pectoral fin well developed; short trunk; anus placed before mid-body; tongue free; well developed flanges on upper and lower lips; premaxillae expanded forward and upward over the snout (Smith 1965).

This genus is represented by 3 valid species, *B. echinorhynchus* Alcock, 1889b (Indo-West Pacific); *B. simus* Smith, 1965 (Western Pacific) and *B. smithi* Castle, 1968e (Western Indian Ocean) (Fricke et al. 2018a). In Indian EEZ this genus is represented by a single species, *B. echinorhynchus* Alcock, 1889b.

Bathymyrus echinorhynchus Alcock, 1889

Fig. 3.9, Table 3.5

Holotype: ZSI F12440, 261 mm TL, off the mouth of Devi river, Bay of Bengal; Investigator Station 32; 124 m; ***Paratype:*** SAIAB 821 (ex ZSI F1 3757), 168 mm TL; off Orissa, 174 m.

Collection locations: BoB: 15°54·918’N, 81°24.851’E, 228 m, 05.08.2014, (Cr.327, St.08), EXPO

Voucher specimen No.: 3270802 (CMLRE)

Diagnosis: Body stout; dorsal-fin origin slightly behind the pectoral-fin base; anus located before mid-body; flanges on upper and lower lip; posterior nostril a concave slit, located above upper lip just before the level of anterior margin of eye; intermaxillary tooth fully exposed and curves upward on to anterior snout; tip of tail stiff and round.

Description: Body moderately elongate, cylindrical anteriorly and laterally compressed posteriorly; dorsal and anal fins well developed and confluent with caudal fin; caudal fin tip stiff and round; dorsal-fin origin slightly behind the pectoral-fin base, predorsal 22.7% TL; pectoral fin elongated and well developed, its length 39% HL; anal fin begins immediately behind anus; anus positioned before mid-body, preanal 41.7% TL; head moderate in length 20.1% TL; snout less than eye diameter, its tip is bluntly pointed with holding extension of intermaxillary teeth; snout length 14.8% HL; tongue free; presence of a median longitudinal ridge on dorsal side of snout which extent to the interorbital region and is prominent after preservation; upper jaw slightly projects beyond the tip of lower jaw; flange present on upper and lower lips; mouth moderate and rictus restricted to the level of posterior margin of eye; eye large spherical its horizontal diameter 17.2% HL; anterior nostril tubular positioned at anterior extremity of lip, posterior nostril a concave slit above the upper lip just before the level of anterior margin of eye; gill-opening length large, 21.6% HL, ventrolateral with less interbranchial space and its upper margin is at level with upper margin of pectoral base; maximum depth at gill opening 6.1% TL; lateral-line pores small but conspicuous: prepectoral 11; predorsal 14 and preanal 43; veretebrae: predorsal 15, preanal 45 and total 124; cephalic pores small:

SO 4; IO 5; POM 9 and ST 1; teeth small and conical, intermaxillary teeth on ventral side is having 7 teeth as 2 transverse rows which extends to the tip of snout with a cluster of another 15 teeth, pre-maxillary teeth extension is about half the diameter of eye; vomerine teeth begins after a small gap as a cluster of 10 conical teeth; Maxillary teeth starts as irregular biserial group and followed by about 70 uniserial till end; mandibular teeth begin as small cluster of 2 to 3 series followed by biserial teeth of 6 smaller teeth continued by uniserial teeth till the end. Colour when fresh brown dorsally and pale ventrally, median fins and pectoral fins pale.

Distribution: Northern Indian Ocean: Pakistan (Moazzam & Osmani 2015; Psomadakis et al. 2015); Indian EEZ: Bay of Bengal: (Alcock 1889b; Ray 2016; Present study [Figure 3.28B]).

Remarks: For long time *Bathymyrus echinorynchus* was known only from the type locality Bay of Bengal waters till its recent record from Pakistan. Present study recorded a single specimen from Bay of Bengal.

Table 3.5: Comparison of morphometric and meristic characters of *Bathymyrus echinorhynchus* Alcock, 1889b with previous study.

	Smith 1965 (n=2)	**Present study (n=1)**
Total length	168-261	278
% TL		
Preanal length	41.7	41.7
Predorsal length	20.8-21.3	22.7
Head length	19-19.2	20.1
Trunk length	21.4-22	21.6
Depth at gill-opening	_	6.1
Depth at anus	7.1	5.9
% HL		
Snout length	_	14.8
Eye diameter	16.1	17.2
Interorbital width	_	14.1
Upper-jaw length	_	29.9
Lower-jaw length	_	26.8
Gill-opening length	_	21.6
Interbranchial width	_	7.9
Pectoral-fin length	_	39.0
Pectoral-fin base length	_	6.6
Meristics		
Lateral-line pores		
Prepectoral	9	11
Predorsal	_	14
Preanal	43	43
Head pores		
Supraorbital	_	4
Infraorbital pores	_	5
Preoperculomandubular	_	9
Supratemporal	_	1
Vertebrae		
Predorsal	_	15
Preanal	_	45
Total	_	124

(2) Subfamily Congrinae Kaup, 1856a

Genus *Bathycongrus* Ogilby, 1898

Type species: *Congromuraena nasica* Alcock, 1894a valid as *Bathycongrus nasicus* (Alcock, 1894a); Bay of Bengal, India.

Diagnosis: Moderately elongate body; flexible, slender and attenuated tail; dorsal fin origin over or slightly behind pectoral fin; anal fin origin just behind anus; median fins continues, well developed pectoral fin; snout projects beyond the lower jaw, fleshy tip of snout extends beyond intermaxillary teeth; flange present on lower lip, rudimentary or absent on upper lip; adnasal pore absent; anterior nostril tubular positioned near tip of snout, posterior nostril oval in front of middle or upper portion of eye; pores along upper jaw, second and third supraorbital pores and third preoperculomandibular pore enlarged; teeth small to moderate to slightly enlarged; Intermaxillary teeth 2 to several rows exposed when mouth closed; vomerine teeth variable, with slightly elongated multiserial patch of small teeth or few large teeth surrounded by variable number of small teeth; maxillary and mandibular teeth in bands (Smith 1989j; Karmovskaya & Smith 2008; Smith & Ho 2018a).

This genus is one of the abundant among the congrid genera with 28 valid species (Huang et al. 2018). In Indian EEZ genus *Bathycongrus* is represented by 5 species among them two are new species (*Bathycongrus* sp. A & *Bathycongrus sp. B*), 1 species (*B. trimaculatus*) is new record from Indian EEZ and remaining 2 species (*B. nasicus* and *B. macrocercus*) were previously recorded from Indian waters.

Bathycongrus macrocercus (Alcock, 1894b)

Fig. 3.10, Table 3.6

Synonyms: *Congromuraena longicauda* Alcock, 1889a; *Congromuraena macrocercus* Alcock, 1894b

Collection locations*:* AN: 11°08.920’N, 92°19.650’E, 514 m, 19.09.2010, (Cr.280, St.17), EXPO; 08°23.352’N, 93°20.534’E, 622 m, 29.01.2015, (Cr.334, St.03), HOT; 12°44·58’N, 93°6.30’E, 332 m, 10.04.2016, (Cr.349, St.06), HSDT-CV; 13°15.902’N, 93°15.827’E, 635 m, 26.11.2017, (Cr.367, St.08), HSDT-CV

Voucher specimen No.: 3670807 (CMLRE)

Lectotype*:* ZSI 11782, male C. 400 mm TL, Andaman Sea, 7 miles South of Ross Island, 485 m, Investigator Station 13; ***Paralectotype****:* ZSI 11781 (1), 380 mm TL (same data); ZSI 13452 (320 mm) 420–460 m.

Diagnosis: Dorsal-fin origin slightly before the pectoral-fin base, predorsal 43.2–45.5%, head length 42.4–47.5%, trunk length 52.5–57.6% PAL; snout length 23.5–26.3% HL; total vertebrae 161.

Description: Body moderately elongated, cylindrical anteriorly and laterally compressed posteriorly with attenuated tail; dorsal and anal fins well developed and continuous with caudal fin; dorsal-fin origin slightly anterior to pectoral-fin base, predorsal 43.2–45.5% PAL; anal fin originates immediately behind anus, preanal length 36.4–38.1% of TL; pectoral fin well developed, its length is 24.5–29% HL; head moderate, head length 42.4–47.5 % PAL; snout moderately elongated, 23.5–26.3% HL; trunk length 52.5–57.6% PAL; fleshy tip of the snout extends beyond the intermaxillary teeth; tongue free; upper jaw overhangs the lower jaw; flange present on lower lip, absent on upper lip; mouth moderate, rictus ends at the level of posterior margin of eye; eye moderate, oval in shape its horizontal diameter 15.8–17.5% HL; anterior nostril tubular located laterally near tip of snout, posterior nostril elliptical with slightly raised rim located in front of eye at mid-level, gill-opening length 12.1–14.6% HL; depth at gill almost similar to depth at anus; lateral-line pores conspicuous: prepectoral 7, predorsal 7–8; preanal 37–38; vertebrae: predorsal 8, preanal 39 and total vertebrae 161; head pores conspicuous: SO 3; IO 5; POM 10; ST 1; teeth conical, intermaxillary with 3–4 rows separated from maxillary teeth, maxillary and mandibular teeth in bands with 4 rows anteriorly and 1-2 rows posteriorly, vomorine teeth in short elongate patch with few enlarged central teeth encircled by many smaller teeth. Colour when fresh is grey and ventral surface of the body lighter than dorsal surface, pectoral fin light, median fin ends with black margin.

Distribution: Northern Indian Ocean: (Castle 1968b; Castle & smith 1999; Karmovskaya 2009). Indian EEZ: Known only from Andaman Sea (Alcock 1894b; present study [Figure 3.28B].

Table 3.6: Comparison of morphometric and meristic characters of *Bathycongrus macrocercus* (Alcock, 1894b) with previous study.

	Karmovskaya 2009 (n=5)	Present study (n=3)		
		Range	Mean	SD
Total length (mm)	123-408	272-365		
% TL				
Preanal length	35.3-37.3	36.4-38.1	37.3	0.8
Predorsal length	15.5-16.5	15.9-16.9	16.5	0.5
Head length	15.8-17	16.2-17.3	16.9	0.6
Trunk length		19.1-21.9	20.4	1.4
Depth at gill-opening	4.5-5	4.6-5.3	5.0	0.4
Depth at anus	4.5-5	4.4-5.2	4.7	0.4
% HL				
Snout length	24.5-26.5	23.5-26.3	25.8	2.1
Eye diameter	14.5-17.5	15.8-17.5	16.7	0.8
Interorbital width	5.1-7.5	7.4–7.6	7.5	0.1
Upper- jaw length	31.3-35.9	31.7-35.8	33.8	2
Lower- jaw length	-	27.3-31.3	29.6	2.1
Gill-opening length	10-19.3	12.1-14.6	12.9	1.4
Interbranchial width	12.5-15.7	14.4-15.7	15	0.7
Pectoral-fin length	20.5-28.6	24.5-29	26.9	2.2
Pectoral-fin base length	-	5-5.9	5.3	0.5
% PAL				
Predorsal length	42.1-46.7	43.2-45.5	44.6	1.3
Head length	43.2-48.3	42.4-47.5	45.4	2.6
Trunk length	51.7-56.8	52.5-57.6	54.6	2.6
Meristics				
Lateral-line pores				
Prepectoral	-	7		
Predorsal	8-9	7-8		
Preanal	37-39	37-38		
Head pores				
Supraorbital	3	3		
Infraorbital	5	5		
Preoperculomandubular	10	10		
Supratemporal	1	1		
Vertebrae				
Predorsal	8-9	8		
Preanal	38-40	39		
Total	160-162	161		

***Bathycongrus nasicus*, (Alcock, 1894a)**

Fig. 3.11, Table 3.7

Synonyms: *Congromuraena nasica* Alcock, 1894a

***Lectotype**:* ZSI F13454, 247 mm TL; ***Paralectotypes**:* ZSI F13453 (1), F13455-56 (1, 1); 163–249 mm TL; USNM 46753, 255 mm TL, (ex ZSI 13674), off Madras coast, Bay of Bengal, 15°04'07"N, 80°25'07"E, Investigator Station.137, 234 m; Additional specimens, Regd. Nos. 13649–13692 (Alcock 1889).

Collection locations: AN: 11°08·920’N, 92°19.650’E, 514 m, 19.09.2010, (Cr.280, St.17), EXPO

Voucher specimen No.: 2801700 (CMLRE)

Diagnosis: Dorsal-fin origin slightly before pectoral fin base, predorsal 51.1% PAL; head length 52.3% PAL; preanal lateral-line pores 30; Vertebrae $142^{+.}$

Discription: Body moderately elongated cylindrical anteriorly and laterally compressed posteriorly, with incomplete tail; dorsal and anal fins well developed and continuous with caudal fin; dorsal-fin origin slightly before the pectoral-fin base, predorsal 51.1% of PAL; anal fin commences immediately behind anus; pectoral fin long and slender, pectoral-fin length 13.5% PAL; head elongated and pointed its length 52.3% PAL; snout long and slender, snout length 13.6% of PAL; fleshy tip of the snout extends beyond the intermaxillary teeth; tongue free; upper jaw overhangs the lower jaw; flange present on lower lip, absent on upper lip; mouth moderate, rictus ends at the level of posterior margin of pupil; eye moderate, oval in shape, its horizontal diameter, 5.7% of PAL; narrow interorbital width less than eye diameter; anterior nostril tubular located laterally near tip of snout, posterior nostril oval with slightly raised rim located before the eye at mid-level; gill opening moderate greater than interbranchial, gill-opening length 5.5% of PAL; depth at anus more than depth at gill opening (11.0% vs. 8.8% PAL). lateral-line pores small, inconspicuous: prepectoral 9, predorsal 8, and preanal 30; vertebrae: Predorsal 10, preanal 31, and total vertebrae 142^{+}; head pores conspicuous: SO 3; IO pores 5; POM 10; ST 1; teeth conical slightly curved back, maxillary and mandibular teeth multiserial in 4 rows anteriorly and ends as single row posteriorly with outer row teeth larger, intermaxillary teeth 4 transverse rows completely exposed when mouth closed; vomerine teeth in a cluster, several are prominent and sharp; colour (in formaldehyde) light brown body with pale median fins and pectoral fin.

Distribution: Northern Indian Ocean: Bay of Bengal (Alccok 1894a); Andaman Sea (present study [Figure 3.28B]).

Remarks: Known only from Indian EEZ of BoB; Present study is the first report on *Bathyuroconger nasicus* from Andaman Sea.

Table 3.7: Comparison of morphometric and meristic characters of *Bathycongrus nasicus*, (Alcock, 1894a) with previous study.

	Castle 1995 (n=5)	**Present study (n=1)**
Total length (mm)	163-255	
% PAL		
Preanal	58-93	100
Predorsal	48.1-52.4	51.1
Head length	53.1-55.8	52.3
Snout length	11.1-13.7	13.6
Eye diameter	5.7-6.9	5.7
Upper-jaw length	16.7-19.8	16.6
Pectoral-fin length	9.8-13.4	13.5
Depth at anus	9-15.5	11.0
Trunk length	-	47.7
Interorbital width	-	1.6
Lawer-jaw length	-	14.5
Gill-opening length	-	5.5
Depth at gill-opening	-	8.8
Interbranchial width	-	1.4
Meristics		
Lateral-line pores		
Prepectoral	-	9
Predorsal	-	8
Preanal	29-32	30
Head pores		
Supraorbital	-	3
Infraorbital	-	5
Preoperculomandubular	-	10
Supratemporal	-	1
Vertebrae		
Predorsal	-	10
Preanal	-	31
Total	106+ -152	142+

Bathycongrus sp. A (New species)

Fig. 3.12, Table 3.8

Collection locations: AS: 09°59·575’N, 75°35.768’E, 214 m, 08.08.2010, (Cr.278, St.01), HSDT-CV; 08°28·994’N, 78°35.583’E, 200 m, 15.01.2014, (Cr.322, St.12), HSDT-CV

Voucher specimen No.: 3221223 (CMLRE)

Diagnosis: Body moderately elongated, cylindrical anteriorly and compressed posteriorly with attenuated tail; dorsal-fin origin just above the pectoral-fin base; shorter trunk less than head; well developed flange on lower lip; head broad and in slightly raised profile on dorsal side slightly behind the eye; posterior nostril placed high on the head near the upper margin of eye with a slightly raised rim; teeth conical, blunt in the form of bands.

Description: Body moderately elongated, cylindrical anteriorly and compressed posteriorly with attenuated tail; tail frequently damaged or regenerated; dorsal and anal fins continuous with cauadal fin; dorsal-fin origin above the pectoral fin, predorsal 52.9–55.2% PAL; anus well before the mid-body, preanal 35.5% TL (intact specimen 211mm TL), others have regenerated tail); anal fin originates just after the anus; pectoral fin elongated, its length 27–29.1% HL; head broad, slightly raised dorsal profile behind eye, head length 53.9–56.8% PAL; short trunk less than head length, trunk length 43.2–46.1% PAL; snout moderately elongated with blunt and fleshy tip just projects the intermaxillary teeth, snout length 21.5–23.7% HL; eye moderate, sub circular covered by membrane, its horizontal diameter is 10.8–14.2% HL; mouth terminal rictus ends at mid-level of eye; flange present on lower lip, absent on upper lip; tongue free; anterior nostril tubular placed laterally near tip of the snout, posterior nostril placed high on the head near the upper margin of eye with a slightly raised rim; gill-opening length larger than interbranchial, gill-opening length 17.4–21% HL; depth at gill opening more than depth at anus, 18.1–21.8% vs. 15.9–18.1% PAL; lateral-line pores conspicuous: prepectoral 8–9, predorsal 8–9 and preanal 30–31; vertebrae: predorsal 10, preanal 32 and total vertebrae 122; head pores conspicuous: SO 3, IO 5, POM 10 and ST 3; teeth small and conical, intermaxillary teeth in 2 transverse rows which is larger than maxillary and mandibular teeths; maxillary and mandibular teeth in irregular bands broader anteriorly with 4-5 teeths and narrower posteriorly with 1–2 teeths; vomer with elongated patch of teeth, broader anteriorly with 4–5 teeths and ends as a single teeth posteriorly and ends just behind the middle of anterior and posterior nostril; colour (in formaldehyde) is yellowish brown with pale ventral region, median fins pale with black margin and pale pectoral fin.

Distribution: This species is known only from Arabia Sea (present study [Figure 3.28B]).

Discussion: *Bathycongrus* sp. A appears similar to *B. macroporis* (Kotthaus, 1968) [originally described from southwest of Sokotra Island and recently reported from Taiwan by Smith & Ho (2018a)] in general appearance, condition and position of posterior nostril, cephalic pore counts and teeth pattern. However, it differs in certain morphometric characteristics from *B. macroporis*. *Bathycongrus* sp. A have more elongated head (53.9–56.8% vs. 42–42.9% PAL in *B. macroporis*), longer predorsal length (52.9–55.2% vs. 43.3–45.8% PAL in *B. macroporis*), more anterior origin of dorsal fin (dorsal-fin origin above pectoral fin vs. slightly behind in *B. macroporis*), shorter trunk (less than the head vs. longer than the head in *B. macroporis*, large gill opening (gill opening greater than interbranchial vs. gill opening less than interbranchial in *B. macroporis*). In addition *Bathycongrus* sp. A have more prepectoral pores (8–10 vs. 5), more predorsal pores (8–10 vs. 6–7) and lesser total vertebral counts (104^{+}–122 vs.117^{+}–126^{+}) compared to *B. macroporis*.

Remarks: *Bathycongrus* sp.A is a species new to science. Kotthaus (1968) placed his species (*B.macroporis*) in the genus *Pseudophichthys* Roule, 1915. Smith (1989j) and Castle (1995) have clearly mentioned that Kotthaus species does not belong to the *Pseudophichthys*. Based on the above discussed characters both *B.macroporis* and present species have more affinity towards *Bathycongrus* Ogilby, 1898. But some characters such as elevated position of posterior nostril near the upper margin of eye and absence of any enlarged teeth and broad as well as long vomerine teeth does not match the *Bathycongrus* genus. Smith & Ho (2018a) recently reported Kotthaus species (*Pseudophichthys macroporis*) from Taiwan and removed it from from *Psudophichthys* genus and placed provisionally in a more comfortable genus *Bathycongrus* and now the species is valid as *Bathycongrus macroporis* (Kotthaus, 1968). Detailed taxonomic and osteological studies by including similar species from all over the world may create a new genus for them in near future.

Table 3.8: Comparison of morphometric and meristic characters of *Bathycongrus* sp. A with congener

	Kotthaus 1968 ***B. macroporis***	**Present study (n=3)** ***Bathycongrus* sp. A**		
		Range	**Mean**	**SD**
Total length (mm)	220+	211-297		
% TL*				
Preanal length	39.5	35.5		
Predorsal length	19.1	19		
Head length	17.7	19.9		
Trunk length	19.5	15.6		
Depth at gill-opening	9.8	6.4		
Depth at anus	_	5.7		
% PAL				
Predorsal length	48.0	52.9-55.2	53.8	1.2
Head length	45.0	53.9-56.8	55.6	1.5
Trunk length	48.0	43.2-46.1	44.4	1.5
Depth at gill-opening	24.7	18.1-21.8	19.8	1.9
% HL				
Snout length	22.6	21.5-23.7	22.3	1.1
Eye diameter	16.7	10.8-14.2	12.6	1.7
Interorbital width	14.1	10.4-12.5	11.4	1.0
Upper- jaw length	32.1	29.9-32.1	30.6	1.1
Lower- jaw length	_	24.5-28.8	26.7	2.0
Gill-opening length	_	17.4-21	19.1	1.7
Interbranchial width	_	14.5-17.8	16.6	1.8
Pectoral-fin length	33.3	27-29.1	28.1	1.0
Pectoral-fin base length	_	5.8-7	6.1	0.7
Meristics				
Lateral-line pores				
Prepectoral	_	8-9		
Predorsal	_	8-9		
Preanal	_	30-31		
Head pores				
Supraorbital	_	3		
Infraorbital	_	5		
Preoperculomandubular	_	10		
Supratemporal	_	3		
Vertebrae				
Predorsal	_	10		
Preanal	_	32		
Total	_	122		

* %TL measurement is taken only for intact specimen (211mm) in the present study.

Bathycongrus sp. B (New species)
Fig. 3.13, Table 3.9
Deep sea conger eel

Collection locations: AS: 09°53.600’N, 75°31.907’E, 975 m, 08.08.2010, (Cr.278, St.02), HSDT-CV; 08°28·550’N, 76°20.710’E, 1060 m, 19.08.2012, (Cr.305, St.01), HSDT-CV; 07°47·482’N, 76°27.317’E, 1338 m, 15.07.2013, (Cr.316, St.02), HSDT-CV; 08°00·845’N, 76°25.914’E, 1152 m, 10.12.2013, (Cr.321, St.16), HSDT-CV; 08°25·107’N, 75°55.184’E, 1244 m, 11.12.2013, (Cr.321, St.18), HSDT-CV; 08°31·775’N, 75°59.743’E, 1045 m, 12.12.2013, (Cr.321, St.20), HSDT-CV; 11°04·195’N, 74°55.430’E, 1000 m, 08.01.2014, (Cr.322, St.02), HSDT-CV; 11°58·355’N, 74°16.791’E, 1000 m, 09.01.2014, (Cr.322, St.04), HSDT-CV; 08°05·718’N, 76°25.842’E, 1000 m, 12.01.2014, (Cr.322, St.09), HSDT-CV; 08°29·994’N, 78°35.583’E, 1000 m, 15.01.2014, (Cr.322, St.13), HSDT-CV

Voucher specimen No.: 3212013 (CMLRE)

Diagnosis: Body elongate, tip of the tail tapering and filiform; dorsal-fin origin slightly behind the base of pectoral fin, predorsal 44.6–47.3% PAL; head length 40.2–44.6% PAL; trunk length 1.2-1.5 times HL; lateral-line pores: predorsal 8–9, preanal 32–35; vomer with 2 enlarged teeth.

Description: Body moderately elongated, cylindrical anteriorly and laterally compressed posteriorly with attenuated tail; dorsal and anal fins well developed and continuous with caudal fin; dorsal-fin origin slightly behind the base of pectoral fin approximately near its middle; pre-dorsal length 44.6–47.3% PAL; anal fin positioned just after the anus, preanal length 36.8–37.5% TL; pectoral fin well developed, its length 23.4–24.2% HL; head conical in shape, head length 40.2–44.6% PAL; snout moderate bluntly pointed, snout length 25.2–27.2% HL; eye moderate, oval in shape, its horizontal diameter is 13.7–14.3% HL; anterior nostril tubular positioned laterally near tip of the snout, posterior nostril an oval slit in front of eye at midlevel; flange present on lower lip, absent on upper lip; upper jaw slightly overhangs the lower jaw; mouth moderately elongated rictus ends at midlevel of eye; gill opening large, its anterior margin at level with the lower margin of pectoral fin base, gill-opening length 12.7–17.1% HL; maximum depth at gill opening 6% TL; lateral-line pores large and conspicuous: prepectoral 6, predorsal 8–9 and preanal 32–35; Vertebrae not discernible; head pores conspicuous: SO 3, IO 5, POM 10, ST 1; teeth sharp and conical and slightly recurved, intermaxillary teeth in 3 rows fully exposed when mouth closed and separated from other teeths with an edentulous groove; vomer is of elongated oval patch with 2 large teeth in middle surrounded by 6–8 small teeth on both sides, which ends before the posterior nostril. Maxillary and mandibular teeth small, in 4 irregular rows with outer teeth larger than the inner ones and also reducing the size towards posteriorly; colour (in formaldehyde) dark brown body with slightly lighter ventral side, pectoral fin brown, median fins ends with dark rim near caudal region.

Distribution: known only from Arabian Sea (present study [Figure 3.28B]).

Discussion: *Bathycongrus* sp. B with congeners having 2 enlarged teeth on the vomer surrounded by small teeths, includes 9 species (*B. albimarginatus* Huang, Smith, Chang & Chen, 2018; *B. guttulatus* (Günther, 18887); *B. longicavis* Karmovskaya, 2009; *B. macrocercus* (Alcock, 1894b); *B. nasicus* (Alcock, 1894a), *B. odontostomus* (Fowler, 1934); *B. parapolyporus*

Karmovskaya, 2009, *B. retrotinctus* (Jordan & Synder, 1901) and *B. wallacei* (Castle, 1968b). *Bathycogrus* sp. B can be differentiated from Indo-West Pacific species *B. wallacei* and South Pacific species *B. longicavis* in having less preanal lateral-line pores (32–35 vs. 38–43 and 46), longer head (15.3–16.4 vs. 12.6–14.4 and 12.9% TL) and longer predorsal (16.7–17.4 vs. 13.2–15.8 and 14.5% TL). Bathycongrus sp. B differs from recently described species from eastern Taiwan, *B. albimarginatus* and another Pacific Ocean species, *B. parapolyporus* in having less POM pores (10 vs.11) and less IO pores (5 vs. 8). *Bathycongrus* sp. B differs from the Northern Indian Ocean spp. *B. nasicus* and *B. macrocercus* in more posterior orgin of dorsal fin (dorsal-fin origin approximately near the middle of pectoral fin vs. directly above to slightly anterior of pectoral fin base in *B. nasicus* and *B. macrocercus). Bathycongrus* sp. B can be distinguished from Indo-west Pacific species *B. odontostomus* in the shape of the vomer (elongate oval vs. round) and in the colouration of oral and branchial cavity (not dark vs. dark) in *B. odontostomus*. Present new species also differs from another Indo-West pacific species *B. retrotinctus* in having shorter preanal length (36.8–37.5 vs. 37.9–41% TL), upper jaw (36–39 vs. 38–43% HL), interorbital width (10.7–12.5 vs. 14.3–20.4% HL) and pectoral fin length (23.4–24.2 vs. 25.9–35.5). *Bathycongrus* sp. B is more similar to Indo-West Pacific species, *B. guttulatus* in most of the body proportions and pore pattern (head and lateral line) but differs in shorter trunk, its length 1.2–1.5 vs.1.6–1.9 times in head length, longer head (40.2–44.6 vs. 34.4–42.8% PAL and more predorsal lateral-line pores (8–9 vs. 6–8).

Remarks: New to science previously misidentified as *B. guttulatus* due to their close affinity in body proportions.

Table 3.9: Comparison of morphometric and meristic characters of *Bathycongrus* sp. B (New species) with congeners.

	Huang et al. 2018	**Smith & Ho 2018a**			**Karmovskaya 2009**					**Castle 1995**	**Present study**
	***B.albimarginatus* (n=17)**	***B. guttulatus* (n=7)**	***B. wallacei* (n=36)**	***B. retrotinctus* (n=16)**	***B. longicavus* (n=1)**	***B. parapolyporus* (n=3)**	***B.odontostomus* (n=23)**	***B.macrocercus* (n=5)**	***B.guttulatus* (n=41)**	***B.nasicus* (n=5)**	**Bathycongrus sp. B (n=2)**
Total length (mm)	379-651+	231-470	231+-523+	225-403	386	198-348	218-520	123-157	185-430	163-255	500-544
Trunk/HL		1.6-1.9	1.5-1.7	1.3-1.6							1.2-1.5
% TL											
Head length	10.9-13.1	13.2-14.6	12.6-14.4	15.7-18.6	12.9	14.6-15.1	13.8-15.6	15.8-17	13.5-16.1	-	15.3-16.4
Preanal length	37.5-40.3	37-39	34-36.6	37.9-41	37.6	34.3-35.1	34.1-40.2	34.1-40.6	35.3-37.3	-	36.8-37.5
Predorsal length	14.7-16.4	14-16.2	13.2-15.8	16.1-18.1	14.5	15.9-16.2	13.3-17.4	15.5-16.5	13.8-17.4	-	16.7-17.4
Trunk length	25.9-27.9	23.6-25.3	20.7-23	21.7-24.6	24.6	19.6-20				-	20.4-22.2
Tail length	59.7-62.8	61-63	63.4-66	59-62.1						-	62.5-63.2
% PAL											
Head length	27.9-33.5	34.4-38	36.4-40.3	39.1-44.1	34.5	40.4-43	36.4-43	43.2-48.3	35.6-42.8	53.1-55.8	40.2-44.6
Predorsal length	36.6-41.7	37.7-41.6	37.7-44	40.8-46.1	38.6	45.2-47.1	39.2-48.1	42.1-46.7	39.7-46.3	48.1-52.4	44.6-47.3
Head depth		10.7-14.3	12.3-16.2	13.5-16.9							
Head width		8.9-11.1	9.7-13.5	12-14.4							

% HL											
Snout length	24.5-29.1	25.1-30.9	27.5-31.9	25.3-29.4	31	24.7-27.9	26.1-33.8	24.5-26.5	27.5-33.6	-	25.2-27.2
Eye diameter	13.1-17.8	12.1-18.7	14.6-18.8	12.6-17.1	16	13.8-14.8	14-18	14.5-17.5	12.5-19.7	-	13.7-14.3
Interorbital width	21.1-25.9	10.1-14.4	14.7-19.4	14.3-20.4	14	6.5-9.9	5.8-10.9	5.1-7.5	6.4-11.1	-	10.7-12.5
Upper-jaw length	38.9-42.1	36.4-44.2	41.2-47	38-44.3	45	33.9-36.3	38.1-40.2	31.3-35.9	36.1-42.6	-	36.3-39
Gill-opening length	13.1-18.1	8.9-14.5	10.8-16.6	10.9-15.9	13	11.6-19.6	10.6-15.8	10-19.3	10.1-17.5	-	12.7-17.1
Interbranchial width	26.2-30.9	12.9-19.9	14.1-22.8	14.6-24.5	21	15.5-23.8	17.1-28.7	12.5-15.7	15.2-20.7	-	13.6-16.3
Pectoral-fin length	31-38.4	22.8-28.7	25.2-31.9	25.9-35.5	36	23.2-26.7	21.7-32.8	20.5-28.6	24.6-36.9	-	23.4-24.2
Meristics											
Lateral-line pores											
Prepectoral	5-6	3-6	5-7	4-6		5-6	5-6			-	6
Predorsal	11-13	6-8	6-9	4-7		8-9	7-8	8-9	7-8	-	8-9
Preanal	48-53	32-36	38-43	30-35	46	31-33	35-42	37-39	35-41	29-32	32-35
Head pores											
SO pores	9	3	3	3	3	5-6	3	3	3	-	3
IO pores	8	5	5	5	5	7-8	5	5	5	-	5
POM	11	10-11	10	10	10	11	10	10	10	-	10
ST pores	5	1	1	1	1	1	1	1	1	-	1
Vertebrae											
Predorsal	14	9-11	9-11	8-10	9	9-10	9-10	8-9	7-10	9-10	-
preanal	50-52	35-41	38-44	35-38	47	33-35	35-42	38-40	36-41	30-33	-
Precaudal	68-70	45-52	53-57	42-48	67	41-42	45-54	46-47	48-53	43-47	-
Total	196-201	156-163	169-181	143-151	167+	158-160	164-177	149+-162	154+-169	149-152	-

Bathycongrus trimaculatus **Karmovskaya & Smith, 2008**
Fig. 3.14, Table 3.10

Holotype: MNHN 2002-3924, male, 155 mm TL, Solomon Island, station CP 1747, 9°21'S, 159°58'E, 364–402 m, beam trawl

Paratypes: New Caledonia : MNHN 1995-0398 (2),112 & 119 mm TL, 470–480 m; MNHN 1995-0415 (3), 118–143 mm TL, 435–460 m ; MNHN 2000-1105 (1), 131 mm TL, 495–550 m; MNHN 2000-0925 (1), 161 mm TL, MNHN 2002-3735 (4), 112–153 mm TL, Fiji, 478–500 m; MHNH 2005-2589 (2), 65–95 mm TL, 357–359 m; MNHN 2007-0237 (2), 116–140 mm TL, Solomon Island, 364–402 m.

Collection locations: AN: 13°06·78'N, 93°01.14'E, 411 m, 11.04.2016, (Cr.349, St.08), HSDT-CV

Voucher specimen No.: 3490801 (CMLRE)

Diagnosis: Predorsal 18.9% TL; two large black spots on anterior half of dorsal fin and one large spot on anal fin almost opposite at the level of posterior spot on dorsal fin; tail attenuate; teeth small, conical in 4–5 rows on jaws, vomerine teeth in short oval patch; interemaxillary teeth exposed when mouth is closed; lateral-line pores: predorsal 6, preanal 26; total vertebrae 118.

Description: Body moderately elongated, cylindrical anteriorly and compressed posteriorly with moderately attenuated tail, not filiform; dorsal and anal fins well developed and continuous with caudal fin; pectoral fin well developed, pectoral-fin length 36.1% HL; dorsal-fin origin slightly behind the pectoral-fin base, predorsal length 18.9% TL; anal fin begins immediately behind anus; anus located anterior to mid-body, preanal length

35.8% TL; head moderate, head length 17.9% TL; snout slightly greater than the eye diameter, projects well beyond the anterior end of intermaxillary teeth; fleshy part of snout with slight median keel on lower side, snout length 25.6% HL; tongue free; upper jaw slightly overhangs the lower jaw; flange reduced on upper jaw, lower jaw with a down turned flange; mouth moderate and inferior, rictus ends at level below the anterior region of eye; eye large and oval in shape, its horizontal diameter 19.7% HL; anterior nostril tubular near tip of snot, posterior nostril elliptical with a raised rim and located in front of eye at mid-level; gill opening moderate and its anterior margin at mid-level of pectoral fin base, gill-opening length 12.5% HL; depth at gill opening greater than depth at anus, depth at gill opening 5.5% TL; lateral-line pores small but discernible: prepectoral 4, predorsal 6 and preanal 26; vertebrae predorsal 7; preanal 28 and total vertebrae 118; head pores conspicuous: SO 3; IO 5; POM 10, ST 1; teeth on jaws moderately large and conical; intermaxillary teeth in 2 transverse rows which is exposed when mouth closed; maxillary and mandibular teeth in bands with outer row of teeth larger than inner row; maxillary teeth with 5 rows anteriorly and 2 rows posteriorly; mandibular teeth with 4 rows anteriorly and 1 row posteriorly; vomerine teeth conical, longer than broad and reaches up to the level of posterior nostrils in 4 rows anteriorly and 1 row posteriorly. coloration (after preservation in formaldehyde) body uniform light brown with black pigmentation on top of snout, interorbital region and a dark patch on opercle before pectoral fin; Pectoral fin pale, dorsal and anal fins pale except two large black spots on anterior half of dorsal fin and one large spot on anal fin almost opposite at the level of posterior spot on dorsal fin.

Distribution: Indo West Pacific: New Caledonia, Fiji & Solomon Islands (Karmovkaya & Smith 2008; Karmovskaya 2011); Indian EEZ: Andaman Sea (Present study [Figure 3.28B]).

Remarks: *B. trimaculatus* is a new record from Indian Ocean

Table 3.10: Comparison of morphometric and meristic characters of *Bathycongrus trimaculatus* Karmovskaya & Smith, 2008 with previous study.

	Karmovskaya & Smith 2008 (n=16)	**Present study (n=1)**
Total length (mm)	65-161	201
% TL		
Preanal length	32.8-36.6	35.8
Predorsal length	17.2-19.6	18.9
Head length	14.7-16.4	17.9
Trunk length	17.2-20.9	17.9
Depth at gill-opening	5.2-6.8	5.5
Depth at anus	4.2-5.6	3.7
% HL		
Snout length	21.5-25.4	25.6
Eye diameter	19.4-23.8	19.7
Interorbital length	-	8.6
Upper-jaw length	31.6-35.7	34.7
Lower-jaw length	-	29.4
Gill-opening length	13.5-15.9	12.5
Interbranchial width	18.4-21.4	16.9
Pectoral-fin length	31.1-37.5	36.1
Pectoral-fin base length	-	7.2
Meristics		
Lateral-line pores		
Prepectoral	-	4
Predorsal	-	6
Preanal	26-29	26
Head pores		
Supraorbital	3	3
Infraorbital	5	5
Preoperculomandubular	10	10
Supratemporal	1	1
Vertebrae		
Predorsal	7-9	7
Preanal	28-30	28
Total	117-119	118

Genus *Bathyuroconger* Fowler, 1934

Type species: *Uroconger braueri* Weber & de Beufort, 1916 by (original designation) Sumatra, Indonasia & eastern Africa.

Diagnosis: Moderately elongated body with slender, attenuated and delicate tail; slimy and loosely attached skin; dorsal-fin origin above or slightly behind the pectoral-fin base; preanal length 33-42% TL; Jaws even or upper jaw slightly projecting; flanges absent on both jaws; anterior nostril as short tube near tip of the snout and posterior nostril as a round slit in front of eye at level of mid-eye; head large and robust; terminal mouth; intermaxillary and anterior mandibular teeth enlarged and fang like; gill opening variable from small circular opening to a moderate semicircular shape with upper corner touching base of pectoral fin; SO pores 3 (rarely 4), IO pores 5, POM 7 (rarely 6-8) + 3 and a single ST pore (Smith et al. 2018a).

This genus contains 6 valid species *B. vicinus* (Vaillant, 1888); *B. parvibranchialis* (Fowler, 1934) *B. albus* Smith, Ho & Tashiro 2018; *B. dolichosomus* Smith, Ho & Tashiro 2018; *B. fowleri* Smith, Ho & Tashiro 2018; *B. hawaiiensis* Smith, Ho & Tashiro 2018 (Fricke et al. 2018a). This genus was previously recognized by only 2 species (*B. vicinus* and *B. parvibranchilis*). Earlier there was one more species from Indian Ocean *B. braueri* which has been synonymysed with *B. vicinus* (Blache & Bauchot 1976; Smith 1989j). Among the 6 valid species 4 species were recently described by smith et al. (2018a) during their study on specimens from northwestern Pacific. Their study reveals that *B. vicinus* described from Atlantic which is usually recognized as a word wide species actually represents a complex of species. Hence further studies are required globally to clarify the exact diversity of this genus. In Indian water this genus is represented by a single species *B. vicinus*.

Bathyuroconger vicinus **(Vaillant, 1888)**

Fig. 3.15, Table 3.11

Large-toothed conger

Synonyms: *Uroconger braueri* Weber & de Beaufort, 1916; *Leptocephalus mediopunctatus* Castle, 1964b; *Uroconger vicinus* Vaillant, 1888

Holotype: MHNH: 1884-0436 (1); ***Syntypes:*** MNHN 1884-0433 (1), 1884-0434 (1), 1884-0437 (1), Coasts of Soudan, 932 m; Argnin Bank 1495 m, and Cape Verde Islands, 1633 m.

Collection locations: AS: 09°53·600'N, 75°31.907'E, 975 m, 08.08.2010, (Cr.278, St.02), HSDT-CV; 08°21·601'N, 76°10.171'E, 995 m, 12.10.2010, (Cr.281, 03), HSDT-CV; 10°06·020'N, 75°37.190'E, 400 m, 14.10.2010, (Cr.281, 09), HSDT-CV; 08°28·550'N, 76°20.710'E, 1060 m, 19.08.2012, (Cr.305, St.01), HSDT-CV; 11°98·490'N, 74°42.770'E, 210 m, 20.08.2012, (Cr.305, St.04), HSDT-CV; 12°20·743'N, 74°.19.010'E, 909 m, 22.08.2012, (Cr.305, St.06), HSDT-CV; 08°17·199'N, 76°12.341'E, 1055 m, 14.07.2013, (Cr.316, St.01), HSDT-CV; 07°47·482'N, 76°27.317'E, 1338 m, 15.07.2013, (Cr.316, St.02), HSDT-CV; 08°24·837'N, 75°53.151'E, 1241 m, 17.07.2013, (Cr.316, St.09), HSDT-CV; 12°28·170'N, 74°09.142'E, 445 m, 24.08.2013, (Cr.318, St.01), EXPO;12°06·221'N, 74°19.145', 320 m, 26.08.2013, (Cr.318, St.10), EXPO; 11°17·481'N, 74°52.701'E, 249 m, 28.08.2013, (Cr.318, St.18), EXPO; 07°53·232'N, 76°25.780'E, 1258 m, 09.09.2013, (Cr.319, St.08), EXPO; 08°00·845’N, 76°25.914’E, 1152 m, 10.12.2013, (Cr.321, St.16), HSDT-CV; 08°25·107’N, 75°55.184’E, 1244 m, 11.12.2013, (Cr.321, St.18), HSDT-CV; 08°31·775’N, 75°59.743’E, 1045 m, 12.12.2013, (Cr.321, St.St.20), HSDT-CV; 11°04·195’N, 74°.55.430’E, 1000 m, 08.01.2014, (Cr.322, St.02), HSDT-CV; 11°58·355’N, 74°16.791’E, 1000 m, 09.01.2014, (Cr.322, St.04), HSDT-CV; 08°53·593’N, 75°27.288’E, 1000 m, 11.01.2014, (Cr.322, St.08), HSDT-CV; 08°05·718’N, 76°25.842’E, 1000m, 12.01.2014, (Cr.322, St.09), HSDT-CV; 08°29·994’N, 78°35.583’E, 1000 m, 15.01.2014, (Cr.322, St.13), HSDT-CV; 08°29·180’N, 76°01.372’E, 1080 m, 25.07.2014, (Cr.327, St.01), HSDT-CV; 07°51·476’N, 76°24.880’E, 1345 m, 26.07.2014, (Cr.327, St.02), HSDT-CV; 09°17·958’N, 75°39.942’E, 392 m, 02.11.2014, (Cr.331, St.01), HSDT-CV; 08°29·844’N, 76°01.289’E, 1024 m, 03.11.2014, (Cr.331, St.02), HSDT-CV; 08°21·335’N, 76°08.562’E, 1055 m, 20.10.2017, (Cr.366, St.01), HSDT-CV; 08°21.520’N, 76°14.101’E, 942 m, 20.10.2017, (Cr.366, St.03), HSDT-CV

BoB: 10°57·946’N, 80°20.203 E’, 645 m, 26.08.2010, (Cr.279, St.01), HSDT-CV; 11°07·660’N, 80°11.840’E, 540 m, 27.08.2010, (Cr.279, St.05), HSDT-CV; 07°31·460’N, 93°24.091’E, 567 m, 24.09.2010, (Cr.280, St.38), EXPO; 18°50·436’N, 85°23.119’E, 644 m, 29.10.2011, (Cr.291, St.03), EXPO; 11°54·788’N, 80°08.719’E, 645 m, 05.11.2011, (Cr.291, St.11), EXPO; 10°58·428’N, 80°19.779’E, 652 m, 06.11.2011, (Cr.291, St.13), EXPO; 10°38·440’N, 80°31.036’E, 654 m, 07.11.2011, (Cr.291, St.14), EXPO; 10°37·411’N, 80°31.460’E, 648 m, 07.11.2011, (Cr.291, St.15), EXPO; 10°55·950’N, 80°21.519’E, 650 m, 08.11.2011, (Cr.291, St.16), EXPO

AN: 11°08·930’N, 92°20.210’E, 526 m, 22.11.2011, (Cr.292, St.06), EXPO; 07°30·110’N, 93°24.911’E, 580 m, 11.12.2011, (Cr.292, St.89), HSDT-CV; 10°57·418’N, 80°28.114’E, 1131 m, 31.07.2014, (Cr.327, St.04), HSDT-CV; 11°17·465’N, 92°47.886’E, 907 m, 16.01.2015, (Cr.334, St.12), HOT; 07°28·734’N, 93°24.510’E, 650 m, 04.04.2016, (Cr.349, St.02), HSDT-CV; 13°15.902’N, 93°15.827’E, 635 m, 26.11.2017, (Cr.367, St.08), HSDT-CV; 11°47.889’N, 92°05.437’E, 646 m, 28.11.2017, (Cr.367, St.15), HSDT-CV

Voucher specimen No.: 3670807 (CMLRE)

Diagnosis: Delicate slimy and loosely attached skin; large head, head length 12.8–14.3% TL; dorsal-fin origin slightly behind pectoral-fin base, predorsal length 14.8–16.1% TL; preanal 33.5–39.1% TL; flanges absent on both upper and lower lips; teeth strong and fang like; jaws almost equal; adnasal pore absent.

Description: Body moderately elongated, cylindrical anteriorly and laterally compressed posteriorly; tail attenuated; dorsal and anal fins well developed and continuous with caudal fin; dorsa-fin origin slightly behind pectoral-fin base, predorsal length 14.8–16.1% TL; pectoral fin well developed, its length 23.3–39.8% HL; anal fin originates immediately behind anus; anus anterior to mid-body, preanal length 33.5–39.1% TL; head large, broad and massive, head length 12.8–14.3% TL; snout deep and moderately elongated, snout length 24–31% HL; fleshy part of snout does not extend beyond the tip of intermaxillary teeth; tongue free; upper jaw and lower jaw almost equal devoid of flanges; mouth moderately large and terminal, rictus ends almost below the level of posterior margin of eye; eye moderately large and circular, its horizontal diameter is 12.6–17.7% HL; anterior nostril tubular located laterally near tip of snout, posterior nostril a large pore with slightly elevated anterior margin located in front of the eye slightly below its upper edge; gill opening small, less than interbranchial; gill-opening length 11.2–21.1% TL; maximum depth slightly behind the gill opening; depth at gill opening 5–7.4% TL; depth at anus 2.9–6.2% TL; lateral-line pores conspicous: prepectoral 6–7, predorsal 8–9, and preanal 43–44; vertebrae: predorsa l9, preanl 45 and total vertebrae 184; cephalic pores large and conspicuous: SO 3; IO 5; POM 10 and ST pores 1; teeth fang like in 3 rows anteriorly and 1 row posteriorly in both jaws, outer teeths more prominent; intermaxillary teeth large and arranged in 2 transverse rows separated by a gap from vomerine and maxillary teeth; mandible symphysis also have similar large sized teeth with points directed backward; vomer with 1–2 large greatly enlarged teeth in centre and 2–3 smaller teeth in front, behind and at side of them; maxillary teeth in narrow bands, narrower posteriorly, outer teeth largest; mandibular teeth in 2–3 rows irregular rows with anterior teeth greatly enlarged; colour when fresh light grey all over the body, median fins edged in black posteriorly and pectoral fin pale; smaller specimens with irregular series of black pigmented dots above and below the lateral line with another series in the middle and a bluish black tinge on opercular region.

Distribution: Circumglobal (Smith 1989j; Karmovskaya 2004; Ho et al. 2015b); Smith et al. (2018a) doubt the global distribution of B. vicinus.

Indian EEZ: Arabian Sea (Alcock 1896; Jayaprakash et al. 2006; Venu 2009; Hashim 2012; Sudhakar et al. 2013; Present study [Figure 3.28A]); Bay of Bengal (Alcock 1892; Hashim 2012; present study[Figure 3.28A]).); Andaman Sea (present study [Figure 3.28A]).

Remarks: Widely distributrd in Indian EEZ; The Indian Ocean species was earlier known as *Uroconger braueri* Weber & de Befaurt, 1916 and later Blache & Bauchot 1976 reinstated the genus *Bathyuroconger* and synonymysed *B. braueri* with *B. vicinus*. Smith (1989j) follows this treatment by indicating the dissimilarity and overlap of characteristics. Indian specimens from AS, BoB & AN represent a single species with large sized gill opening in contact with pectoral fin base hence we provisionally considered it as *B. vicinus* following Smith (1989j), Karmovskaya (2004) and Smith et al. (2018a). Further genetic and taxonomic studies including specimens from world-wide can define the species properly. Even though the status of distribution of *B. vicnus* is world-wide, there are no published reports of this species from Andaman Sea. Present study reports this species from Andaman Sea of the Indian EEZ for the first time. Recent study by Smith et al. (2018a) noted that by considering its wide distribution in the world Oceans *B. vicinus* represents a complex of species. Further studies including genetic and taxonomic details are necessary to clarify the Indian Ocean specimens. Tentatively we consider present species as *B. vicinus*.

Table 3.11: Comparison of morphometric and meristic characters of *Bathyuroconger vicinus* (Vaillant, 1888) with previous study.

	Karmovskaya 2004 (n=40)	Present study (n=8)		
		Range	Mean	SD
Total length (mm)	215-995	257-705		
% TL				
Preanal length	33.3-40.0	33.5-39.1	36	1.9
Predorsal length	10.6-16.9	14.8-16.1	15.7	0.8
Head length	11.2-14.3	12.8-14.3	13.6	0.5
Trunk length	20.7-26.0	20.8-25	22.3	1.4
Depth at gill-opening	_	5-7.4	6.4	0.9
Depth at anus	_	2.9-6.2	4.9	1.1
% HL				
Snout length	19.3-31.7	24.0-31	27.6	2.8
Eye diameter	8.9-17.8	12.6-17.7	15.2	1.5
Interorbital width	9.1-21.4	15.9-20.9	18.8	1.6
Upper-jaw length	_	38.5-42.8	41	1.7
Lower-jaw length	_	36.7-41.4	39.2	1.6
Gill-opening length	11.2-35.0	11.2-21.1	16.1	3.2
Interbranchial width	12.2-47.6	19.5-31.9	26.1	4.5
Pectoral-fin length	20.6-45.8	23.3-39.8	32.6	6
Pectoral-fin base length	_	5.5-9.6	6.9	1.4
% PAL				
Predorsal length	30.9-45	40.1-45	43.6	1.6
Head length	28.8-39.0	37.7-38.9	38.3	0.5
Trunk length	61.4-71.3	61.6-62.5	62.2	0.7
Meristics				
Lateral-line pores				
Prepectoral	6-7	6-7		
Predorsal	7-11	8-9		
Preanal	41-49	43-44		
Head pores				
Supraorbital	3	3		
Infraorbital pores	5	5		
Preoperculomandubular	10	10		
Supratemporal	1	1		
Vertebrae				
Predorsal	_	9		
Preanal	_	45		
Total	142^{+}-205	184		

Genus *Congrhynchus* Fowler, 1934

Diagnosis: Same as given in species diagnosis.

Type species: *Congrhynchus talabonoides* Fowler, 1934 (monotypic), Philippines.

Congrhynchus talabonoides Fowler, 1934

Fig. 3.16, Table 3.12

Holotype: USNM 92350 (288 mm TL) northern Mindanao Island, Philippines, 8°37'37"N, 124°35'E, Albatross station 5502, 391 m; ***Paratypes:*** USNM 93347 (1, 300, immature female), Philippines, between Burias and Luzon, Anima Sola Island, 12°52’N, 123 23’30”E, 393 m, Albatross station 5216. USNM 93348 (1, 116), Philippines, Gulf of Davao, Dumalag Island (S.), 7°02’N, 125°38’45”E, 247 m, Albatross station 5247.

Collection locations: AN: 12°49·602’N, 93°12.782’E, 441 m, 17.09.2010, (Cr.280, St.16), EXPO; 12°44·580’N, 93°06.302’E, 332 m, 10.04.2016, (Cr.349, St.06), HSDT-CV; 13°06·78’N, 93°01.14’E, 411 m, 11.04.2016, (Cr.349, St.08), HSDT-CV; 12°29·719’N, 93°10.732’E, 314 m, 25.11.2017, (Cr.367, St.05), HSDT-CV

Voucher specimen No.: 3670535.(CMLRE)

Diagnosis: Moderately elongate body with slender and filiform caudal end; dorsal fin originates above the pectoral fin; pectoral fin small but well developed; snout slender and elongate, extending beyond tip of lower jaw; upper labial flange absent; posterior nostril a slit at mid-eye level; Teeth sharp, multiserial bands on jaws, exposed when mouth closed; vomerine teeth in a short, narrow patch, some enlarged; Predorsal vertebrae 7–8, preanal 37-40, total 131^{+}–160^{+}; No pores between or behind eyes; one supratemporal pore.

Distribution: Taiwan, Philippines, India (Andaman Sea [Figure 3.28A]) (Fowler 1934; Smith et al. 2018c).

Description: Body moderately elongated cylindrical anteriorly before anus and compressed posteriorly in tail region. Tip of the tail slender and filiform, mostly regenerated; dorsal and anal fins continuous with caudal fin; dorsal-fin origin slightly before to just above the pectoral-fin base; predorsal length 40.4–47.5% PAL; anal fin commences immediately behind anus; anus placed before mid-body, preanal length 36.2–39.7% TL; pectoral fin long pointed, with narrow base, pectoral-fin length 14.9–22.4% HL; Snout pointed, triangular in dorsal view and projects beyond the lower jaw, snout length 28.5–32.3% HL; fleshy part of the snout narrow extends beyond the intermaxillary tooth patch; tongue mostly connected to the floor of mouth, upper jaw overhangs the lower jaw; lips without flange; rictus slightly behind the posterior margin of eye; eye moderate and oval in shape, its horizontal diameter 11–14% HL; anterior nostril tubular located laterally near tip of the snot, posterior nostril an oval slit, with slightly raised rim located before eye at mid-level; gill opening large its height almost same as eye diameter, gill height 5.9–15.5% HL; maximum depth at gill opening 8.9–13.8% PAL; lateral-line pores conspicuous: prepectoral 7–8, predorsal 7 and preanal 34–38; head pores large and conspicuous: SO 3, IO 5, POM 10; ST 1; vertebrae: predorsal 7–8, preanal 37–40 and total vertebrae 131^{+}–160^{+}; colour when fresh is light brown body with posterior of dorsal and anal fins black and pectoral fin pale.

Remarks: New record from Indian Ocean.

Table 3.12: Morphometric and meristic characters of *Congrhynchus talabonoides* Fowler, 1934 including specimens from Taiwan and Philippines.

	present study (n=8)		
	Range	**Mean**	**SD**
Total length (mm)	116-417		
% of TL			
Preanal length	36.2-39.7	37.6	1.2
Predorsal length	15.3-18.1	16.5	0.9
Head length	15.3–18.7	16.9	1.2
% PAL			
Predorsal length	40.4–47.5	43.9	2.5
Head length	41.1–49.2	45.1	3.1
Trunk length	50.8–58.9	54.9	3.1
Depth at gill-opening	8.9–13.8	11.4	1.3
Depth at anus	10.3–14.8	12.4	1.7
% HL			
Snout length	28.5-32.3	30.1	1.4
Eye diameter	11.0-14.0	12.5	1.0
Interorbital width	6.6-7.7	7.2	0.4
Upper- jaw length	39.9-44.2	41.9	1.6
Lower- jaw length	34.1-36.4	35.1	1.0
Gill-opening length	5.9-15.5	11.7	2.9
Interbranchial width	7.2-12.4	11.1	1.7
Pectoral-fin length	14.9-22.4	19.7	2.4
Pectoral-fin base length	3.1-3.7	3.4	0.3
Meristic characters			
Lateral-line pores			
Prepectoral	8		
Predorsal	7		
Preanal	34-38		
Head pores			
Supraorbital	3		
Infraorbital	5		
Preoperculomandubular	10		
Supratemporal	1		
Vertebrae			
Predorsal	7–8		
Preanal	37–40		
Total	131^{+}–160^{+}		

“*Congromuraena*” (technically a synonym of Ariosoma Swainson, 1838)

“Congromuraena” musteliceps Alcock, 1894b

Fig. 3.17

Lectotype: ZSI 13698, Bay of Bengal, off Madras coast 13° 51′ 12″ N, 80° 28′ 12″ E, 265–457 m.

Diagnosis: Body moderately elongated, round in cross section anteriorly and compressed along the tail; dorsal-fin origin slightly before pectoral-fin base, predorsal 16.7–18.4% TL; head longer than trunk (18.7–20.1 vs. 14.6–15.7% TL); anus near anterior third of total length, preanal 33.3–35.7% TL; snout 22.1–22.4%, eye 8.6–8.8, gill opening 17.5–19.2 and interbranchial 11.7–12.3 % HL; head pores: SO 6, IO 8, POM 10 and ST 3 (Smith et al. 2017).

Description: Detailed description of this species is given by (Alcock 1894b; Castle 1995; Smith et al. 2017).

Remarks: This species was described by Alcock (1894b) based on 5 specimens from Bay of Bengal. He originally placed this species in the genus “Congromuraena” (alternative spelling of (*Congermuraena* Kaup, 1856b). Later Castle (1995) redescribed this species based on Alcock’s specimens and provisionally included them in the genus *Gnathophis* Kaup, 1859. For long time this species was known only from the Investigator collection from type locality, Bay of Bengal. Recently Smith et al. (2017) reported 2 additional specimens of this species from Oman waters. According to him it does not belong to the genus *Gnathophis* rather reminiscent to genus *Japonoconger* Asano, 1958. He also commented that this species may not fit to any of the valid genera of Congridae. Hence further study is needed to allocate proper genus to this species.

Genus *Gavialiceps* Alcock, 1889a

Type species: *Gavialiceps taeniola* Alcock, 1889a; Bay of Bengal & Andaman Sea.

Diagnosis: Elongate and laterally compressed body; anus positioned before mid-body; thread like tail; elongated and pointed head; gill opening at lateral side of head; dorsal-fin origin on a vertical of gill slit or just anterior or posterior to gill slit; pectoral fin absent; maxillary teeth series with an inner row separated by an outer row; median row of vomerine teeth enlarged; supraorbital pores are slit like (Karmovskaya 1994a; Lin et al. 2013; Lin & Ho 2018).

The genus *Gavialiceps* was thought to be monotypic earlier with a single species *G. taeniola*. Two species *G. arabicus* from western Indian Ocean and *G. taiwanensis* from Western Pacific was previously considered as junior synonyms of *G. teaeniola*. Karrer (1983) misidentified a species of genus *Gavialiceps* from Mozambique as *G. taenola*. Karmovskaya (1994a) done a systematic review of this genus with specimens from all over the world and identified Karrer's Mozambique specimen as a new species *G. bertelensi* and disovered another new species *G. javanicus* from Java Island and North Western Australia and also confirmed the validity of *G. arabicus and G. taiwanensis* and finally came out with 5 valid species, *G. arabicus*

(D'Ancona, 1928) from Western Indian Ocean; *G. bertelseni* Karmovskaya, 1994a from Southwestern Indian Ocean; *G. javanicus,* Karmovskaya 1994a & *G. taeniola* Alcock, 1889 from Indo-West Pacific and *G. taiwanensis* (Chen & Weng, 1967) from Western Pacific.

The position of the genus *Gavialiceps* was ambiguous; Smith (1989j) placed this genus in Congridae. Later Karmovskaya (1994a) placed the genus *Gavialiceps* under the family Muraenesocidae. Ho et al. (2015b) pointed out that the placement of this genus under family Muraenesocidae is provisional. Smith et al. (2017) again made a comment that genus *Gavialiceps* should be removed from Muraenesocidae, as it resembles *Xenomystax* of family Congridae in head morphology and dentition. Recently Lin & Ho (2018) followed Smith 1989j & Smith et al. 2017 and placed this genus under the family Congridae while redescribing the Taiwan species *G. taiwanensis*. Our molecular study also support the placement of *Gavialiceps* under the family Congridae.

Indian EEZ this genus was represented by a single species *G. taeniola* Alcock, 1889a. Present study reports *G. taeniola* as well as added a new species to this genus from India.

***Gavialiceps* sp. A (New species)**

Fig. 3.18, Table 3.13

Andaman pike conger

Collection locations: AN: 12°48·640’N, 93°05.055’E, 323 m, 17.09.2010, (Cr.280, St.15), EXPO; 12°49·602’N, 93°12.782’E, 441 m, 17.09.2010, (Cr.280, St.16), EXPO; 11°08·920’N, 92°19.650’E, 514 m, 19.09.2010, (Cr.280, St.17), EXPO; 07°31·460’N, 93°24.091’E, 567 m, 24.09.2010, (Cr.280, St.38), EXPO; 11°08·930’N, 92°20.210’E, 526 m, 22.11.2011, (Cr.292, St.06), EXPO; 07°30·110’N, 93°24.911’E, 580 m, 11.12.2011, (Cr.292, St.89), 08°21·621’N, 93°20.065’E, 574 m, 14.12.2011, (Cr.292, St.91), HSDT-CV; 08°23·352’N, 93°20.534’E, 622 m, 29.01.2015, (Cr.334, St.03), HOT; 07°30·260’N, 93°25.240’E, 553 m, 02.02.2015, (Cr.334, St.05), HOT; 11°04·7850’N, 92°21.909’E, 530 m, 15.01.2015, (Cr.334, St.11), HOT; 11°25·393’N, 92°48.177’E, 812 m, 16.01.2015, (Cr.334, St.13), HOT; 11°25·893’N, 92°20.210’E, 576 m, 04.04.2016, (Cr.349, St.01), HSDT-CV; 07°28·734’N, 93°24.510’E, 650 m, 04.04.2016, (Cr.349, St.02), HSDT-CV; 08°22·401’N, 93°20.363’E, 591 m, 05.04.2016, (Cr.349, St.03), HSDT-CV; 12°44·580 N’, 93°06.302’E, 332 m, 10.04.2016, (Cr.349, St.06), HSDT-CV; 11°10·95’N, 92°20.18’E, 520 m, 14.04.2016, (Cr.349, St.10), HSDT-CV; 08°20·073’N, 93°19.264’E, 695 m, 15.11.2017, (Cr.367, St.04), HSDT-CV; 13°15.902’N, 93°15.827’E, 635 m, 26.11.2017, (Cr.367, St.08), HSDT-CV; 11°47.889’N, 92°05.437’E, 646 m, 28.11.2017, (Cr.367, St.15), HSDT-CV

Voucher specimen No.: 3670803 (CMLRE)

Diagnosis: As % PAL: head length 31.3–34.5%; maximum body depth at anus 5.5–9.3%; predorsal 30.9–33.8%; AS % HL: snout 36.3–41.9; eye diameter; 6.2–8.6%; lateral-line pores: pregill 8–9; predorsal 8–9; preanal 47–48.

Description: Body elongated, laterally compressed with a thread like tail; dorsal and anal fins well developed and continuous with caudal fin; dorsal fin originates above the gill opening, predorsal 30.9–33.8% PAL; anal fin commences immediately behind anus; pectoral fin absent; anus positioned anterior to mid-body; head elongated and pointed, head length 31.3–34.5% PAL; snout elongated and slender, 36.3–41.9% HL; edge of the tongue free; upper jaw strongly overhangs the lower jaw; intermaxillary teeth fully exposed when mouth closed; mouth large, toothed portion of the maxillae extends beyond the posterior margin of eye; eyes spherical and slightly protrudes above the upper profile of head; anterior nostril tubular and placed in between posterior nostril and tip of the snout; posterior nostril elongated oval slit, located far forward on snout closer to posterior nostril than to eye; gill opening moderate and located almost ventrally with very less interbranchial space, gill-opening length 5.2-8.6% HL; maximum depth at anus 5.5–9.3% PAL; lateral-line pores conspicuous, elliptical in shape: pregill 8–9; predorsal 8–9; preanal 47–48; vertebrae: predorsal 10–11; preanal 49–50 and total vertebrae not discernible; head pores numerous, large slit like or oval: SO 6; IO 8; POM 14; ST 3; teeth conical, granular and slightly recurved and exposed when mouth closed; interemaxillary teeth somewhat large, in the form of oval patches followed by a notch into which a similarly enlarged teeth of mandibular symphisis fits; maxillary teeth are small and numerous in rows, the inner row of teeth is separated from the outer rows by a smooth toothless groove; mandibular teeth small and numerous arranged in rows; vomerine teeth in 3 rows, middle row is very larger than the outer rows;

colour (in formaldehyde) is almost uniform dark brown with a black head; dorsal and anal fins greyish; visceral peritoneum with black pigmentation.

Discussion: *Gavialiceps* sp. A can be differentiated from *G. bertelseni* and *G. javanicus* by having longer head (31.3–34.5% vs. 23.4–28.30% PAL), longer predorsal length (30.9–33.8 vs. 25.7–28.6% PAL), relatively short trunk (65.5–68.7 vs. 70.6–73.6% PAL) and in having more number of preanal pores (48–56 vs. 47–48). It differs from *G. taeniola* by its shorter predorsal length (30.9–33.8% vs. 34.1–38.3% PAL), relatively more interbranchial width (1.7–1.9 vs. 2.7–4.9% HL), more preanal lateral-line pores (47–48 vs.40–43} and less pregill lateral-line pores (7–8 vs.10–12}. *Gavialiceps* sp. A can be separated from another species *G. taiwanensis* in having longer head (30.9–33.8% vs. 26.7–33.3% PAL], shorter trunk (65.5–68.7% vs.66.6–71.1% PAL), smaller eye (6.2–8.6% vs.10–10.4% HL} and also in more number of pregill lateral-line pores (8–9 vs. 6). *Gavialiceps* sp. A is similar to Western Indian Ocean congener, *G. arabicus* in most of the general body proportions and head pore counts; present species is having similar number of predorsal lateral-line pores and pre-gill lateral-line pores (8–9 vs. 7–9) and (8–9 vs.8–10) respectively. *Gavialiceps* sp. A can be separated from *G. arabicus* by its slightly longer trunk (65.5–68.7% vs. 64.4–66.9% PAL), relatively longer snout (36.3–41.95% vs. 35.4–39.7% HL) and more interbranchial width (2.7–4.9 vs. 2.1–3.6.

Distribution: Known only from the Andaman Sea through the present study [Figure 3.28C].

Remarks: New to science

Table 3.13: Comparison of morphometric and meristic characters of ***Gavialiceps* sp. A** (New species) with congeners .

						Present study (n=12)		
	***G. taeniola* (n=10)**	***G. arabicus* (n=12)**	**Karmovskaya 1994a *G. taiwanensis* (n=2)**	***G. bertelseni* (n=5)**	***G.javanicus* (n=5)**	**Range**	**Mean**	**SD**
Total length (mm)	290-647	150-840	190-700+	655-840	435-890	490-829		
Preanal length (mm)						148-275		
% PAL								
Predorsal length	34.1-38.3	29.6-36.9	26.7-33.3	25.7-27.6	26.7-28.6	30.9-33.8	32.4	1.1
Head length	38.9-42.1	32.3-35.5	28.9-30	23.4-28.3	26.4-27.3	31.3-34.5	32.8	1.2
Trunk length	57.9-61	64.4-66.9	66.6-71.1	71.4-73.3	70.6-73.6	65.5-68.7	67.2	1.2
Depth at gill-opening	_	_	_	_	_	4.3-6.7	5.6	0.8
Depth at anus	5.2-9.4	5-9.6	8.3-12.9	8.8-12.2	6.9-9.8	5.5-9.3	7.1	1.4
% HL								
Snout length	33.3-38.3	35.4-39.7	40-43.3	43.2-46.4	38.9-41.4	36.3-41.9	39.4	1.7
Eye diameter	4.6-7.2	5.7-9.2	10-10.4	7.6-9	7.1-9.8	6.2-8.6	7.6	0.7
Interorbital width	_	_	_	_	_	3-6.8	5.2	1.3
Upper-jaw length	_	_	_	_	_	47.5-52.7	50.7	1.7
Lower-jaw length	_	_	_	_	_	43.8-48.6	46.5	1.8
Gill-opening length	_	_	_	_	_	5.2-8.6	6.7	1.3
Interbranchial width	1.7-1.9	2.1-3.6	4.3-7	4.3-7	2.2-4.1	2.7-4.9	3.7	0.7
Meristics								
Lateral-line pores								
pregill	10-12	8-10	6	7-9	7-9	8-9		
predorsal	7-8	7-9	_	_	7-8	8-9		
Preanal	40-43	43-49	44-48	54-56	48-52	47-48		
Head pores								
Supraorbital	6	_	_	_	_	6		
Infraorbital	8	_	_	_	_	8		
Preoperculomandubular	14-15	13-14	_	13-15	15	14		
Supratemporal	3	_	_	_	_	3		
Vertebrae								
Predorsal	_	_	_	_	_	10-11		
Preanal	_	_	_	_	_	49-50		
Total	208-215	220-231	188+-210	182+	155+-210+	_		

Gavialiceps taeniola Alcock, 1889a

Fig. 3.19, Table 3.14

Synonyms: *Nettastoma taeniola* Alcock, 1891; *Saurenchelys taeniola* Alcock, 1899

Holotype: unknown; ***Syntypes:*** BMNH 1892.6.17.8 (1) Bay of Bengal, 1892.6.17.9 [ex ZSI F11311] (1) Bay of Bengal; ZSI 11312-3 (2, poor condition), 12467 (1, not found).

Collection locations: AS: 12°28·170’N, 74°09.142’E, 445 m, 24.08.2013, (Cr.318, St.01), EXPO; 08°31·775’N, 75°59.743’E, 1045 m, 12.12.2013, (Cr.321, St.20), HSDT-CV; 08°05·718’N, 76°25.842’E, 1000 m, 12.01.2014, (Cr.322, St.09), HSDT-CV

BoB: 11°54·788’N, 80°08.719’E, 645 m, 05.11.2011, (Cr.291, St.11), EXPO; 10°58·428’N, 80°19.779’E, 652 m, 06.11.2011, (Cr.291, St.13), EXPO; 10°38·440’N, 80°31.036’E, 654 m, 07.11.2011, (Cr.291, St.14), EXPO; 10°37·411’N, 80°31.460’E, 648 m, 07.11.2011, (Cr.291, St.15), EXPO; 10°55·957’N, 80°21.519’E, 650 m, 08.11.2011, (Cr.291, St.16), EXPO; 11°54·696’N, 80°08.649’E, 653 m, 09.11.2011, (Cr.291, St.17), EXPO; 16°52·178’N, 83°08.179’E, 1001 m, 7.08.2014, (Cr.327, St.11), EXPO

Voucher specimen No.: 3220912 (CMLRE)

Diagnosis: As % PAL: head length 38–44.7%; greatest body depth 7.1–9.4%; predorsal 33.8–36%; AS % HL: snout 32.8–37.9%; Eye diameter 5.2–7.2%; lateral-line pores: pregill 10–12; predorsal 7–8; preanal 40–42 and total vertebrae 213.

Description: Body elongated, laterally compressed with a thread like tail; dorsal and anal fins well developed and continuous with caudal fin; dorsal-fin origin slightly before gill opening, predorsal 33.8–36% PAL; anal fin commences immediately behind anus; pectoral fin absent; anus placed anterior to mid-body; head elongated and pointed, 38–44.7% PAL; snout elongated and slender 32.8–37.9% HL; edge of the tongue free; upper jaw strongly overhangs the lower jaw; intermaxillary teeth fully exposed when mouth closed; mouth large toothed portion of the maxillae extends beyond the posterior margin of eye; eye spherical and slightly protrudes above the upper profile of head, its horizontal diameter 5.2–7.2% HL; anterior nostril tubular and placed in between posterior nostril and tip of the snout, posterior nostril an elongated oval slit, located far forward on snout closer to posterior nostril than to eye; gill opening moderate and located almost ventrally with a very less interbranchial width, gill-opening length 8.5–10.9% HL; maximum depth at anus 7.1–9.4% PAL; lateral-line pores conspicuous, elliptical in shape and disappears at posterior end of tail; lateral-line pores: predorsal 7–8, pregill 10–12 and preanal 40–42; vertebrae predorsal 10, preanal 43 and total vertebrae 213; head pores numerous large and slit like: SO 6, POM 14–15, IO 8 and ST 3; teeth conical, granular and slightly recurved and exposed when mouth closed; intermaxillary teeth somewhat large in form of oval patches followed by a notch into which similarly enlarged teeth of mandibular symphysis fits; maxillary teeth are small and numerous in rows, the inner row of teeth is separated from the outer rows by a smooth toothless groove; mandibular teeth small and arranged in numerous rows; vomerine teeth in 3 rows, middle row is very larger than the outer rows; colour in formaldehyde is almost uniform dark brown with a black head, dorsal and anal fins greyish and visceral peritoneum with black pigmentation.

Distribution: Northern Indian Ocean: Oman, Pakistan, Myanmar (Alcock 1889a; Norman 1939; Moazzam & Osmani 2015; Psomadaksis et al. 2015)

Indian EEZ: Arabian Sea (Nair & Madhusoodanan 1982; Jayaprakash et al. 2006; Sajeevan et al. 2009; Venu 2009; Hashim 2012; Sudhakar et al. 2013; present study [Figure 3.28C]; Bay of Bengal (Alcock 1891; Alcock 1899; Hashim 2012; present study [Figure 3.28C]); Andaman Sea (Alcock 1889a; Alcock 1899; Rajan et al. 2013).

Table 3.14: Comparison of morphometric and meristic characters of *Gavialiceps taeniola* Alock, 1889 with previous study.

	Karmovskaya 1994a (n=6)	**Present Study (n=10)**		
		Range	**Mean**	**SD**
Total length (mm)	197-215	538-707		
Pre-anal length (mm)		200-234		
% PAL				
Predorsal length	34.1-38.3	33.8-36	34.7	0.6
Head length	38.9-42.1	38-44.7	41.2	1.3
Trunk length	57.9-61	57-62	58.8	1.3
Depth at gill-opening	-	6.6-8.3	7.4	0.5
Depth at anus	5.2-9.4	7.1-9.4	8.0	0.7
Depth at dorsal	-	5.3-7.5	6.5	0.8
% HL				
Snout length	33.3-38.3	32.8-37.9	34.2	1.6
Eye diameter	4.6-7.2	5.2-7.2	6.4	0.8
Interorbital width	-	4-8.2	6.2	1.4
Upper-jaw length	-	40.5-45.8	44.1	1.6
Lower-jaw length	-	38.8-43.7	41.2	1.4
Gill-opening length	-	8.5-10.9	9.8	0.9
Interbranchial width	1.7-1.9	1.6-1.9	1.7	0.1
Meristics				
Lateral-line pores				
Pregill	10-12	10-12		
Predorsal	7-8	7-8		
Preanal	40-43	40-42		
Head pores				
Supraorbital	6	6		
Infraorbital	8	8		
Preoperculomandubular	14-15	14-15		
Supratemporal	3	3		
Vertebrae				
Predorsal	-	10		
Preanal	-	43		
Total	208-215	213		

Genus *Gnathophis* Kaup, 1859

Type species: *Myrophis heterognathus* Bleeker, 1858 (by original designation), off Nagasaki.

***Diagnosis**:* Body moderately elongate with slightly stiffened blunt tail; presence of longitudinal keel on ventral side of snout; fleshy part of the snout projects well beyond the intermaxillary teeth; flange on upper lip narrow; anterior nostril tubular near tip of the snout, posterior nostril elliptical in front of eye at midlevel; cephalic pores small; adnasal pore absent; pores on upper jaw positioned on flange; intermaxillary teeth longer than broad; vomerine as elongate patch, maxillary and mandibular teeth in narrow bands (Smith 1989j).

Presently there are 27 valid species in this genus (Fricke et al. 2018a). During the redescription of Alcock's congrid eels, Castle (1995) provisionally placed a species from India (*Congromuraena musteliceps* Alcock, 1894a) in the genus *Gnathophis*. Recently Smith et al. (2017) reported same species from Oman and clearly pointed out the distinction of this species from *Gnathophis* and proposed for detailed study to determine the exact generic identity. Present study reports the genus for the first time from Indian EEZ as well as from the Northern Indian Ocean with 2 new species from deep-waters of Arabian Sea and Andaman Sea. Further surveys can add more species of *Gnathophis* to Indian EEZ.

Gnathophis sp. A (New species)

Fig. 3.20, Table 3.15

Collection locations: AS: 08°28·994'N, 78°35.583'E, 200 m, 15.01.2014, (Cr.322, St.12), HSDT-CV

Voucher specimen No.: 3221224 (CMLRE)

Diagnosis: Body robust and moderately elongated; head conical, head length 20.9% TL, snout pointed, with a fleshy keel on ventral side, snout length 26.2% HL; snout longer than eye diameter; dorsal-fin origin above pectoral fin, predorsal 22.8% TL; anus placed well before mid-body; trunk length less than head length; lateral-line pores: prepectoral 7; predorsal 10 and preanal 31; in addition to 2nd lateral-line pore 10–15th pores also elevated; total vertebrae 118.

Descrioption: Body robust and moderately elongated, cylindrical anteriorly and laterally compressed along the tail; dorsal and anal fins continuous with caudal fin; caudal fin stiff, circular not attenuated; dorsal-fin origin above the pectoral fin, predorsal 22.8% TL; anus well before mid-body, preanal 39.2% TL; anal fin commences just near to the anus; pectoral fin elongated, its length 27.6% HL; head conical its length 20.9% TL; snout pointed, its length 26.2% HL; eye spherical, its horizontal diameter 14.9% HL; anterior nostril tubular located at ventral side near tip of the snout, posterior nostril an oval slit infront of eye at mid-level; flange on upper lip weak, well developed on lower lip; mouth inferior, rictus ends at mid-eye level; tongue free; gill-opening small, 14% HL which is less than interbranchial space; depth at gill, 5.6% TL which is slightly greater than depth at anus; lateral-line pores small conspicuous: prepectoral 7, predorsal 10 and preanal 31; 2nd lateral-line pore elevated in addition 10–15th pores also elevated; vertebrae: predorsal 10, preanal 32 and total vertebrae 118; head pore small but conspicuous: SO 6, IO 8, POM 10 and ST 3; teeth sharp, small and conical except vomerine teeth;

intermaxillary teeth in an oval patch, longer than broad mostly exposed when mouth is closed; maxillary and mandibular teeth in bands, maxillary teeth in 5 rows anteriorly and biserial posteriorly, mandibular teeth with 6 rows anteriorly and 2 rows posteriorly; vomerine teeth elongated oval patch which extends to the level just before posterior nostril, anteriorly with 3 rows and ending as uniserial teeth; colour (in formaldehyde) light brown, with pale ventral region. Pectoral fin pale, dorsal and anal fins pale with black margin and caudal fin blackish.

Discussion: *Gnathophis* sp. A is similar to *Gnathophis heterognathus* (Bleekar, 1858) from Philippines, Japan and Taiwan and *G.heterolinea* (Kotthaus, 1968) from southern Somalia in having elevated lateral-line pores above the pectoral fin in addition to elevated 2nd lateral-line pore and in vertebral counts. But *Gnathophis* sp. A differs in certain morphometric characteristics from *G. heterognathus,* such as slightly longer head (22.8% vs. 17.7–20.7% TL), longer predorsal (22.8% vs. 17.7–20.7% TL) smaller trunk (18.3% vs. 20–22% TL) and smaller eye (14.9% vs. 17–26.2 % HL).

Gnathophis sp. A also differs from *G. heterolinea* in the condition of tail (less attenuated vs. greatly attenuated tail), smaller gill opening (less than eye diameter vs. less than half as great as eye diameter), Smaller eye diameter (1.75 times in snout vs. equal to snout) and lesser vertebral count (118 vs. 120). Finally *Gnathophis* sp. A is having larger than trunk vs. smaller head than trunk in *G. heterolinea.*

Distribution: Known only from the type specimen collected from South Eastern Arabian Sea through the present study [Figure 3.28C]

Remarks: *Gnathophis* sp.A is new to science. New record of the genus *Gnathophis* from Indian EEZ.

Table 3.15: Morphometric and meristic characters of *Gnathophis* sp. A (New species)

	Present study (n=1)
Total length (mm)	263
% TL	
Preanal length	39.2
Predorsal length	22.8
Head length	20.9
Trunk length	18.3
Depth at gill-opening	5.6
Depth at anus	4.7
% HL	
Snout length	26.2
Eye diameter	14.9
Interorbital width	8.9
Upper- jaw length	34.4
Lower- jaw length	28.2
Gill-opening length	14.0
Interbranchial width	18.0
Pectoral-fin length	27.6
Pectoral-fin base length	4.9
Meristics	
Lateral-line pores	
Prepectoral	7
Predorsal	10
Preanal	31
Head pores	
Supraorbital	6
Infraorbital	8
Preoperculomandubular	10
Supratemporal	3
Vertebrae	
Predorsal	10
Preanal	32
Total	118

***Gnathophis* sp. B (New species)**

Fig. 3.21, Table 3.16

Collection locations: AN: 12°49·602'N, 93°12.782'E, 441 m, 17.09.2010, (Cr.280, St.16), EXPO; 10°51·520'N, 92°11.336'E, 363 m, 26.01.2015, (Cr.334, St.01), HOT

Voucher specimen No.: 2801648 (CMLRE)

Diagnosis: Body moderately elongated and slender; head conical, its length 16.8–17.2% TL, snout pointed, with a fleshy keel on ventral side, snout length 25–26.5 % HL; predorsal length 18.4–18.6% TL; anus placed well before mid-body, preanal 35.8–38% TL; pale stomach; lateral-line pores: 2nd lateral-line pore elevated; prepectoral 6, predorsal 8–9 and preanal 36; postorbital pores 2; SO_5 absent; total vertebral count 147.

Description: Body moderately elongated, cylindrical anteriorly and laterally compressed posteriorly along the tail; dorsal and anal fins continuous with the caudal fin, caudal fin rounded and stiff; dorsal-fin origin above pectoral fin, predorsal 18.4–18.6% TL; anal fin origin just near to anus; anus placed well before mid-body, preanal 35.8–38% TL; pectoral fin elongated and slender, pectoral-fin length 24.3–26.5% HL; head conical, moderately elongated, its length 16.8–17.2% TL; snout pointed almost equal to eye diameter which is almost circular in shape; snout 25-26.5% HL; eye diameter 21.1–23.8% HL; anterior nostril tubular located at ventral side near tip of the snout, posterior nostril an oval slit in front of eye at mid-level; flange on upper lip weak, well developed on lower lip; mouth inferior, rictus ends just in front of level with mid-eye; tongue free; upper jaw slightly overhangs the lower jaw; gill-opening length small, 11.9–13.6% HL which is less than interbranchial width (17.1–

19.5% HL); depth at gill opening (3.9–4.2% TL) which is slightly greater than depth at anus (2.7–3.3% TL); lateral-line pores small conspicuous: 2nd lateral-line pore elevated, prepectoral 6, predorsal 8–9, and preanal 36; vertebrae: predorsal 10, preanal vertebrae 38 and total vertebrae 147; head pores small but conspicuous: SO 5, IO 7, POM 9 and ST 3; teeth sharp, small and conical except vomerine teeth; intermaxillary teeth in an oval patch, longer than broad and fully exposed when mouth is closed; maxillary and mandibular teeth in bands with 4 rows anteriorly and ends as single row; vomerine teeth as elongated oval patch which extends to the mid-level of posterior nostril, anteriorly with 3 rows and ending as uniserial teeth. Colour (in formaldehyde) light brown and paler ventrally, dorsal and anal fins pale with slight blackish margin at the end of dorsal fin, pectoral fin pale with a small black spot at base, black transverse line on supratemporal region and a blackish tinge on dorsal region of snout and in front of the gill opening.

Discussion: *Gnathophis* sp. B is close to *G. parini* Karmovskaya, 1990 from eastern Pacific in general body proportions, cephalic pore counts; condition of lateral-line pores (only second lateral-line pore elevated), colouration of median fins (margins of median fins light) and total vertebral count (147 vs. 146–147). However *Gnathophis sp.* B differs from *G. parini* in having slightly anterior origin of dorsal fin (above 8th-9th lateral-line pore vs. 12th lateral-line pore), less number of preanal pores (36 vs. 40–42) and in pale colouration of stomach vs. dark in *G. parini* and in cephalic pore pattern (SO 6, IO 8, & POM 10 vs. SO 5, IO 7 & POM 9).

Gnathophis sp. B also resembles another species *Gnathophis umbrellabius* (Whitley, 1948) of Southwestern Pacific in general body proportions and vertebral counts but differs in cephalic pore pattern except ST pores (SO 5, SO_5 absent, IO 7 & POM 9 vs. SO 6, SO_5 present, IO 8 & POM 10 in *G. umbrellabius*) and in coloration of stomach (pale vs. dark in *G. umbrellabius*).

Distribution: known only from the Andaman Sea (present study [Figure 3.28C]).

Remarks: New to science; New record of the genus from Indian EEZ.

Table 3.16: Morphometric and meristic characters of *Gnathophis* sp. B (New species)

	Present study (n=2)		
	Range	**Mean**	**SD**
Total length (mm)	215-250		
% TL			
Preanal length	35.8-38	36.9	1.5
Predorsal length	18.4-18.6	18.5	0.1
Head length	16.8-17.2	17.0	0.3
Trunk length	18.6-21.2	19.9	1.8
Depth at gill-opening	3.9-4.2	4.0	0.2
Depth at anus	2.7-3.3	3.0	0.4
% HL			
Snout length	25-26.5	25.7	1.1
Eye diameter	21.1-23.8	22.4	1.9
Interorbital width	8.9-9.3	9.1	0.3
Upper- jaw length	37.3-38.1	37.7	0.6
Lower- jaw length	29.5-31	30.2	1.1
Gill-opening length	11.9-13.6	12.7	1.2
Interbranchial width	17.1-19.5	18.3	1.6
Pectoral-fin length	24.3-26.5	25.4	1.6
Pectoral-fin base length	4.3-4.6	4.4	0.2
Meristics			
Lateral-line pores			
Prepectoral	6		
Predorsal	8-9		
Preanal	36		
Head pores			
Supraorbital	5		
Infraorbital	7		
Preoperculomandubular	9		
Supratemporal	3		
Vertebrae			
Predorsal	10		
Preanal	38		
Total	147		

Genus *Japonoconger* Asano, 1958

Type species: *Ariosoma sivicola* Mastubra & Ochiai, 1951 (by original designation), off Owase, Kumano-Nada, Japan.

Diagnosis: Snout projects before lower jaw, fleshy part projects beyond intermaxillary teeth; anterior nostril tubular, near tip of snout, posterior nostril a slit in front of eye at midlevel; adnasal pore absent; flange present only on lower lip; dorsal fin begins slightly ahead of pectoral-fin base; anus before mid-body, preanal less than 40% TL; pectoral fin well developed. teeth small conical in granular patches, intermaxillary tooth round, vomerine tooth as elongated patch and maxillary and mandibular tooth in bands wider anteriorly and narrow posteriorly (Smith 1989j).

This genus comprises 4 valid species *J. africanus* (Poll, 1953) (Eastern Atlantic) *J. caribbeus* Smith & Kanazawa 1977 (Caribbean Sea, North Western Atlantic) *J. proriger* (Gilbert 1891) (Eastern Pacific) and *Japonoconger sivicolus* (Matsubara & Ochiai 1951) (Western North Pacific) (Fricke et al. 2018a).

Among them *Japonoconger prorigor* (Gilbert 1891) (originally described as *Ophisoma prorigerum* Gilbert 1891) differs from others in having s short trunk. *Ophisoma* is a synonym of *Ariosoma* Swainson, 1838. According to Smith (1944) this species does not belong to *Ariosoma* and therefore he placed the species provisionally under the genus *Japonoconger* on the basis of some similar characters. On personal communication, David G. Smith commented the need for detailed osteological and taxonomic study for this genus.

***Japonoconger* sp. A**

Fig. 3.22, Table 3.17

Shorttrunk Japonoconger

Collection locations: BoB: 13°26.968'N, 80°31.807'E, 430 m, 17.06.2017, (Cr.361, St.10), Naturalist dredge

Voucher specimen No.: 3611004 (CMLRE)

Diagnosis: Moderately elongate body; dorsal-fin origin approximately an eye diameter in front of pectoral-fin base; anus placed well before mid-body; trunk smaller than head, trunk length 1.8 times in HL; pectoral fin elongated with pointed tip; upper jaw well overhangs the lower jaw; intermaxillary teeth fully exposed when mouth closed; gill opening large almost near to length of lower jaw;

Description: Moderately elongate body, cylindrical anteriorly and laterally compressed posteriorly along the tail; dorsal and anal fins continuous with caudal fin; tip of the tail attenuated; dorsal fin placed approximately an eye diameter ahead from the base of pectoral fin; predorsal 56.7% PAL; anal fin originates immediately behind anus; anus placed well before mid-body, preanal ca. 30.1% TL; pectoral fin elongated with pointed tip, its length 27.6% HL; head flattened in dorsal view, 63.9% PAL; trunk smaller than head, trunk length1.8 times head length; trunk length 36.1% PAL; snout long with pointed tip, its length 21.8% HL; fleshy part of the snout extends beyond the intermaxillary teeth; tongue well attached to mouth floor; upper jaw well overhangs the lower jaw; intermaxillary teeth fully exposed when mouth closed; flange absent on upper lip, present on lower lip; rictus ends at mid-level of eye; eye large less than half the length of snout, its horizontal diameter 11% HL; anterior nostril tubular near tip of snout pointing forward and downward, posterior nostril an oval slit in front of eye at mid-level; gill opening-length large almost equal to length of lower jaw (18.7% vs. 18.4% HL); depth at gill opening greater than depth at anus (22.7% vs. 14.5% PAL); lateral-line pores conspicuous: predorsal 9, prepectoral 11 and preanal 29; veretebrae: predorsal 10, preanal 34 and total veretebrae 138+; head pores small but conspicous: SO 6; IO 8; POM 9; ST 5; teeth small conical in bands on jaws and vomer; intermaxillary teeth in semicircular pattern mostly exposed when mouth closed and is separated from maxillary and vomerine teeth, maxillary and mandibular teeth wider anteriorly commences with 4-5.teeths and narrower posteriorly ends in 2 teeths, vomerine teeth in an elongated oval patch which is separated from intermaxillary and maxillary teeth, its length is almost double its width and extends up to the mid level of posterior nostril; colour (after preservation in formaldehyde) is uniform dark brown with black preopercular region, median fins and pectoral fin.

Distribution: Known only from Bay of Bengal waters (Present study [Figure 3.28C]).

Discussion: *Japonoconger* sp. A differs from *J. africanus* (Poll 1953), *J. caribbeus* Smith & Kanazawa 1977 & *Japonoconger sivicolus* (Matsubara & Ochiai 1951) in having shorter trunk (trunk shorter than head vs. trunk longer than head). *Japonoconger* sp. A is similar to *J. proriger* (Gilbert 1891) from Eastern Pacific in having shorter trunk less than head. But *Japonoconger* sp. A differs from *J. proriger* in combination of other characters such as longer predorsal length (56.7% vs. 46.5% PAL), larger head (63.9% vs. 51.5% PAL), larger gill-opening length (18.7% vs. 15% HL), longer pectoral-fin length (27.6%–26.3% HL) and lesser trunk length (36.1% vs. 48.5% PAL) and lesser interbranchaial width (13.2% vs. 21%

HL). It also differs in number of preanal lateral-line pores (29 vs. 36) cephalic pore counts (SO 6, IO 5+3, POM 5+4 vs. SO 4, IO 5+1, POM 6+4 in *J. proriger*) and finally in the condition of pectoral fin (Pointed tip vs. circular in *J. proriger*).

Remarks: *Japonoconger* sp. A is a species new to science; New record of genus from Indian Ocean.

Table 3.17: Comparison of morphometric and meristic characters of *Japonoconger* sp. A (New species) with similar congener.

	J. proriger **(n=1)**	**Present study (n=1)**
Total length (mm)	262	322
Preanal length (mm)	101	97
% PAL		
Predorsal length	46.5	56.7
Head length	51.5	63.9
Trunk length	48.5	36.1
Depth at gill-opening	_	22.7
Depth at anus	17.2	14.5
% HL		
Snout length	21.7	21.8
Eye diameter	11.3	11
Interorbital width	_	9.4
Upper- jaw length	29.4	28.5
Lower- jaw length	_	18.4
Gill-opening length	15	18.7
Interbranchial width	21	13.2
Pectoral-fin length	26.3	27.6
Meristics		
Lateral-line pores		
Prepectoral	_	11
Predorsal	_	9
Preanal	36	29
Head pores		
Supraorbital	4	6
Infraorbital	5+1	5+3
Preoperculomandubular	6+4	5+4
Supratemporal	_	5
Vertebrae		
Predorsal	9	10
Preanal	38	34
Total	147+	138+

Genus *Macrocephenchelys* Fowler, 1934

Type species: *Macrocephenchelys brachialis* Fowler, 1934

Diagnosis: Moderately elongate to elongate body; slender tail not greatly attenuated, blunt and short snout; small mouth; dorsal fin origin over or slightly beyond the pectoral fin tip; elongated and well developed pectoral fin; gill opening small; preanal length less than 35% of TL; fleshy papillae on lower jaw and sometimes on dorsal region of head; few species have small sensory pits on ventral portion of head and abdomen; ST pores one or absent (Lin et al. 2018).

This genus contains 4 valid species, *M. brachialis* Fowler, 1934; *M. brevirostris* (Chen & weng, 1967) *M. soela* Castle, 1990 and *M. nigriventris* Lin, Shao & Smith, 2018 (Lin et al. 2018). This genus has not been reported from Indian EEZ. Present study reports a new species from Arabian Sea and Andaman Sea.

Macrocephenchelys sp. A (New species)

Fig. 3.23, Table 3.18
Indian rubbernose conger

Collection locations: AS: 09°17·958'N, 75°39.942'E, 392 m, 02.11.2014, (Cr.331, St.01), HSDT-CV

AN: 12°48·640'N, 93°05.055'E, 323 m, 17.09.2010, (Cr.280, St.15), EXPO; 11°15·550'N, 92°20.440'E, 392 m, 15.01.2015, (Cr.334, St.10), HOT; 12°44·580'N, 93°06.302'E, 332 m, 10.04.2016, (Cr.349, St.06), HSDT-CV

Voucher specimen No.: 2801519 (CMLRE)

Diagnosis: Robust body and head; longer head 14.9–16.7% TL; dorsal-fin origin slightly before the tip of pectoral fin; small fleshy papillae on lower jaw and dorsal region of head; sensory pits on ventral surface of head and body; mandibular pores 2; ST absent; preanal lateral-line pores 26–29; Total vertebrae 155.

Description: Body moderately elongated, cylindrical anteriorly with a deep trunk and slender tail not greatly attenuated; dorsal and anal fins continuous with caudal fin; dorsal-fin origin slightly before the tip of pectoral fin, predorsal 18–19.6% TL; pectoral fin elongated and well developed, pectoral-fin length 40.4–52.1% HL; anus anterior to mid-body; anal fin origin immediately behind anus, preanal 29.4–31.1% TL; head moderate and robust, head length 14.9.–16.7% TL; snout short, blunt and swollen with folds reaching inside buccal cavity, its length 18–20.5% HL; tongue free; upper jaw slightly overhangs the lower jaw; flange present on lower lip absent on upper lip; mouth small and inferior, rictus ends below the mid-level of eye; eye moderate size and circular its horizontal diameter is 10.4–12.6% HL; anterior nostril tubular located laterally near tip of snout, posterior nostril oval with slightly elevated margin located on top of snout in front of the eye; gill opening small located below pectoral fin base, gill-opening length 13–16.3% HL; maximum depth at gill opening 4.7-6.2% TL; small fleshy papillae on lower jaw and dorsal region of head; ventral surface of the body from throat to anus with numerous sensory pores; lateral-line pores small and conspicuous: prepectoral 5–7, predorsal 12–13, preanal 26–29; vertebrae:

predorsal 14; preanal 30 and total vertebrae 155; cephalic pores small difficult to count: SO 3; IO 5; POM 5; ST 0; teeth on jaws small, bluntly conical and multiserial arranged as wide bands anteriorly and narrowing posteriorly; maxillary teeth 4 rows anteriorly and 1 row posteriorly; mandibular teeth 5 rows anteriorly and 1 row posteriorly; intermaxillary teeth larger and pointed with 3 transverse rows; vomerine teeth conical and blunt arranged irregularly in 3 anteroposterior rows which extends to the level of posterior end of posterior nostril; Colour when fresh greyish brown dorsally and pale white on ventral region, dorsal, anal and pectoral fins pale and black gill opening.

Distribution: Known from Arabian Sea and Andaman Sea of Indian EEZ through the present study [Figure 3.28C]).

Discussion: *Macrocephenchylus* sp. A differs from *M. branchialis* in having longer head (14.9–16.7% vs. 7.1–9.5% TL), more anterior origin of dorsal fin (slightly before the tip of pectoral fin vs. well behind tip of pectoral fin of by a distance equal to length of pectoral fin), shorter trunk (12.7–15.7% vs. 16.1–22.6% TL), longer upper jaw (22.7–28% vs. 16–21.9% HL), relatively large gill opening (13–16.3% vs. 3.9–6.7% HL), absence of ST pore vs. 1 and presence of sensory pits on ventral surface of head and body vs. absent and fewer vertebrae (154–155 vs. 173–183). It differs from *M. nigriventris* by the absence of conspicuous patch of melanophores around the anus, more anterior origin of dorsal fin (slightly before pectoral fin vs. origin near tip of pectoral fin), longer head (14.9–16.7% vs. 10.4–12.7% TL), longer preanal length (29.4–31.1% vs. 24.4–28% TL), more number of preanal lateral-line pores (26–29 vs. 19–24), and in more total vertebrae (155 vs. 125–135), *Macrocephenchylus* sp. A is similar to *M. soela* in having longer head but differs in origin of dorsal fin (slightly before tip of pectoral fin vs. middle of pectoral fin), shorter preanal length (29.4–31.1% vs. 32.4–35.2% TL), shorter trunk (12.7–15.7% vs. 18.1–19.6% TL), shorter interorbital width (11–13.6 vs. 14–16.6% TL) and more total vertebrae (155 vs. 150–151). *Macrocephenchylus* sp. A is most similar to *M. brevirostris* in most of the body proportions and number of pores (lateral line and head) but can be differentiated from *M. brevirostris* from their longer head (14.9–16.7 vs. 10.5–13.9% of TL), relatively large gill-opening length (13–16.3% vs. 7.4–13.7% HL) and shorter interbranchial width (20–27.8% vs. 25.3–39.7% HL).

Remarks: *Macrocephenchylus* sp. A is a species new to Science; new record of the genus from Indian EEZ.

Table 3.18: Comparison of morphometric and meristic characters of *Macrocephenchelys* sp. A with congeners.

	Karmovskaya 2004		**Lin et al. 2018**			**Present study**		
	***M. brevirostris* (n=9)**	***M. soela* (n=5)**	***M. nigriventris* (n=28)**	***M. brevirostris* (n=49)**	***M. brachialis* (n=92)**	**Range (n=8)**	**Mean**	**SD**
Total length (mm)	258-367	259-298	153-241	199-460	155-703	245-350		
% TL								
Preanal length	28.6-30.7	32.4-35.2	24.4-28	27.1-33.5	24.8-31	29.4-31.1	30.0	0.6
Predorsal length	16.8-19.1	16.9-18.8	16.7-19.8	15.9-19.7	14.9-17.9	18-19.6	18.9	0.6
Head length	12.4-13.9	14.3-15.6	10.4-12.7	10.5-13.9	7.1-9.5	14.9-16.7	15.6	0.6
Trunk length	15.5-17.8	18.1-19.6	12.5-15.7	14.4-20.6	16.1-22.6	12.7-15.7	14.4	1.0
Depth at gill-opening	4.6-6.9	5.4-6.7	4.4-6	4.8-6	3.6-5.0	4.7-6.2	5.6	0.5
Depth at anus	_	_	3.4-5.6	3.3-6.3	2.2-5.9	3.5-5.1	4.4	0.5
% HL								
Snout length	16.3-22.1	19.2-22	18.3-27.4	15.7-24.9	11.2-20.5	18-20.5	19.1	0.9
Eye diameter	8.8-14.1	9.8-11.5	8.3-14.9	8.7-15.3	10-18.7	10.4-12.6	11.6	0.7
Interorbital width	8.8-17.1	14-16.6	10.0-18.7	9.4-23.1	6.9-18.4	11-13.6	11.5	1.7
Upper-jaw length	-	-	18.6-25.5	19.2-35.7	16-21.9	22.7-28	25.4	1.7
Lower-jaw length	-	-	17.1-22.5	16.3-24.4	10.4-15.2	16.6-23.7	19.9	2.4
Gill-opening length	11.8-13.7	10.1-16.3	7.7-4.8	7.4-13.6	3.9-6.7	13-16.3	14.7	1.2
Interbranchial width	27.9-34.1	28.0-34.2	19.7-38.7	25.3-39.7	22.9-46.8	20-27.8	24.8	2.6
Pectoral-fin length	44.1-58.7	43.8-51	38.3-53.3	40.6-68.4	42.4-74.5	40.4-52.1	44.3	3.8
Pectoral-fin base length						4.5-6.2	5.3	0.5
Meristics								
Lateral-line pores								
Prepectoral	4-6	5	5-6	5-7	5	5-7		
Predorsal	11-13	9-11	13-14	11-13	16-18	12-13		
Preanal	25-28	28-30	19-24	25-32	33-36	26-29		
Head pores								
Supraorbital	3	3	3	3	3	3		
Infraorbital	5	5	5	5	5	5		
Preoperculomandubular	5-6	2	5	6	5	5		
Supratemporal	0	0	0	0	1	0		
Vertebrae								
Predorsal	12-13	10-11	12-16	12-15	14-20	14		
Preanal	27-30	29-30	22-25	27-32	28-38	30		
Total	150-155	150-151	125-135	147-154	173-183	155		

Genus *Promyllantor* Alcock, 1890

Type species: *Promyllantor purpureus* Alcock, 1890, Arabian Sea, India.

Diagnosis: This genus is characterized by a robust and deep body; broad snout; short mouth; broad vomerine tooth patch; dorsal fin origin posterior to pectoral fin base; anus before mid-body (Castle 1995; Karmovskaya 2006b).

This genus is constituted by 3 valid species; *P. purpureus* Alcock, 1890 (Indian Ocean), *P. adenensis* (Klausewitz, 1991) (Indo-Pacific) and *P. atlanticus* Karmovskaya, 2006a (Southeastern Atlantic) (Karmovskaya 2006a). In Indian EEZ this genus is represented by a single species *P. purpureus.*

Promyllantor purpureus Alcock, 1890

Fig. 3.24, Table 3.19

Holotype: ZSI 12878, 419 mm TL; female; Off Elicapeni Bank, Laccadive Sea, 11°12'47"N, 74°25'30"E, Investigator Station 104, 1829 m.

Collection locations: AS: 07°53·232'N, 76°25.780'E, 1258 m, 09.09.2013, (Cr.319, St.08), EXPO

Voucher specimen No.: 3190801 (CMLRE)

Diagnosis: Robust body; broad and short snout, less than twice the eye diameter; short mouth which ends at the level of posterior nostril; dorsal-fin origin slightly posterior to tip of pectoral fin; anus placed before mid-body; head pores: IO 3; mandibular pores 2; ST 0; vertebrae 110.

Description: Body moderately elongated, cylindrical anteriorly and much compressed posteriorly with attenuated tail; deep and massive trunk; dorsal and anal fin continuous with caudal fin; dorsal-fin origin slightly posterior to tip of pectoral fin, predorsal length 26.2% TL; pectoral fin moderately well developed, its length 32.8% HL; anal fin commences just after the anus; anus anterior to mid-body, preanal length 47.1% TL; head almost cylindrical, moderately elongated with well-developed muciferous cavities; head length 19.3% TL; snout very broad, short and blunt, less than twice the horizontal eye diameter, snout length 26.8% HL; presence of sensory papillae on both jaws and dorsal side of head; tongue free at anterior tip; upper jaw slightly overhangs the lower jaw; mouth very short with thick lips, flange present on upper and lower lips; rictus ends at level of posterior nostril; eye large and circular its horizontal diameter 13.9% HL; anterior nostril a very short tube near tip of the snout; posterior nostril a large oval slit with slightly raised rim immediately in front of eye at mid-level; gill opening, semi lunate located well before and below the pectoral-fin base; gill-opening length 13.5% HL; maximum depth at anus 10.1% TL; lateral-line pores conspicuous are in the form of short tubes: prepectoral 8, predorsal 17, preanal 38; head pores moderate and few in numbers; IO 3; POM 2; SO 3; ST 0; vertebrae: predorsal 20, preanal 39 and total vertebrae 110; maxillary and mandibular teeth small, conical, as bands of about 4 rows anteriorly and ends as uniserial; intermaxillary in a transversely oval patch completely exposed when mouth is closed, vomerine tooth broad and sub triangular with 3 teeth at anterior region and 12 teeth at its posterior row which ends slightly before the level of posterior nostril, there is distinct gap between intermaxillary; colour (in formaldehyde) is uniform light brown, with dark brown patches more concentrated on head region. Pectoral and median fins brown to black.

Distribution: Indian Ocean: Indonesia, Sulawesi (Castle 1995; Karmovskaya 2006a); Indian EEZ: Arabian Sea (Alcock 1890; Venu 2009; Present study [Figure 3.28A]).

Remarks: *Promyllantor purpurous* barely looks like an eel due to its more body depth and laterally compressed body. In Indian EEZ this species is known only from Arabian Sea.

Table 3.19: Comparison of morphometric and meristic characters of *Promyllantor purpureus* Alcock, 1890 with previous study.

	Karmovskaya 2006a (n=2)	**Present study (n=1)**
Total length (mm)	419-442	497
% TL		
Preanal length	45.3-46.4	47.1
Predorsal length	23.6-25.3	26.2
Head length	16.1-19	19.3
Trunk length	27.4-29.2	29.0
Depth at gill-opening	_	8.9
Depth at anus	9.2-10.4	10.1
% HL		
Snout length	22.2-27.3	26.8
Eye diameter	13.5-15.4	13.9
Interorbital width	11.9-21.9	16.9
Upper-jaw length	_	22.4
Lower-jaw length	_	18.9
Gill-opening length	14.8-16.6	13.5
Interbranchial width	24.1	23.4
Pectoral-fin length	29.8-33.7	32.8
Pectoral-fin base length	_	6.4
Meristics		
Lateral-line pores		
Prepectoral	5-8	8
Predorsal	13-17	17
Preanal	38-41	38
Head pores		
Supraorbital	3	3
Infraorbital	3	3
Preoperculomandubular	2	2
Supratemporal	0	0
Vertebrae		
Predorsal		20
Preanal	37-38	39
Total	110-112	110

Genus *Rhynchoconger* Jordan & Hubbs, 1925

Type species: *Leptocephalus ectenurus* Jordan & Richardson, 1909 (by original designation), Takao, South Western Taiwan.

Diagnosis: Moderately elongate body; tail slender and attenuate, frequently damaged; dorsal-fin origin over or slightly ahead of pectoral fin base; upper jaw overhangs the lower jaw; fleshy part of the snout extends beyond the intermaxillary teeth; flange present on upper and lower lip, flange on upper lip narrow; head pores small; pores on upper jaw located on flange; maxillary and mandibular teeth in narrow bands (Smith 1989j, Ben-Tuvia 1993)

This genus contain 7 valid species *R. gracilior* (Ginsburg, 1951), *R. guppyi* (Norman, 1925 and *R. flavus* (Goode & Bean, 1896) (Western Atlantic), *R. ectenurus* (Jordan & Richardson, 1909), *R. nitens* (Jordan & Bollman, 1890) (Eastern Pacific), *R. squaliceps* (Alcock, 1894b) (Northern Indian Ocean), *R. trewavasae* Ben-Tuvia, 1993 (Red Sea; Mediterranean Sea) (Fricke et al. 2018a). Indian EEZ represents only a single species *R. squaliceps.*

Rhynchoconger squaliceps Alcock, (1894a)

Fig. 3.25, Table 3.20

Synonyms: *Congromuraena squaliceps* Alcock, 1894a

Holotype: ZSI F13450 (damaged condition), Ca. 300 mm TL, Bay of Bengal, 15°04'07"N, 80°25'07"E, Investigator station 137, 234 m.

Collection locations: AS: 12°28·170’N, 74°09.142’E, 445 m, 24.08.2013, (Cr.318, St.01), EXPO; 11°57·317’N, 74°26.081’E, 200 m, 09.01.2014, (Cr.322, St.05), HSDT-CV

BoB: 14°09·197'N, 80°24.745'E, 225, 03.08.2014, (Cr.327, St.06), HSDT-CV

Voucher specimen No.: 3220515 (CMLRE)

Diagnosis: Dorsal-fin originates slightly before the pectoral-fin base; anus placed before mid-body; presence of median longitudinal ridge on ventral side of snout; presence of sensory papillae on surface of snout and head; upper jaw flange rudimentary, lower jaw flange well developed; teeth small and conical; intermaxillary teeth fully exposed when mouth closed, vomerine teeth in a compact cluster.

Description: Body moderately elongated, cylindrical anteriorly and laterally compressed posteriorly with attenuated tail, tail tip soft and flexible, frequently regenerated; dorsal and anal fins continuous with caudal fin; dorsal-fin origin slightly before the pectoral-fin base, predorsal 48–50.8% PAL; anal fin commences immediately behind anus; anus placed before mid-body; pectoral fin long slender, its length 13.7–16% PAL; snout elongated and blunt at tip, snout length 11.7–13.3% PAL; fleshy tip of the snout extends beyond the intermaxillary teeth; presence of a median longitudinal ridge on tip of snout on its ventral side; presence of minute sensory papillae on surface of head and snout; tongue free; upper jaw overhangs the lower jaw; upper jaw labial flange rudimentary, lower jaw labial flange well developed; mouth moderate, rictus ends at the level of posterior margin of eye; eye moderate and oval in shape, its horizontal diameter 5.5–7.4% PAL; anterior nostril tubular, located laterally near tip of the snot, posterior nostril an oval slit, with slightly raised rim located before eye at midlevel; gill opening greater than interbranchial, gill-opening length 14–15.3% HL; maximum depth at gill opening 15-15.9% of PAL. lateral-line pores conspicous: prepectoral 10; predorsal 7 preanal 30; vertebrae: predorsal 8, preanal 31 and total vertebrae 150^+; head pores small but conspicous: SO 3, IO 5, POM 10 and ST 1; teeth on jaws small and conical not prominent; maxillary and mandibular teeth in 3–4 rows anteriorly and ends posteriorly as 2 rows; maxillary and mandibular teeth boarded by fleshy ridges with numerous minute sensory papillae which is less prominent in later (not clear); intermaxillary teeth slightly larger and recurved, forming a transversely oval patch and completely exposed when mouth closed; vomer: there is a compact cluster of about 20-22 teeth. Colour when fresh is light brown dorsally and pale ventrally, posterior part of median fins ends in black margin. Pectoral fin pale.

Distribution: Northern Indian Ocean: Pakistan (Moazzam & Osmani 2015; Psomadakis et al. 2015); Indian EEZ: Bay of Bengal (Alcock 1894a; Castle 1995); Arabian Sea (present study [Figure 3.28A])

Remarks: *Rhynchoconger squaliceps* is most similar to *Rhynchoconger ectenurus* distributed in Indo-Pacific waters. According to Castle (1995) the main characters which makes *R. squaliceps* distinct is its longer head and vertebral count not graeatly exceeding 152 compared to *R. ectenerus*. *R. ectenurus* was reported from Indian EEZ (Northwest of Bombay, Arabian Sea) by Kottaus (1968) from a depth of 74–80m. Even though Venu (2009) reported same species from Arabian sea from a greater depth 200–500 m, species identity is doubtfull (*R. ectenurus* or *R. squaliceps*) due to the lack of voucher specimen as well as difficulties to arrive in a conclusion based on the description of the species. Present species well matches with the data of *R. squaliceps* given by Castle (1995).

Table 3.20: Comparison of morphometric and meristic characters of *Rhynchoconger squaliceps* Alcock, (1894a) with previous study.

	Castle 1995 (n=2)		**Present study (n=3)**		
			Range	**Mean**	**SD**
Total length (mm)	351	ca. 300	311-347		
Preanal length (mm)	126	_	110-123		
% PAL					
Predorsal length	45.8	_	48-50.8	49.9	2.7
Head length	56.9	_	55.6-60.9	57.7	3.0
Trunk length	43.1	_	39.1-46.3	43.3	4.4
Depth at anus	13.1	_	10.5-11.9	11.6	1.5
Snout length	11.3	_	11.7-13.3	12.4	0.7
Eye diameter	8.2	_	5.5-7.4	6.4	1.0
Upper-jaw length	17.1	_	17.2-19.7	18.5	1.4
Pectoral-fin length	14.7	_	13.7-16	14.7	1.0
% HL					
Snout length	_	_	21.1-21.9	21.3	0.4
Eye diameter	_	_	8.7-12.1	10.5	1.5
Interorbital width	_	_	11.6-133	12.4	0.8
Upper- jaw length	_	_	30.7-32.3	31.7	1.0
Lower- jaw length	_	_	22.8-25.1	24.3	1.0
Gill-opening length	_	_	14-15.3	14.9	0.6
Interbranchial width	_	_	9.4-12.0	11.4	1.4
Pectoral-fin length	_	_	23.5-28.2	25.3	2.1
Pectoral-fin base length	_	_	4.4-5.7	4.8	0.6
Meristics					
Lateral-line pores					
Prepectoral	_	_	10		
Predorsal	_	_	7		
Preanal	30	28	30		
Head pores					
Supraorbital	_	_	3		
Infraorbital	_	_	5		
Preoperculomandubular	_	_	10		
Supratemporal	_	_	1		
Vertebrae					
Predorsal	_	_	8		
Preanal	_	_	31		
Total	140+	152+	150+		

Genus *Uroconger* Kaup, 1856b

Type species: *Congrus lepturus* Richardson, 1845 (by original designation); Canton, China.

This genus contains 3 valid species, *U. lepturus* (Richardson, 1845) (Indo-Pacific) *U. erythraeus* Castle, 1982 (endemic to red sea) *U. syringinus* Ginsburg, 1954 (Atlantic) (Fricke et al. 2018a).

Diagnosis: Body moderately elongated; greatly attenuated tail; dorsal-fin origin slightly anterior to or slightly posterior to pectoral-fin base; preanal length less than 40% of TL; snout projecting slightly beyond lower jaw; fleshy part of snout projects slightly beyond intermaxillary teeth; flange present on lower lip, absent on upper lip; adnasal pore absent (Castle 1968b; Smith 1989j).

Uroconger lepturus, (Richardson 1845)

Fig. 3.26, Table 3.21
Slender conger

Holotype: BMNH 1978.3.1.1. (Unique), Canton, China.

Synonyms: *Congerodon indicus* Kaup, 1856b; *Congrus lepturus* Richardson, 1845

Collection locations: AS: 14°15·650’N, 73°15.970’E, 214 m, 15.10.2010, (Cr.281, St.19), HSDT-CV

Voucher specimen No.: 2811904 (CMLRE)

Diagnosis: Body moderately elongated and slender; dorsal-fin origin above gill opening, predorsal length 37.8–38.5% PAL; anus located before mid-body; attenuated tail; terminal mouth; interbranchial width less than gill-opening length; vomerine teeth in a single row extending far back to the level of posterior nostril, with 4 closely arranged larger teeth anteriorly; total vertebrae 208.

Description: Body moderately elongated and slender, almost cylindrical anteriorly and laterally compressed posteriorly; greatly attenuated tail, caudal region is readily subjected to damage; dorsal and anal fins well developed and continuous with caudal fin; dorsal-fin origin above the gill opening, predorsal length 37.8–38.5% of PAL; pectoral fin well developed, its length 23.2–27.3% HL; anal fin originates immediately behind anus; anus anterior to mid-body, preanal length 32.2% TL (for intact specimen, 298 mm TL); head moderate, its length 37.8–39.6% PAL; snout moderate with flattened dorsal profile and blunt tip, fleshy part at the tip projects slightly beyond inter-maxillary teeth, snout length 26.6–28.2% HL; tongue free; upper jaw slightly overhangs the lower jaw; flange present on lower lip, absent on upper lip; mouth terminal, rictus ends below the level of posterior margin of eye; eye moderate, oval in shape its horizontal diameter 13.5–13.9% HL; anterior nostril tubular located near tip of snout, directed anterolaterally, posterior nostril elliptical in front of eye at mid-level; gill opening more than interbranchial, gill-opening length 16.3–18.4% HL; depth at anus slightly more than depth at gill opening, 11.6–13.9% vs. 10.7–12.2% PAL; lateral-line pores small, conspicuous: prepectoral 9, predorsal 8 and preanal 42; vertebrae: predorsal 9, preanal 44 and total vertebrae 208;

head pores small, discernible: SO 3; IO 5; POM 10; ST 3; teeth canine like, maxillary and mandibular teeth biserial except few patch on anterior part of mandible; intermaxillary teeth 6–7 in numbers in a transverse row exposed when mouth is closed; vomerine teeth in a single row extending far back to the posterior end of posterior nostril with 4 closely arranged larger teeth anteriorly. Colour (in formaldehyde), dark brown body, light ventrally, median fins pale with black along their margins and pectoral fin pale.

Distribution: Southern Red Sea, Indo-West Pacific: KwaZulu-Natal and Madagascar east to Philippines, north to southern Japan, south to northern Australia; Hawaiian Islands (Fricke et al. 2018a). Indian EEZ: (Malabar: Day 1889; Gulf of Mannar: Nair 1948; Madras: Nair 1946; Kerala: Bijukumar & Raghavan 2015; Bombay: Fowler 1927; Kotthaus 1968; Bal & Mohamed 1957). Present study [Figure 3.28A]

Remarks: *Uroconger lepturus* is mostly found to be distributed in shallow waters (Froese & Pauly 2018) but there are reports of their distribution up to 200 m depths in Fish Database of Taiwan (Shao 2018). In Indian EEZ this species was previously reported only from shallow waters. Present study extends the bathymetric range of this species to much deeper waters of about 214 m.

Table 3.21: Comparison of morphometric and meristic characters of *Uroconger lepturus* (Richardson, 1845) with previous study.

	Castle 1968b (n=5)	Present study (n=3)		
		Range	Mean	SD
Total length (mm)	348-426	241-298		
% TL*				
Preanal length	29-31.8	32.2		
Predorsal length	11.7-13.2	12.4		
Head length	12-13.5	12.8		
Depth at gill-opening	3.9-4.9	3.9		
Depth at anus	4.2-4.7	4.5		
Snout length	3-3.4	3.4		
Eye diameter	1.1-1.6	1.8		
Interorbital width	1.9-2.2	2.1		
Gill-opening length	1.9-2.5	2.1		
Interbranchial width	1.3-1.5	1.8		
Pectoral-fin length	2.8-3.2	3.2		
Upper jaw length	4.2-4.9	4.9		
% HL				
Snout length	_	26.6-28.2	27.6	0.9
Eye diameter	_	13.5-13.9	13.7	0.2
Interorbital width	_	16.8-19.2	17.7	1.3
Upper- jaw length	_	38.7-41.5	40.5	1.6
Lower- jaw length	_	36.8-37.1	36.9	0.2
Gill-opening length	_	16.3-18.4	17.6	1.2
Interbranchial width	_	11.5-14.5	13.1	1.5
Pectoral-fin length	_	23.2-27.3	25.1	2.1
Pectoral-fin base length	_	5.5-6.5	6.1	0.5
% PAL				
Predorsal length	_	37.8-38.5		
Head length	_	37.8-39.6		
Trunk length	_	60.4-62.2		
Depth at gill-opening	_	10.7-12.2		
Depth at anus	_	11.6-13.9		
Meristics				
Lateral-line pores				
Prepectoral	_	9		
Predorsal	_	8		
Preanal	42-44	42		
Head pores				
Supraorbital	_	3		
Infraorbital	_	5		
Preoperculomandubular	_	10		
Supratemporal	_	3		
Vertebrae				
Predorsal	_	9		
Preanal	_	44		
Total	210	208		

*% of TL only for intact specimen TL 298

Genus *Xenomystax* Gilbert, 1891

Type species: *Xenomystax atrarius* Gilbert, 1891; off Ecudor, Eastern Pacific.

Diagnosis: Body moderately elongate; dorsal-fin origin slightly before or slightly behind base of pectoral fin; anus before mid-body, preanal length 30–40% TL; snout projects beyond lower jaw, fleshy part of snout does not extend anteriorly beyond intermaxillary teeth; teeth exposed when mouth closed; flanges absent on upper and lower lip; large mouth, toothed portion of upper jaw extends beyond posterior margin of eye; adnasal pore absent (Smith 1989j).

This genus contains 5 valid species *X. atrarius* Gilbert, 1891 (eastern Pacific); *X. austrinus* Smith & Kanazawa, 1989 and *X. bidentatus* (Reid, 1940) (western Atlantic) *X. congroides* Smith & Kanazawa, 1989 (eastern & western Atlantic) and *X. trucidans* Alcock, 1894b (Indo-west Pacific) (Smith et al. 2017). In India this genus is represented by a single species *X. trucidans*.

Xenomystax trucidans Alcock, 1894b

Fig. 3.27, Table 3.22

Holotype: ZSI F13704, Laccadive Sea, 7°05′ 45″ N, 75°04′ E, Investigator station 150; 648 mm TL, 1315 m.

Collection locations: AS: 12°28·170'N, 74°9.142'E, 445 m, 24.08.2013, (Cr.318, St.01), EXPO; 09°17·958'N, 75°39.942'E, 392 m, 02.11.2014, (Cr.331, St.01), HSDT-CV

BoB: 10°57·946’N, 80°20.203’E, 645 m, 26.08.2010, (Cr.279, St.01), HSDT-CV; 11°55·127’N, 80°08.838’E, 634 m, 05.11.2011, (Cr.291, St.10), EXPO; 11°54·788’N, 80°08.719’E, 645 m, 05.11.2011, (Cr.291, St.11), EXPO; 10°56·270’N, 80°21.253’E, 670 m, 06.11.2011, (Cr.291, St.12), EXPO; 10°38·440’N, 80°31.036’E, 654 m, 07.11.2011, (Cr.291, St.14), EXPO; 10°37·411’N, 80°31.460’E, 648 m, 07.11.2011, (Cr.291, St.15), EXPO; 10°55·957’N, 80°21.519’E, 650 m, 08.11.2011, (Cr.291, St.16), EXPO; 11°54·696’N, 80°08.649’E, 653 m, 09.11.2011, (Cr.291, St.17), EXPO

AN: 07°31·460’N, 93°24.091’E, 567 m, 24.09.2010, (Cr.280, St.38), EXPO; 07°30·110’N, 93°24.911’E, 580 m, 11.12.2011, (Cr.292, St.89), HSDT-CV; 11°04·7850’N, 92°21.909’E, 530 m, 15.01.2015, (Cr.334, St.11), HOT; 11°17·465’N, 92°47.886’E, 907 m, 16.01.2015, (Cr.334, St.12), HOT; 13°15.902’N, 93°15.827’E, 635 m, 26.11.2017, (Cr.367, St.08), HSDT-CV; 11°47.889’N, 92°05.437’E, 646 m, 28.11.2017, (Cr.367, St.15), HSDT-CV

Voucher specimen No.: 3671507 (CMLRE)

Diagnosis: Dorsal-fin origin slightly in advance of pectoral-fin base; anus anterior to mid-body; posterior nostril elliptical, placed one or slightly less than one eye diameter in front of eye at mid-eye level; large gill opening and total vertebrae 200.

Description: Body moderately elongated, cylindrical anteriorly and laterally compressed posteriorly with attenuated tail; dorsal and anal fins confluent with caudal fin; dorsal-fin origin slightly anterior to pectoral-fin base, predorsal length 12.7–15.2% TL; pectoral fin elongated and pointed, pectoral-fin length 18.8–22.3% HL; anal fin originates immediately behind anus; anus located anterior to mid-body, preanal 32.5–40.4% TL; head elongated, head length 16–19.6% TL; snout depressed and pointed, fleshy part of the snout does not extend anteriorly beyond intermaxillary teeth, snout length 34.9–37.1% HL; tongue not free except its anterior tip; upper jaw overhangs the lower jaw, intermaxillary teeth fully exposed when mouth closed; flanges absent on upper and lower lip; mouth large, toothed portion of maxillae extends beyond posterior margin of eye; eye moderate and oval in shape, its horizontal diameter 9–12.3% HL; anterior nostril tubular located laterally just behind the intermaxillary teeth, posterior nostril elliptical, located about one or slightly less than one eye diameter in front of eye at mid-eye level; gill opening large and deep with less interbranchial width, its anterior margin at level with upper margin of pectoral-fin base, gill-opening length 13.9–17.4% HL; maximum depth at gill 3.9–5.3% TL; lateral-line pores conspicuous: prepectoral 7–9, predorsal 4–5 and preanal 36–39; vertebrae: predorsal 9; preanal 40 and total vertebrae 200; head pores numerous some are conspicuously enlarged,: SO 6; IO 8; POM 13–14; ST 3; teeth slender and conical, exposed when mouth closed; intermaxillary tooth in 5 longitudinal rows, slightly longer than its width and separated from maxillary and vomerine teeth by a edentulous gap; maxillary teeth in 2 distinct series, outer teeth as small bands and inner teeth in a single row well separated from outer teeth by a smooth edentulous grove; mandibular teeth 4 rows which increase in size inwards, and a inner narrow band of small rigid teeth separated from outer teeth, which begins slightly posteriorly from the anterior end of jaw; anterior mandibular teeth enlarged and fits into the space after the intermaxillary when mouth closed, vomerine teeth with 4-5 enlarged median teeth anteriorly with a series of small teeth in anterior and posterior region; mandibular teeth in 5 narrow bands, inner teeth larger except the innermost row, which are very small and slightly separated from outer teeth. Colour when fresh, light brown with pale dorsal and anal fins except the posterior part. Pectoral fin pale with slightly brown base.

Distribution: Indo-west Pacific (Smith et al. 2017)

Indian EEZ: Arabian Sea (Alcock 1894b; Jayaprakash et al. 2006; Venu 2009; Hashim 2012; Sudhakar et al. 2013; Present study [Figure 3.28.A]); Bay of Bengal (Present study [Figure 3.28.A]) and Andaman Sea (Present study [Figure 3.28.A]).

Remarks: Present specimens show slight variation in some characters such as gill opening, eye diameter and interorbital width compared to data of Smith et al. (2017). For long period *Xenomystax trucidans* was known only from South Eastern Arabian Sea, Western Indian Ocean. Smith (1989j) discussed about a specimen (ANSP 11209) of *Xenomystax* from Indian Ocean and doubted as *X. trucidans*. Recently Smith et al. 2017 recorded 2 specimens from Oman and also confirmed the ANSP 11209 specimen as *X. trucidans* from Andaman Sea of Thailand. Thus the geographical distribution of *X. trucidans* extends from Western Indian Ocean to western Pacific. Present study reveals this species is widely distributed in Indian EEZ (Arabian Sea, Bay of Bengal and Andaman Sea).

Table 3.22: Comparison of morphometric and meristic characters of *Xenomystax trucidans*, Alcock, 1894b with previous study.

	Smith et al. 2017 (n=4)	Present study (n=6)		
		Range	Mean	SD
Total length (mm)	250-413	292-635		
% TL				
Preanal length	33.9-39.2	32.5-40.4	36.4	2.7
Predorsal length	14-16.4	12.7-15.2	14.6	1.1
Head length	16.4-19.1	16-19.6	17.9	1.4
Trunk length	_	15.8-20.7	18.6	1.7
Depth at gill-opening	_	3.9-5.3	4.6	0.6
Depth at anus	2.6-3.6	3.4-4.4	3.8	0.4
% PAL				
Predorsal length	40.2-45.2	38.9-42.3	40.1	1.3
Head length	47.1-51.7	45.6-51.1	49.0	2.2
Depth at anus	6.7-10.5	9.3-12.4	10.6	1.2
% HL				
Snout length	35.2-39.5	34.9-37.1	36.3	1.2
Eye diameter	8-9.5	9-12.3	10.5	1.1
Interorbital width	4.4-4.8	5.3-10.1	8.5	1.8
Upper-jaw length	42.9-55.6	48.8-53.8	51.1	2.0
Lower jaw length	_	42.7-49.9	45.6	2.7
Gill-opening length	7.3-13.8	13.9-17.4	12.7	6.4
Interbranchial width	3.6-5.6	3.3-6.8	5.3	1.3
Pectoral-fin length	15.7-21.6	18.8-22.3	20.5	1.3
Pectoral-fin base length	_	2.8-3.9	3.3	0.4
Meristics				
Lateral-line pores				
Prepectoral	_	7-9		
Predorsal	_	4-5		
Preanal	_	36-39		
Head pores				
Supraorbital	6	6		
Infraorbital	8	8		
Preoperculomandubular	13-14	13-14		
Supratemporal	3	3		
Vertebrae				
Predorsal	6-9	9		
Preanal	39-41	40		
Total	198-200	200		

Family Congridae

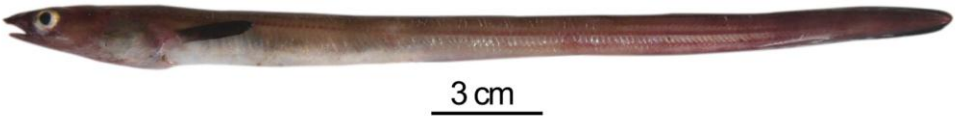

Figure 3.7: *Ariosoma gnanadossi*

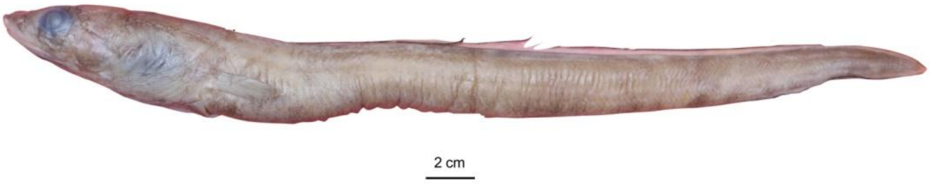

Figure 3.8: *Ariosoma* sp. A: New species. Reccorded from Arabian Sea

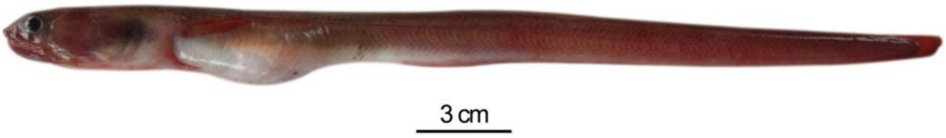

Figure 3.9: *Bathymyrus echinorhynchus*

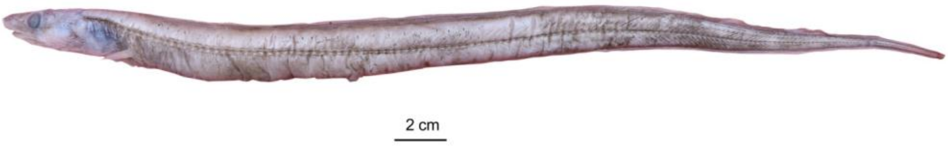

Figure 3.10: *Bathycongrus macrocercus*

Figure 3.11: *Bathycongrus nasicus*: New record from Andaman Sea

Figure 3.12: *Bathycongrus* sp. A: New species. Specimen collected from Arabian Sea

Figure 3.13: *Bathycongrus* sp. B: New species. Specimen from Arabian Sea

Figure 3.14: *Bathycongrus trimaculatus*: A.Dorsal view, B. Ventral view; New record from Indian Ocean

Figure 3.15: *Bathyuroconger vicinus*: New record from Andaman Sea; Widely distributed in Indian EEZ;

Figure 3.16: *Congrhynchus talabonoides*: New Record from Indian Ocean

Figure 3.17: *“Congromuraena” musteliceps*, from Smith et al. (2018), fig. 2: Not encountered in the present study

Figure 3.18: *Gavialiceps* sp. A: New species. Specimen from Andaman Sea

Figure 3.19: *Gavialiceps taeniola*: Widely distributed in Indian EEZ

Figure 3.20: *Gnathophis* sp. A: First report of the genus from Indian waters; New species. Collected from Arabian Sea

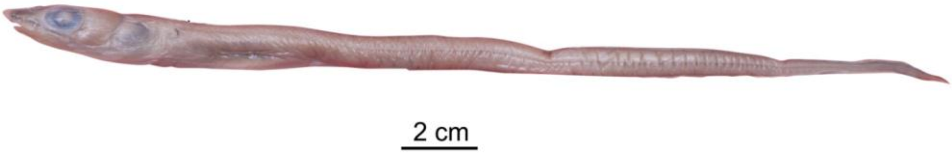

Figure 3.21: *Gnathophis* sp. B: First report of the genus from Indian waters; New species. Collected from Andaman Sea

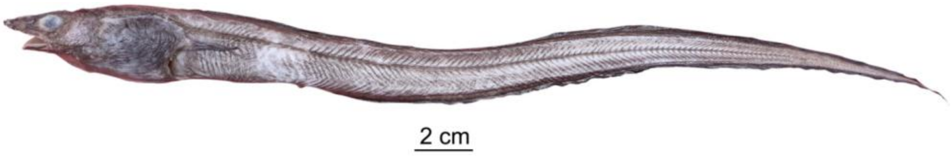

Figure 3.22: *Japonoconger* sp. A: First report of the genus from Indian waters; New species. Collected from Bay of Bengal

Figure 3.23: *Macrocephenchelys* sp. A: First report of the genus from Indian waters; New species. Collected from Arabian Sea and Andaman Sea

Figure 3.24: *Promyllantor purpureus* from Arabian Sea.

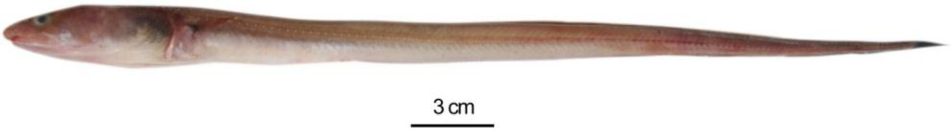

Figure 3.25: *Rhynchoconger squaliceps*: New record from Arabian Sea

Figure 3.26: *Uroconger lepturus*: First report from deep-waters of Indian EEZ, previously reported from shallow-waters

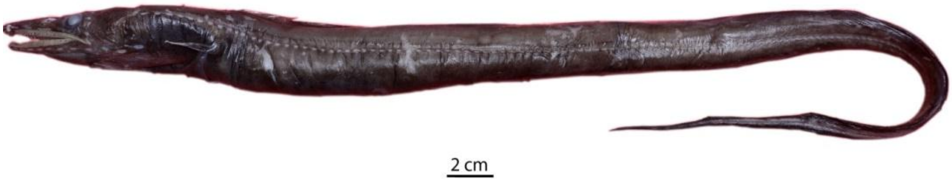

Figure 3.27: *Xenomystax trucidens*: Widely distributed in Indian EEZ; New record from Bay of Bengal and Andaman Sea

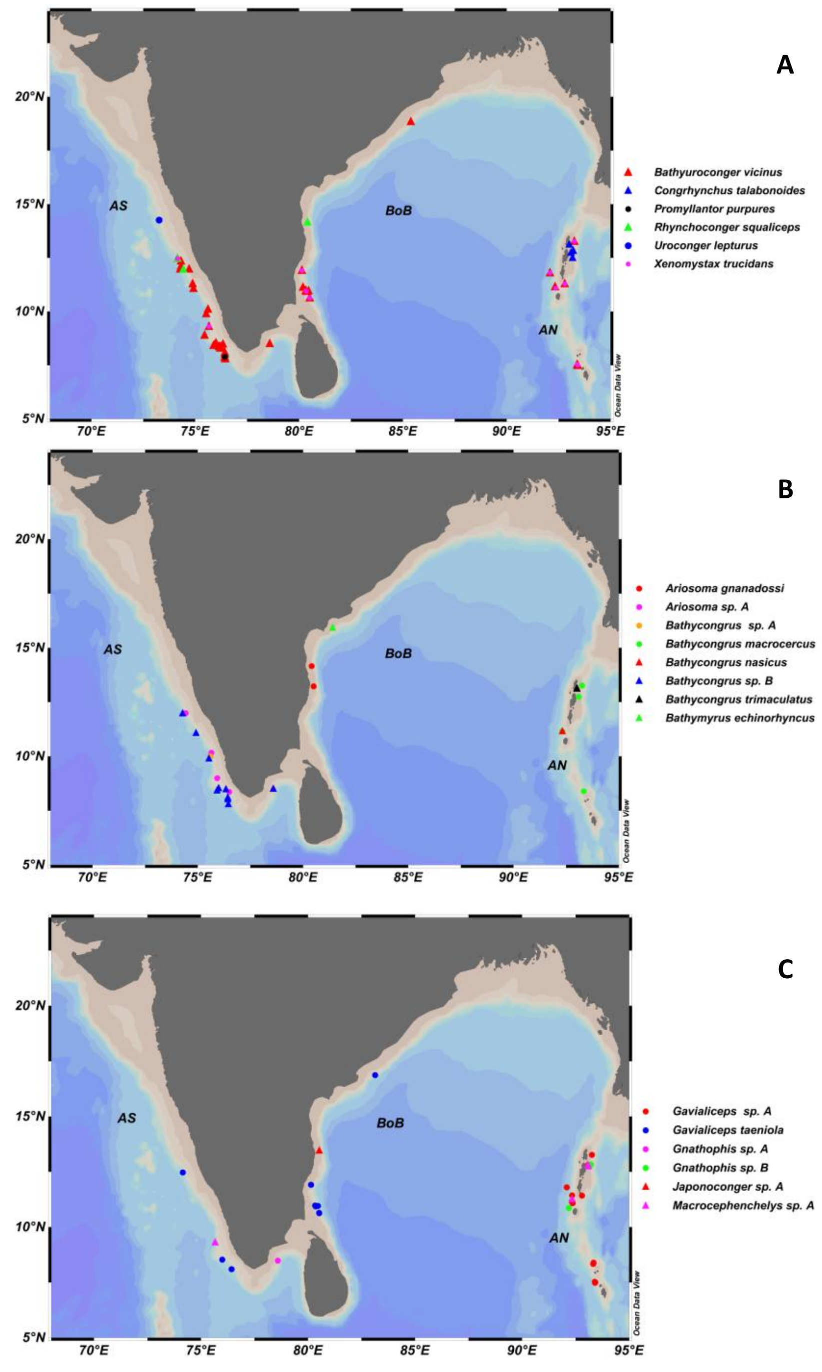

Figure 3.28: (A, B, C) Map showing distribution of deep-sea eels of family Congridae in the Indian EEZ

III. Family DERICHTHYIDAE Gill, 1884

Long neck eels

Diagnosis: Dorsal-fin origin in anterior third of body; anus far posterior; tail equal to or shorter than remainder total length; branchial region rounded and slender; gill opening small; mouth terminal; gape extends either to anterior margin of eye or further to posterior margin; upper jaw projects beyond the tip of lower jaw; nostrils simple and pore like; intermaxillary teeth at least partially exposed; dorsal and anal fins continuous with caudal fin, dorsal and anal fins much lower in tail region; pectoral fin present (Robins 1989).

This family comprises 3 valid species under 2 genera *Derichthys* Gill, 1884 and *Nessorhamphus* Schmidt, 1931. They are mesopelagic eels distributed in all the three Oceans. This family is reported for the first time from the Indian EEZ through the present study with a single species under the genus *Nessorhamphus*.

Genus *Nessorhamphus* Schmidt, 1931

Type species: *Nessorhamphus* Schmidt, 1931 is *Leptocephalus ingolfianus* Schimdt, 1912 Sargasso Sea and the Azores, Northeastern Atlantic.

Diagnosis: Snout long with a spatulate tip; upper jaw well overhangs the lower jaw, interemaxillary teeth fully exposed as a subcircular patch: mouth oblique, rictus ends before midlevel of eye; dorsal-fin origin at anterior third of the body, posterior to a point above the tip of pectoral fin; anus positioned slightly posterior to mid-body; gill opening small, ventral slits just anterior to level of pectoral-fin base; eyes large and well developed; nostrils simple, in the form of pores; vomerine teeth irregularly multiserial anteriorly and becoming uniserial posteriorly; lateral line complete (Karmovskaya 1985; Robins 1989).

This genus constitutes 2 valid species: *N. danae* Schmidt, 1931 (Atlantic, Indo pacific absent in eastern pacific) and *N. ingolfianus* (Indian, Pacific & Atlantic) (Karmovskaya 1985). Present study reports a single species *Nessorhamphus danae* for the first time from Indian EEZ.

***Nessorhamphus danae* Schmidt, 1931**

Fig. 3.29, Table 3.23

Dana duckbill eel

Lectotype: 102 mm TL, ***Paralectotype:*** 86 mm, Indian Ocean west of Sumatra Island.

Collection locations: AS: 08°21.520’N, 76°14.101’E, 942 m, 21.10.2017, (Cr.366, St.03), HSDT-CV

Voucher specimen No.: 3660301 (CMLRE)

Diagnosis: Snout with a spatulated tip, snout length 34% HL; predorsal 20.5% TL, preanal 63%TL, head length 15.6% TL; presence of plicae on snout; lateral-line pores: prepectoral 11, predorsal 19, preanal 80 and total vertebrae 138.

Description: Body moderately elongated, slightly compressed and tail not attenuated ending in a small caudal fin. dorsal and anal fins continuous with caudal fin; dorsal-fin origin slightly behind the appressed pectoral fin, predorsal length 20.5% TL; anus positioned slightly posterior to the mid-body, preanal 63% TL; anal fin commences just behind the anus; pectoral fin moderately elongated, pectoral-fin length 36% HL; head elongated, its length

15.6% TL; snout elongated with a spatulate tip, its length 34% HL; presence of plicae on tip of snout and sensory ridges in postorbital and nape; eye large and oval in shape, 10% HL; upper jaw overhangs the lower jaw; mouth oblique, rictus not extending below the midlevel of eye; tongue free; anterior nostril non tubular slit, just posterior to premaxillaryethmoid tooth patch, posterior nostril also a slit located slightly posterior to anterior nostril; gill opening small just in front and below pectoral fin with slightly less interbranchial width, gill-oprning length 7% HL; lateral-line pores small inconspicuous: prepectoral 11; predorsal 19 and preanal 80; vertebrae: predorsal 20, preanal 81 and total vertebrae 138; head pores small conspicuous: SO 5, IO 7, POM 13 and ST 3; premaxillary tooth conical, slightly recurved in an oval patch of 6-8 transverse rows; vomerine teeth irregular 3-4 series anteriorly and uniserial posteriorly; maxillae with conical teeth decreasing in size posteriorly; mandibular teeth irregular, triserial anteriorly and unisrial posteriorly. Colour when fresh uniform black body, median fins black with pectoral fin and tip of caudal fin pale.

Distribution: Atlantic and Indo pacific absent in eastern pacific (Karmovskaya 1985; Robins 1989b); Indian EEZ: Arabian Sea (Present study [Figure 3.30]).

Remarks: New record of family and species from Indian EEZ; In comparison with Robins (1989b) there is slight variation in snout and head pores (IO & POM). Previous reports of *Nessorhamphus danae* are mostly based on larvae and elvers there are very few reports on adult specimens. Present report is the first collection of adult specimen from Indian Ocean region as well as largest of the specimen collected so far, all over the world. An adult specimen of 286 mm TL reported by Karmovskaya, 1895 is the largest of the specimen ever recorded. Our specimen is larger than the former and measure 346 mm TL.

Table 3.23: Comparison of morphometric and meristic characters of *Nessorhamphus danae* Schmidt, 1931 with previous study.

	Robins 1989 (n =4)	**Karmovskaya 1985 (n=8)**	**Present study (n=1)**
Total length (mm)	168-171	86-286	346
% TL			
Preanal length	60-61	60.8-64.7	63.0
Predorsal length	22-23	20.5-22.9	20.5
Head length	15-16	_	15.6
Trunk length	_	_	47.4
Depth at gill-opening	_	_	3.3
Depth at anus	3.7-5	3.8-4.7	4.5
% HL			
Snout length	38-40	35.9-39.7	34
Eye diameter	12	_	10
Interorbital width	_	_	11
Upper- jaw length	36-45	_	41
Lower- jaw length	_	_	26
Gill-opening length	_	_	7
Interbranchial width	_	_	6
Pectoral-fin length	_	_	36
Pectoral-fin base length	_	_	6
Meristic characters			
Lateral-line pores			
Prepectoral	_	9-10	11
Predorsal	_	17-19	19
Preanal	_	77-80	80
Head pores			
Supraorbital	5	_	5
Infraorbital	8	_	7
Preoperculomandubular	12	_	13
Supratemporal	3	_	3
Vertebrae			
Predorsal	_	_	20
Preanal	_	75-78	81
Total	134-145	136-141	138

Figure 3.29: *Nessorhamphus danae*:New record of family from Indian waters

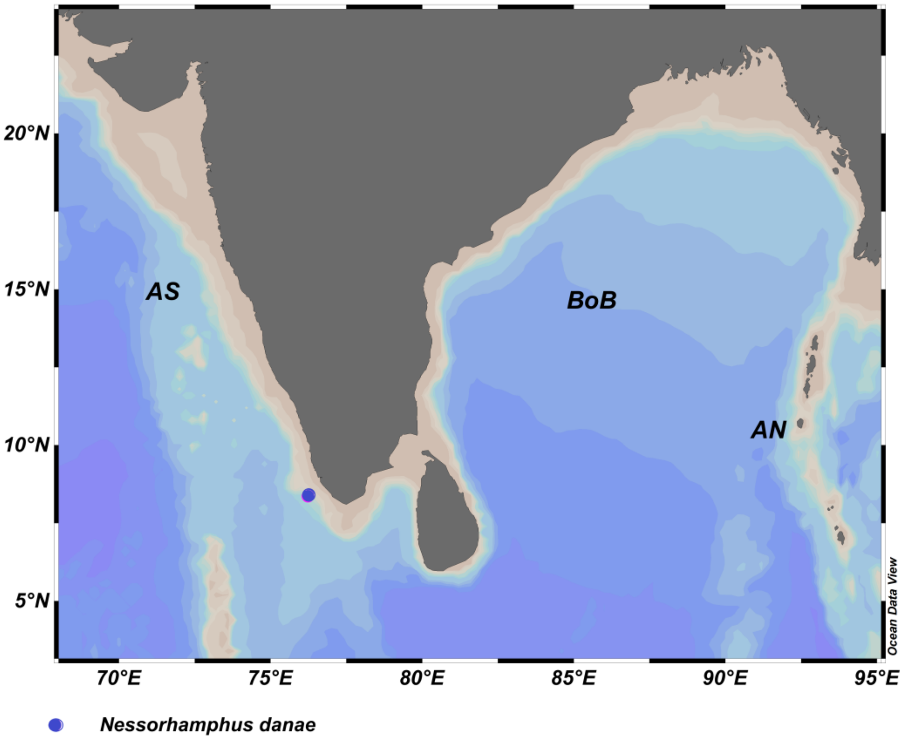

Figure 3.30: Map showing distribution of deep-sea eels of family Derichthyidae in the Indian EEZ.

IV. Family MURAENESOCIDAE Kaup, 1859

Pike congers

Diagnosis: Large to moderately large in size; heavy bodied; tail moderate with flexible tip; preanal length approximately 40% of TL; dorsal-fin origin over or slightly before or above gill opening; mouth very large and extending beyond eye; lips without fleshy flanges; gill opening large and located on lower half; interbranchial much lesser than the gill opening; lateral line complete; teeth large, sharp and multiserial on jaws; vomer in 3 rows with a median row of canines flanked on each side by a row of much smaller teeth (Smith 1989c; 1999a)

Family Muraenesocidae Kaup, 1859 comprises 9 valid species under 5 genera (Fricke et al. 2018a). They inhabit tropical and subtropical coastal to off shore waters of all seas (Castle & Willimson 1975; Smith 1999a). In India 5 species under 3 genera were previously reported. Among them 1 genus (*Sauromuraenesox* Alcock, 1889a) is exclusively deep-water inhabitant. The other two genera *Muraenesox* McClelland, 1844 and *Congresox*, Gill 1890 are frequently encountered in trawl catches from shallow depths from various fish landing centers around India.

Present study reports 2 species under 2 genera (*Sauromuraenesox* & *Muraenesox*) from deep-waters of Indian EEZ.

Genus *Muraenesox* McClleland 1844

Type species: *Muraenesox hamiltonii* McClleland, 1884 (by original designation); Bay of Bengal, India.

Diagnosis: Moderately elongate body, cylindrical anteriorly and compressed posteriorly; anus placed before mid-body; acute head; elongated snout; large gill slits; anterior nostril tubular positioned midway between snout tip and posterior nostril; posterior nostril in front of eye at mid eye level; vomer elongated with 3 rows of teeth. Middle teeth elongated and blade like with a distinct bulge at bases (Castle & Wiliamson 1975; Lin et al. 2013).

This genus constitutes 2 valid species *Muraenesox bagio* (Hamilton, 1822) and *Muraenesox cinereus* (Forsskål, 1775). Both the species have been reported previously from shallow waters of Indian EEZ. Present study reports *M. bagio* from deeper-water of Indian EEZ but *M. cinereus* was not encountered during this survey in deep waters.

Muraenesox bagio **(Hamilton, 1822)**

Fig. 3.31, Table 3.24
Common pike conger

Muraena bagio, Hamilton: 1822, valid as *Muraenesox bagio* (Hamilton, 1822) Estuaries of Ganges, India. No types known.

Synonyms: *Muraena bagio* Hamilton, 1822; *Muraenesox hamiltonii* McClelland, 1844; *Muraenesox yamaguchiensis* Katayama & Takai, 1954

Collection locations: AS: 09°59·575'N, 75°35.768'E, 214 m, 08.08.2010, (Cr.278, St.01), HSDT-CV

Voucher specimen No.: 2881739 (CMLRE)

Diagnosis: Narrow head; posterior nostril slightly nearer to eye than to anterior nostril; eye diameter 2.9 times in snout length; interorbital width

11.3 times the HL; preanal lateral-line pores 36; large and conspicuous teeth; total vertebrae 137.

Description: Body almost cylindrical anteriorly and compressed posteriorly with tapering tail; dorsal and anal fins well developed and continuous with caudal fin; dorsal-fin origin slightly before the pectoral fin base, predorsal 14.1% TL; anal fin commences immediately behind anus; pectoral fin well developed, pectoral-fin length 30.6% of HL; anus placed some what anterior to mid-body, preanal length 39.3% TL; head conical, 16.1% TL; snout elongated, narrow and fleshy, projects beyond the lower jaw, snout 26.7% HL; all the teeth are hidden when mouth is closed; tongue well attached to the floor of mouth; flange absent on upper and lower lips; rictus extends well beyond the posterior margin of eye; eye moderate, oval in shape, its horizontal diameter 9.1% HL; upper margin of eye near to the upper profile of head; anterior nostril tubular, placed at the midpoint of tip of upper jaw and posterior nostril on a slightly raised rim, slightly nearer to eye than anterior nostril positioned at mid-level; gill opening large and placed ventrally, with less interbranchial width, 6.6% HL; maximum depth at anus 5.5 % TL; lateral-line pores complete, discernible; predorsal 6, prepectoral 8 and preanal 36; Vertebrae predorsal 8, preanal 37 and total vertebrae 137; head pores not discernible due to shrinkage of the specimen ; teeth numerous and conical and granular; mandibular and maxillary teeth with several rows; vomerine teeth in three rows with enlarged and compressed blade like middle row having a wider base bordered by single row of small teeth on both sides. Color when fresh light grey to brown on dorsal side and paler on ventral side, median fins with black margin, pectoral fin blackish; formalin preserved specimen appears as dark brown dorsally and paler ventrally, fin colouration almost same as in fresh condition.

Distribution: Red Sea, Indian Ocean to North Western and South Western Pacific (Lin et al. 2013).

Indian EEZ: Arabian Sea (Hamilton 1822; Bijukumar & Deepthi 2009; Bijukumar & Raghavan 2015; present study [Figure 3.33]) Bay of Bengal (Mukherjee 1995; Chatterjee et al. 2000; Khan, 2003; Mishra & Krishnan 2003; Das et al. 2007); Andaman Sea (Rajaram et al. 2004)

Remarks: Katayama & Takai (1954) had reported a new species of pike conger *Muraenesox yamaguchiensis* from inland Sea of Japan which was later identified as *Muraenesox bagio* by Castle and Williamson (1975). This species usually inhabits coastal waters down to 100 m and in estuaries, over soft bottoms (Talwar & Kacker 1984; Smith 1999a). However, there are reports of their collection from waters deeper than 200 m depth from off southwestern Taiwan (Lin et al. 2013). Present study reports the bathymetric extension of this species towards deep-water of about 214 m depth in Indian EEZ. Comparison of present specimen with the data of (Lin et al. 2013) from Taiwan showed that present specimen has slightly longer head, hence the characteristics such as jaw length, interorbital length, eye diameter and interbranchial length proportions(% HL) shows some variations accordingly.

Table 3.24: Comparison of morphometric and meristic characters of *Muraenesox bagio* (Hamilton, 1822) with previous study.

	Lin et al. 2013 (n=7)	**Present study (n=1)**
Total length (mm)	383-855	639
% TL		
Preanal length	36.6-42.8	39.3
Tail	57.2-63.5	60.7
Trunk length	23-23.9	23.2
Predorsal length	14.1-14.4	14.1
Head length	14.1-14.6	16.1
Depth at gill-opening	4.6-5.1	4.7
Depth at anus	4.9*	5.5
% HL		
Interorbital width	9.2-10	8.8
Upper-jaw length	48.9-50	42.2
Lower-jaw length	44-46	39.2
Eye diameter	11.3-13.2	9.1
Snout length	26.1-29.2	26.7
Interbranchial width	10.6*	6.6
Pectoral-fin length	29.8-35.7	30.6
Meristics		
Lateral-line pores		
prepectoral	-	8
predorsal	6-7	6
Preanal	35-37	36
Vertebrae		
Predorsal	8-9	8
Preanal	37-38	37
Total	137-138	137

*Mean value

Genus *Sauromuraenesox* Alcock, 1889a

Type species: *Sauromuraenesox vorax* Alcock, 1899a (monotypic), Bay of Bengal, India

Diagnosis: Head and trunk large and deep; slender tail; dorsal-fin origin before pectoral-fin base; anus positioned and slightly posterior to mid-body; simple enlarged vomerine teeth with absence of cusps, serrations (Smith et al. 2017).

This genus is known only from, Northern Indian Ocean.

Sauromuraenesox vorax Alcock, 1889a

Fig. 3.32, Table 3.25

Holotype: ZSI 11672; 350 mm TL; Off Orissa, Bay of Bengal, India; 20°17'30"N, 88°51'E, Investigator station 14; 353 m

Topotypes: ZSI 13648, 13703; 300 & 310 mm TL; Bay of Bengal, Investigator station; 267–450 m.

Collection locations: AS: 09°59·935’N, 75°36.086’E, 200 m, 10.08.2011, (Cr.288, St.17), HSDT-CV

BoB: 10°57·946’N, 80°20.203’E, 645 m, 26.08.2010, (Cr.279, St.01), HSDT-CV; 11°7·66’N, 80°11.84’E, 540 m, 27.08.2010, (Cr.279, St.05), HSDT-CV; 13°13·26’N, 80°30.47’E, 307 m, 29.08.2010, (Cr.279, St.11), HSDT-CV; 13°14·0’N, 80°38.28’E, 311 m, 29.08.2010, (Cr.279, St.12), HSDT-CV; 17°07·190’N, 83°23.121’E, 567 m, 02.09.2010, (Cr.279, St.23), EXPO; 17°05·841’N, 83°21.15’E, 550 m, 02.09.2010, (Cr.279, St.24), EXPO; 17°05·310'N, 83°20.51'E, 550 m, 02.09.2010, (Cr.279, St.25), EXPO; 18°38·260'N, 85°06.830'E, 562 m, 28.10.2011, (Cr.291, St.02), EXPO; 18°49·831'N, 85°22.616'E, 629 m, 30.10.2011, (Cr.291, St.05), HSDT-CV; 18°52·681'N, 85°23.465'E, 462 m, 30.10.2011, (Cr.291, St.06), HSDT-CV; 11°54·788'N, 80°8.719'E, 645 m, 05.11.2011, (Cr.291, St.11), EXPO; 11°54·696'N, 80°08.649'E, 653 m, 09.11.2011, (Cr.291, St.17), EXPO; 14°09·200'N, 80°24.745'E, 225, 03.08.2014, (Cr.327, St.06), HSDT-CV; 14°56·721'N, 80°25.473'E, 230 m, 04.08.2014, (Cr.327, St.07), EXPO;

AN: 11°08·920'N, 92°19.650'E, 514 m, 19.09.2010, (Cr.280, St.17), EXPO

Voucher specimen No.: 3270611 (CMLRE)

Diagnosis: Head and trunk large and deep; slender tail; dorsal-fin origin before pectoral-fin base; anus positioned slightly posterior to mid-body; vomerine teeth conical, uniserial and slightly curved with a row of 4 teeth's; head pores SO 3 , POM 9, IO 4, and ST absent.

Description: Body moderately elongated, almost laterally compressed with a tapering tail; dorsal and anal fins well developed and continuous with caudal fin; dorsal-fin origin slightly before the pectoral-fin base, predorsal 17.2–20.4% TL; anal fin commences immediately behind anus; anus posterior to mid-body, preanal length 51–55.4% TL; pectoral fin well developed, pectoral-fin length 22–27.5% of HL; head large and deep, slightly compressed, head length 23.1–25.8% TL; snout moderately elongated, 18.8–22.7% HL; snout tip slightly overhung the lower jaw; all teeth are concealed when mouth closed; tongue not free; mouth large, rictus extends far behind the posterior margin of eye; eye well developed almost circular in shape, horizontal eye diameter 8.7–10.3% HL; anterior nostril sub tubular placed somewhat high on snout just behind its notch, posterior nostril circular with a small rim and placed well above the lip in front of eye at mid-level; gill opening large and deep 18.7–21.4% HL; maximum depth at gill opening 6.9–7.8% TL; lateral-line pores small and inconspicuous: prepectoral 12–13, predorsal 9–10 and preanal 49–52; head pores small and inconspicuous: SO 3; IO 4; POM 9 and ST absent; vertebrae: predorsal 10, preanal 54 and total veretebrae 129; teeth sharp, pointed and variable in size; intermaxillary teeth with a row of 5 teeth, middle one is large and teeth on both sides are small; vomerine teeth with a row of 4 slightly backward curved teeth, with an increase in size towards posteriorly; maxillary teeth small and conical, originates just behind the posterior vomerine teeth and are uniserial anteriorly and posteriorly and triserial in middle, with a inner row of small teeth in posterior region lateral to the other teeth's; mandibular teeth begins with two slightly curved large teeth at their tip on both sides which fix in between inter-maxillary and vomerine teeth when mouth is closed, followed by a row of small uniseraial teeth; fresh coloration greyish to dark brown body, dorsal and anal fins dark edged posteriorly and dark pectoral fin.

Distribution: Northern Indian Ocean: Oman, Arabian Sea (Smith et al. 2017).

Indian EEZ: Arabian Sea (Venu 2009; present study [Figure 3.33]) Bay of Bengal (Alcock 1889a; Talwar 1977; Present study [Figure 3.33]) Andaman Sea (present study [Figure 3.33]).

Remarks: *Sauromuraenesox vorax* Alcock, 1889a was described based on a single specimen from Bay of Bengal waters. Later Alcock (1899) added two more specimens from the same region. Further Talwar (1977) redescribed this species by including Alcock's specimens as well as 34 specimens collected from off Madras. For a long period this species was known to be restricted to Bay of Bengal waters only till Venu (2009) recorded this species from South Eastern Arabian Sea based on 3 specimens collected by FORV SS. Recently (Smith et al. 2017) recorded this species with 3 specimens collected from Oman, North Western Arabian Sea and also examined two additional specimens from Arabian Sea and Bay of Bengal waters deposited at ANSP Museum. Present study reports this species from Arabian Sea, Bay of Bengal and Andaman Sea. The record of this species from Andaman Sea extends the geographic distribution further towards Eastern Indian Ocean.

Table 3.25: Comparison of morphometric and meristic characters of *Sauromuraenesox vorax* Alcock, 1889 with previous study.

	Smith et al. 2017 (n=5)	Talwar 1977 (n=37)	Present study (n=8)		
			Range	Mean	SD
Total length (mm)	238-415	200-353	336-504		
% TL					
Preanal length	46.6-55.6	49.0-57.6	51-55.4	53.7	1.5
Predorsal length	16.4-19.3	17.0-19.1	17.2-20.4	19.3	1.1
Head length	19.7-24.3	20.7-24.0	23.1-25.8	24.7	1.1
Trunk length	-	-	27.2-31.4	28.9	1.2
Depth at gill-opening	6.9-7.6	5.6-10.2	6.9-7.8	7.2	0.5
Depth at anus	3.4-4.8	4.1-5.1	3.3-4.6	4.1	0.5
% HL					
Snout length	18.9-21.7	-	18.8-22.7	20.8	1.5
Eye diameter	8.5-9.5	-	8.7-10.3	9.3	0.9
Interorbital width	12-14.1	-	10.4-15.3	12.2	1.7
Upper-jaw length	29.9-35.3	-	33.8-40.4	37.4	2.1
Lower-jaw length			32.5-37.2	35.4	1.5
Gill-opening length	15.1-20.1	-	18.7-21.4	19.3	1.9
Interbranchial width	1.4-5	-	3.5-5.4	4.3	0.9
Pectoral-fin length	24.4-29.6	-	22-27.5	24.0	2.1
Pectoral-fin base length	-	-	4.6-7.7	5.8	1.2
Meristics					
Lateral-line pores					
Prepectoral	-	-	12-13		
Predorsal	-	-	9-10		
Preanal	-	-	49-52		
Head pores					
Supraorbital	3	-	3		
Infraorbital	4	-	4		
Preoperculomandubular	9	-	9		
Supratemporal	0	-	0		
Vertebrae					
Predorsal	8-10	-	10		
Preanal	49-55	-	54		
Total	127-130	-	129		

Family Muraenesocidae

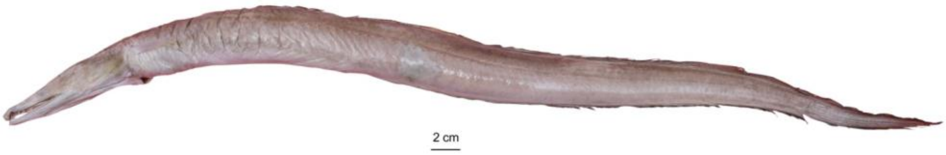

Figure 3.31: *Muraenesox bagio*: First report from deep-waters of Indian EEZ, previously reported from shallow-waters

Figure 3.32: *Sauromuraenesox vorax*: New record from Andaman Sea; Widely distributed in Indian EEZ

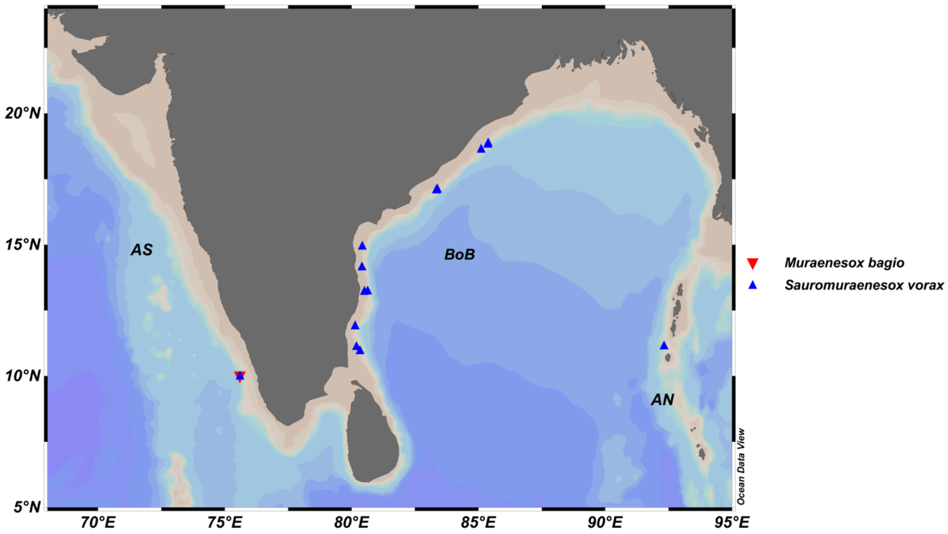

Figure 3.33: Map showing distribution of deep-sea eels of family Muraenesocidae in the Indian EEZ

V. Family NEMICHTHYIDAE Kaup, 1859

Nemichthyids are elongated and highly modified eels occupying the mid waters of all Oceans except the polar Seas, adults are found at depths of several hundred to more than 4000 m. (Nielson & Smith 1978; Nelson 2006). Currently there are 9 valid species among 3 genera (*Nemichthys* Richardson, 1848, *Avocettina* Jordan & Davis 1891 & *Labichthys* Gill & Ryder 1883) (Nielson & Smith 1978)

In Indian EEZ 2 genera (*Avocettina* & *Nemichthys*) have been reported from this family.

Genus *Avocettina* Jordan & Davis, 1891

Type species: *Nemichthys infans* Günther 1878 (by original designation), Mid Atlantic Ocean.

Diagnosis: Body elongate and strongly compressed; posterior end of the tail not filamentous; dorsal-fin origin behind pectoral base (slightly before in mature males); anterior dorsal fin rays are closely arranged than the remainder; anus well posterior to pectoral fin; lateral-line pores in a single row; presence of numerous dermal ridges on head; upper jaw much longer than lower jaw, their tip slightly expended to form a small spatulate knob (Nielson & Smith 1978; Smith & Nielson 1989).

This genus comprises 4 valid species, *A. acuticeps* (Regan, 1916) (Southrern hemisphere); *A. bowersii* (Garman, 1899) (Eastern Pacific); *A. infans* (Günther, 1878) (Circumglobal distribution) and *A. paucipora* Nielsen & Smith, 1978 (Southern Ocean) (Fricke et al. 2018a). Indian EEZ represents a single species *A. infans* (Günther, 1878).

Avocettina infans (Günther 1878)

Fig. 3.34, Table 3.26

Avocet snipe eel

Synonyms: *Labichthys elongatus* Gill & Ryder, 1883; *Avocettina exophthalma* Parr, 1932; *Labichthys gilli* Bean, 1890; *Nemichthys infans* Günther, 1878; *Avocettinops normani* Bertin, 1947; *Leptocephalus oxycephalus* Pappenheim, 1914; *Avocettinops schmidti* Roule & Bertin, 1924

Collection locations: AS: 12°20·743'N, 74°19.010'E, 909 m, 22.08.2012, (Cr.305, St.06), HSDT-CV ; 11°04·195'N, 74°55.430'E, 1000 m, 08.01.2014, (Cr.322, St.02), HSDT-CV; 08°53·593'N, 75°27.288'E, 1000 m, 11.01.2014, (Cr.322, St.08), HSDT-CV; 07°51·476' N, 76°24.880'E, 1345 m, 26.07.2014, (Cr.327, St.02), HSDT-CV;

BoB: 10°58·428'N, 80°19.779'E, 652 m, 06.11.2011, (Cr.291, St.13), EXPO; 10°57·418'N, 80°28.114'E, 1131 m, 31.07.2014, (Cr.327, St.04), HSDT-CV

Voucher specimen No.: 3270412 (CMLRE)

Holotype*:* BMNH 1887.12.7.259, Mid Atlantic, 5°48'N, 14°20'W, Challenger stn. 101, 4572 m

Diagnosis: Upper jaw much longer than lower jaw; dorsal-fin origin behind pectoral base; anus well posterior to pectoral fin; posterior end of the tail not filamentous; lateral-line pores in a single row; presence of sensory ridges on head; predorsal lateral line pores 7; eye diameter 40.4–43% of postorbital ; predorsal 32.5–35% of PAL.

Description: Body elongate and strongly compressed, posterior end of the tail not filamentous; dorsal and anal fin continuous with caudal fin; dorsal-fin origin behind pectoral fin base, anterior most rays of dorsal fin more closer than posterior ones; predorsal length 32.5–35% PAL; anal fin originates just after anus; anus well posterior to pectoral fin; pectoral fin well developed, its length more than half the length of postorbital distance of head; head broad with many sensory ridges situated on snout, behind anterior nostril, behind eye, occiput, and on nape; eye moderately large almost circular in shape its ventral region is close to margin of upper jaw and dorsal region is near upper profile of head; eye 40.4–43% postorbital length; Jaws slender and non occlusible, upper jaw much longer than lower jaw with its tip slightly expanded to form a small spatulate knob; mouth moderate, rictus ends below posterior margin of eye; tongue not free; anterior nostril short tube positioned laterally on side of head just in front of eye at midlevel, posterior nostril a small slit just behind and above the anterior nostril and is placed above the mid level of eye; gill opening crescentic, located in front of and below the pectoral fin; SL_{100} 55-57.5% TL; lateral-line pores small and inconspicuous in a single row; prepectotral 4, predorsal 7; preanal 18; total pores 185; cephalic pores small difficult to count: SO 5–6; suborbital 6–8; post orbital 3–4; preopercular 2–3; ST 1 teeth on jaws small, numerous, closely arranged and posteriorly directed in diagonal rows; maxilla short not reaching midpoint of ethmovomer, less than half length of mandible; anterior end closely appressed to ethmovomer, toothed surface rotated outward anteriorly; anterior teeth of ethvomer expended to spatulate knob; mandible slender and decurved anterior tip expanded to spatulate knob; colour when fresh is uniform brown to black, fins blackish.

Distribution: Circumglobal species occurring in tropical and temperate Seas (Smith & Nielsen 1989); Indian EEZ: Arabian Sea (Kotthaus 1968; present study [Figure 3.36]); Bay of Bengal (Present study [Figure 3.36]); Andaman Sea (Rajan et al. 2013)

Remarks: Widely distributed in Indian EEZ; Kotthaus (1968) reported this species from Goa, Northeastern Arabian Sea in the name *Borodinula infans* (Günther, 1878) which is a synonym of *Avocettina infans* (Günther, 1878). Venu (2009) and Hashim (2012) reported *Avocettina paucipora* Nielson & Smith 1978 from Arabian Sea which is restricted only to southern Ocean, most probably they misidentified, *A. infans* as *A. paucipora.*

Table 3.26: Comparison of morphometric and meristic characters of *Avocettina infans* (Günther 1878) with previous study.

	Smith & Nielsen 1989	**Present study (n=5)**		
		Range	**Mean**	**SD**
Total length	220-745	320-530		
SL_{100} (mm)	95-373	184-305		
% PAL				
Predorsal length	21-39	32.5-35	33.6	1.0
% TL				
SL_{100}	47-58	55-57.5	56.6	1.2
% postorbital				
Eye diameter	24-47	40.4-43	41.9	1.0
Meristics				
Head pores				
Supraorbital	5-8	5-6		
Suborbital	6-10	6-8		
Postorbital	2-4	3-4		
Preopercular	2-3	2-3		
Supratemporal	1	1		
Lateral-line pores				
Prepectoral	3-8	4		
Predorsal	5-8	7		
Preanal	16-26	18		
Total	181-201	188		

Genus *Nemichthys* Richardson, 1848

Type species: *Nemichthys Scolopacea* Richardson, South Atlantic off Brazil.

This genus constitutes 3 valid species: *Nemichthys scolopaceus* Richardson, 1848 and *Nemichthys curvirostris* (Strömman, 1896) (circumglobal distribution); *Nemichthys larseni* Nielsen & Smith, 1978 (Central and eastern Pacific) (Fricke et al. 2018a).

Diagnosis: Tail elongated, slender and filament like; dorsal fin spine like and its origin ahead of pectoral-fin base; anus located under pectoral fin; sensory ridges absent on head; upper jaw slightly longer than lower jaw but not highly expanded; lateral-line pores as set of 5 in the form of rectangle and 5th pore lies in the middle result in 3 longitudinal rows over the body (Nielson & Smith 1978). Indian EEZ represents only a single species *N. scolopaceus*.

Nemichthys scolopaceus Richardson, 1848

Fig. 3.35, Table 3.27

Slender snipe eel

Synonyms: *Nemichthys acanthonotus* Alcock, 1894b; *Leptocephalus andreae* Schmidt, 1912; *Nemichthys avocetta* Jordan &Gilbert, 1881; *Leptocephalus canaricus* Lea, 1913; *Cercomitus flagellifer* Weber, 1913; *Nemichthys fronto* Garman, 1899; *Leptorhynchus leuchtenbergi* Lowe, 1851; *Nemichthys mediterraneus* Ariola, 1904; *Nematoprora polygonifera* Gilbet, 1905; *Nemichthys scolopacea* Richardson, 1848; *Paravocettinops trilinearis* Kanazawa & Maul, 1967

Collection locations: AS: 08°21·601'N, 76°10.171'E, 995 m, 12.10.2010, (Cr.281, St.03), HSDT-CV; 12°20·743'N, 74°19.010'E, 909 m, 22.08.2012, (Cr.305, St.06), HSDT-CV; 08°31·775'N, 75°59.743'E, 1045 m, 12.12.2013, (Cr.321, St.20), HSDT-CV; 08°05·718'N, 76°25.842'E, 1000 m, 12.01.2014, (Cr.322, St.09), HSDT-CV; 08°29·844'N, 76°01.289'E, 1024 m, 03.11.2014, (Cr.331, St.02), HSDT-CV; 08°04·971'N, 76°07.555'E, 1397 m, 04.11.2014, (Cr.331, St.03), HSDT-CV; 08°21·335'N, 76°08.562'E, 1055 m, 20.10.2017, (Cr.366, St.01), HSDT-CV; 08°21.520'N, 76°14.101'E, 942 m, 21.10.2017, (Cr.366, St.03), HSDT-CV

BoB: 11°07·660'N, 80°11.840'E, 540 m, 27.08.2010, (Cr.279, St.05), HSDT-CV; 11°54·788'N, 80°08.719'E, 645 m, 05.11.2011, (Cr.291, St.11), EXPO; 10°55·957'N, 80°21.519'E, 650 m, 08.11.2011, (Cr.291, St.16), EXPO

AN: 12°49·602'N, 93°12.782'E, 441 m, 17.09.2010, (Cr.280, St.16), EXPO; 11°04·785'N, 92°21.909'E, 530 m, 15.01.2015, (Cr.334, St.11), HOT; 11°25.893'N, 92°20.210'E, 576 m, 04.04.2016, (Cr.349, St.01), HOT; 07°28·734'N, 93°24.510'E, 650 m, 04.04.2016, (Cr.349, St.02), HSDT-CV; 11°10·950'N, 92°20.180'E, 520 m, 14.04.2016, (Cr.349, St.10), HSDT-CV; 07°16·698'N, 93°26.511'E, 588 m, 14.11.2017, (Cr.367, St.03), HSDT-CV; 13°15·902'N, 93°15.827'E, 635 m, 26.11.2017, (Cr.367, St.08), HSDT-CV

Voucher specimen No.: 3670807 (CMLRE)

Holotype: BMNH 1871.7.16.1., South Atlantic off Brazil;

Diagnosis: Body extremely elongate and slightly compressed, posterior end of the tail filamentous; upper jaw slightly longer than lower jaw; tip of the jaw without a spatulate knob; dorsal fin origin ahead of pectoral-fin base, dorsal fin rays strong and spine like; anus under pectoral fin; anal fin commences just behind the anus; absence of dark subcutaneous vertical bars between vertebrae; absence of dermal ridges on head; lateral-line pores in 3 longitudinal with 2 dorsal and ventral rows above and below a median row forming a nearly square with 5 pores per segment; predorsal 55.8–62.5% of postorbital; postorbital 2–5.5% as SL_{200}.

Description: Body extremely elongated, moderately compressed with greatly attenuated and filamentous tail; dorsal and anal fins confluent with caudal fin, caudal fin not distinct; dorsal-fin origin ahead of pectoral-fin base, dorsal fin rays spine like; predorsal 55.8–62.5% postorbital; anal fin originates just after anus; anus positioned below anterior region of pectoral fin; preanal 4.1–5.2% $SL_{200;}$ postorbital 2– 5.5% SL_{200}; pectoral fin well developed, its length more than half the length of postorbital distance of head; head broad and devoid of dermal ridges, its greatest depth is slightly more than double the horizontal diameter of eye; absence of subcutaneous vertical bars in between the vertebrae; eye large almost circular in shape its ventral region is close to margin of upper jaw and dorsal region is near upper profile of head; eye 25.2–28.5% postorbital; jaws and snout produced into a long, non occlusible pointed beak but not spatulate at the tip; upper jaw almost equal to lower jaw; mouth large, rictus ends further back slightly behind posterior margin of eye; tongue attached to mouth floor; anterior nostril as slit , positioned laterally on side of head just in front of eye at midlevel, posterior nostril a small slit just behind and above the anterior nostril and is placed well above the midlevel of eye; gill opening crescentic, located in front of and below the pectoral fin; teeth on jaws small and numerous and bears a posteriorly directed cusp; lateral-line pores in 3 longitudinal with 2 dorsal and ventral rows above and below a median row forming a nearly square with 5 pores per segment; vertebrae: prepectoral 9, predorsal 3; preanal 10 and total vertebrae not discernable; cephalic pores small difficult to count: SO 12–14; suborbital 17–18; postorbital 11–12; preopercular 4–5 and ST 8; teeth on jaws small, numerous, with recurved tips and arranged as diagonal rows on maxilla, dentaries and ethmovomer; ethmovomer greatly elongated which forms upper half of beak; maxillary tooth band less than half the length of toothed portion of ethmovomer; dentaries produced as lower half of beak, toothed for entire length without spatulated knob. Colour when fresh is brown darker ventrally and pale dorsally. Median and pectoral fins pale.

Distribution: Circumglobal species occurring in tropical and temperate Seas (Smith & Nielsen 1989).

Indian EEZ: Arabian Sea (Alcock 1899;Venu 2009; Hashim 2012; Present study [Figure 3.36]); Bay of Bengal (Alcock 1894b; Hashim 2012; Present study [Figure 3.36]) Andaman Sea (Hashim 2012; Present study [Figure 3.36]).

Remarks: Widely distributed in Indian EEZ, abundant in mesopelagic zones. The tail of this species is extremely elongate and filamentous, hence most of the specimens are collected with broken tail. Jaws are also slender unlike other members of the order Anguilliformes which also gets damaged during sampling.

Table 3.27: Comparison of morphometric and meristic characters of *Nemichthys scolopaceus* Richardson, 1848 with previous study.

		Present study (n=8)		
	Smith & Nielsen 1989	**Range**	**Mean**	**SD**
SL_{200} (mm)	108-732	112-683		
% SL $_{200}$				
Preanal length	4-9	4.1-5.2	4.8	0.4
Predorsal length	2-5	2-3.8	2.9	0.7
Eye diameter	1-2	1-1.7	1.4	0.3
Postorbital length	2-7	2-5.5	4.1	1.4
% postorbital				
Eye diameter	18-51	25.2-28.5	27.0	1.2
predorsal length	37-96	55.8-62.5	59.5	2.5
Meristics				
Head pores				
Supraorbital	7-22	12-14		
Suborbital	10-23	17-18		
Postorbital	3-20	11-12		
Preopercular	2-18	4-5		
Supratemporal	2-8	8		
Vertebrae				
Prepectoral	5-12	9		
Predorsal	2-5	3		
Preanal	9-15	10		

Family Nemichthyidae

Figure 3.34 *Avocettina infans*: New record from Bay of Bangal

Figure 3.35 *Nemichthys scolopaceus*: Widely distributed in Indian EEZ

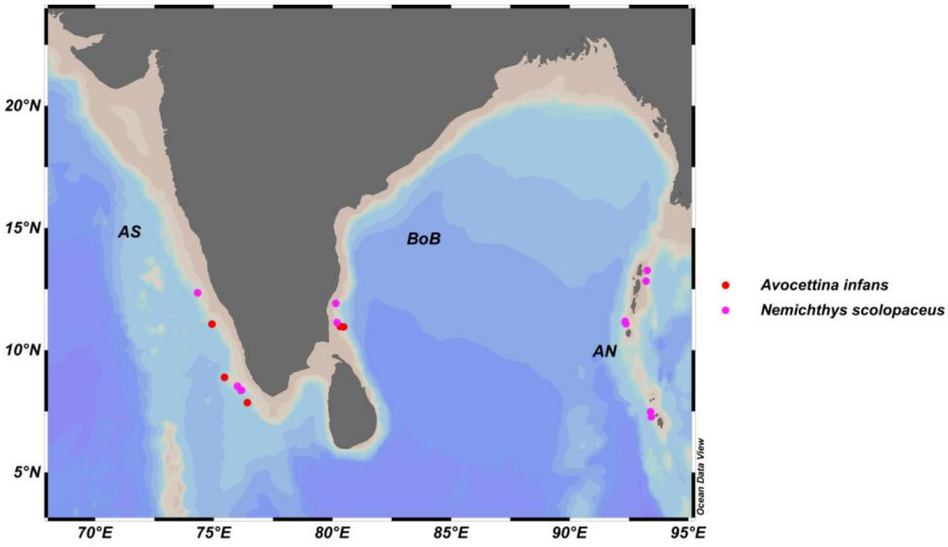

Figure 3.36: Map showing distribution of deep-sea eels of family Nemichthyidae in the Indian EEZ

VI. Family NETTASTOMATIDAE kaup, 1859

Duckbill eels

Diagnosis: Elongate body; anus before mid-body; dorsal-fin origin over or slightly behind gill opening; slender and attenuated tail; slender head; snout and jaws elongated; snout projects beyond the tip of lower jaw; enlarged mouth and gape extends to about rear margin of eye; no fleshy flanges on upper and lower lips; few teeth exposed when mouth closed; pectoral fin present or absent (Smith 1989d).

The family Nettastomatidae Kaup 1859 represents 46 valid species under 6 genera (*Facciolella* Whitley 1938, *Hoplunnis* Kaup 1859, *Nettastoma* Rafinesque 1810, *Nettenchelys* Alcock 1898, *Venefica* Jordan & Davis 1891 & *Saurenchelys* Peters 1864) (Fricke et al. 2018a). They mostly inhabit outer continental shelf and the continental slope of tropical and warm temperate Oceans (Smith et al. 1981; Nelson 2006). Two genera have been reported from deep-waters of India, *Venifica* Jordan & Davis 1891 and *Nettenchelys* Alcock, 1898. Present study reports 4 genera with the addition of 2 more genera *Nettastoma* Rafinesque, 1810 and *Facciolella* Whitley, 1938 to the Nettastomatid fauna of India.

Genus *Facciolella* Whitley, 1938

Type species: *Nettastomella physonema* Facciolà, 1914 = *Leptocephalus oxyrhynchus* Bellotti,1883 now valid as *Faciolella. Oxyrhynchus* (Bellotti, 1883).

Diagnosis: Elongate body with slender and frequently damaged tail; anus near anterior third of TL; dorsal fin origin distinctly behind the level of gill opening; absence of pectoral fin; gill opening crescentic; posterior nostril a longitudinal slit on upper lip in front of eye (Smith 1989d).

This genus comprises 5 valid species: *F. oxyrhynchus* (Bellotti, 1883) (Mediterranean Sea, Eastern Atlantic); *F. equatorialis* (Gilbert, 1891) (Eastern Pacific); *F. saurencheloides* (D'Ancona, 1928) (Red Sea, Indian Ocean); *F. castlei* Parin & Karmovskaya, 1985 (Southeastern Pacific) and *F. karreri* Klausewitz, 1995 (Red Sea, endemic) (Fricke et al. 2018a). In addition to this Smith & castle (1982) have been reported 6 different leptocephali without names (*Facciolella* spp. A-F) and Ho et al. (2018a) recently mentioned about two adult species of *Facciolella* to be described in near future from Taiwan waters. In India there is no representative for this genus. Present study added the genus *Facciolella* to the Indian fauna as well as contributes a new species to the science.

***Facciolella* sp. G (New species)**

Fig. 3.37, Table 3.28

Indian duckbill eel

Collections locations: AN: 11°15·550'N, 92°20.440'E, 392 m, 15.01.2015, (Cr.334, St.10), HOT

Voucher specimen No.:3341008 (CMLRE)

Diagnosis: Elongated, laterally compressed on head and tail and cylindrical before anus; dorsal-fin origin slightly ahead of gill opening, predorsal 15% TL; anus well before mid-body, preanal 35.1% of TL; maximum depth at gill opening 3.7% TL; lateral-line pores: predorsal 13, pregill 17, preanal 50; total vertebrae 194+; head pores: SO 5, IO 9, POM 11, ST 3; body colour when fresh, light brown dorsally and pale white ventrally with numerous black melanophore pigmentation.

Description: Body elongated, laterally compressed in head, cylindrical before anus and gradually tapering and laterally compressed along the tail; dorsal and anal fin continuous with caudal fin; dorsal-fin origin slightly ahead of gill opening, predorsal 15% of TL; anus placed well before mid-body, preanal 35.1% TL; anal fin commences just after the anus; head elongated and pointed and gently sloping towards the snout, head length 16.1% TL; snout elongate with soft tip, 26.8% HL; eye moderate and oval in shape, 6.1% HL; anterior nostril tubular, positioned laterally near tip of the snout. Posterior nostril a long horizontal slit placed infront of ventral margin of eye under a cutaneous fold, terminating under its mid-level; flanges absent on upper and lower lip; mouth inferior, rictus ends slightly beyond the posterior margin of eye; upper jaw overhangs the lower jaw, lower jaw fits into the tooth less gap behind the intermaxillary teeth; tongue well attatched to the mouth floor; gill opening crescentic positioned on latroventral side of the body, gill-opening length 6.8% HL; interbranchial width less than gill opening which is 2% HL; depth at gill opening greater than depth at anus (3.7% vs. 2.4% TL); lateral-line pores small conspicuous: predorsal 13, pregill

17 and preanal 50; vertebrae: predorsal 14, preanal 52 and total vertebrae 194^+; head pores conspicuous: SO 5, IO 9, POM 11 and ST 3 teeth conical, maxillary and mandibular and vomerine teeth in bands; intermaxillary tooth patch short, firmly connected to anterior maxillary teeth. Colour when fresh is light brown on dorsal half and pale white on ventral half, silver colouration with yellow tinge on ventral side of head after the mandible and terminates just prior to the preopercular region; whole body with small black melanophore pigmentation; dorsal and anal fins pale, caudal fin blackish.

Distribution: Known only from the type specimen collected from Andaman Sea of Indian EEZ. Present study [Figure 3.41]

Discussion*:* As mentioned above this genus includes 5 valid species. Present new species differ from Mediterranean, Eastern Atlantic species *F. oxyrhynchus* (Bellotti, 1883) in having more number of pregill lateral-line pores (17 vs. 7–11), more number of ST pores (3 vs. 1) and less total vertebrae (194+ vs. 240–250) and in body colouration. It differs from Eastern Pacific species *F. castlei* Parin & Karmovskaya, 1985 in more anterior origin of dorsal fin (dorsal fin originates at 13th lateral-line pores vs. dorsal fin origin further back at 17th lateral-line pore), larger head (45.8 % vs. 34.5% of PAL), less number of preanal pores (50 vs. 64), less number of POM pores (11 vs.12) and also in less number of vertebrae (194+ vs. 242). Present species differ from Eastern Atlantic species *F. equatorialis* (Gilbert, 1891) in having larger head (45.8% vs. 37.4% of PAL), more anterior origin of dorsal fin, lesser number of predorsal, preanal and total vertebrae (14, 52 & 194+ vs. 18, 57 & 247) and in absence of dark band along the midline of belly. Present new species have similar pre-anal pores with endemic species of Red Sea *F. karreri* Klausewitz, 1995 (50 vs. 51–52) but differ in greater number of total vertebrae (194+ vs. 166–184), more number of ST pores (3 vs. 1), position of dorsal fin origin (originates before gill opening vs. originates half the snout length posterior to gill opening) and larger head (45.8% vs. 36.2% PAL). Present new species is similar to Red Sea and Indian Ocean species *F. saurencheloides* (D'Ancona, 1928) in number of preanal pores (51 vs. 49–51) but differs in other characteristics such as anterior origin of dorsal fin (slightly before gill opening vs. one snout length posterior to gill opening), larger head (45.8% vs. 28.5–32% of PAL) and greater number of IO and ST pores (9 vs. 7 & 3 vs. 1 respectively) and finally lesser number of vertebrae (194+ vs. 235–250).

In addition to 5 valid species of *Facciolella* Smith & castle (1982) have been reported 6 different leptocephali without names (*Facciolella* sp. A-F). They all differ from F.sp.G in more number of total myomere counts.

Remarks: *Facciolella* sp. G is New to Science; it represents a new record of the genus Facciolella from Indian EEZ.

Table 3.28: Morphometric and meristic characters of *Facciolella* sp. G (New species)

	Present study (n=1)
Total length(mm)	473
% TL	
Preanal length	35.1
Predorsal length	15.0
Head length	16.1
Trunk length	19.0
Depth at gill-opening	3.7
Depth at anus	2.4
% HL	
Snout length	26.8
Eye diameter	6.1
Interorbital width	4.3
Upper-jaw length	34.5
Lower-jaw length	32.5
Gill-opening length	6.8
Interbranchial width.	2.0
Meristics	
Lateral-line pores	
pregill	17
predorsal	13
Preanal	50
Head pores	
Supraorbital	5
Infraorbital pores	9
Preoperculomandubular	11
Supratemporal	3
Vertebrae	
Predorsal	14
Preanal	52
Total	194^+

Genus *Nettastoma* Rafinesque, 1810

Type species: *Nettastoma melanura* Rafinesque 1810; Sicily, Italy, Mediterranean Sea.

Diagnosis: Posterior nostril placed dorsally to the top of the head; body deepest in the middle and tapering at both ends; snout with 11–14 pores along the upper jaw; fifth supraorbital pore present; tip of the snout without a prominent fleshy proboscis (Smith et al. 1981).

The genus *Nettastoma* contains 5 valid species: *N. solitarium* Catle & Smith, 1981 and *N. parviceps* Günther, 1877 (Indo-Pacific), *N. syntressis* Smith & Böhlke, 1981 and *N. melanurum* Rafinesque, 1810 (Atlantic) and *N. falcinaris* Parin & Karmovskaya, 1985 (South Eastern Pacific) (Smith et al. 1981; Sumod et al. 2016). Present study reports this genus for the first time from Indian EEZ by the addition of a single *species N. solitarium* Castle & Smith, 1981 from Andaman Sea.

Nettastoma solitarium Castle & Smith, 1981

Fig. 3.38, Table 3.29
Solitary duckbill eel

Holotype: MNHN 1979-0187, 457 mm TL, 415–510 m, MUSORTOM Philippines 50; ***Paratypes*:** MNHN 1979-0188, (465 mm TL: incomplete), 448–484 m, MUSORTOM Philippines 43; MNHN 1979-0188, (405 mm TL: incomplete), 610–592 m, MUSORTOM Philippines 44; AMS I.20301-016, (320 mm TL: incomplete), 502 m, Australia.

***Collection locations:* AN:** 12°49·602’N, 93°12.782’E, 441 m, 17.09.2010, (Cr.280, St.16), EXPO

Voucher specimen No.: 2801617 (CMLRE)

Diagnosis: Six supraorbital pores; fifth supraorbital (SO5) present; pre anal lateral-line pores 43; median vomerine teeth somewhat enlarged; posterior nostril above anterodorsal region of eye.

Description: Body elongate and deepest in the middle, round in cross section and laterally compressed along the tail; tail greatly attenuated; dorsal and anal fins continuous with caudal fin; dorsal-fin origin just above the gill opening, predorsal 36.8% PAL; anus positioned anterior to mid-body, preanal length 41.8% TL; anal fin commences just after the anus; pectoral fin absent; head slender, its length 38.4% PAL; snout elongated, 39% HL; eye oval in shape, its horizontal diameter 7.5% HL; anterior nostril tubular situated near tip of snout, posterior nostril placed in anterodorsal region of eye; upper jaw slightly protruded and lower jaw fits just behind intermaxillary teeth; tongue free; flange absent on upper and lower lips; rictus extends well beyond the posterior margin of eye; lateral-line pores small conspicuous: predorsal 6, preanal 43; vertebrae not discernible; head pores small but conspicuous, SO 6, IO 13 , POM 19, ST 3, SO_5 present; maxillary and mandibular teeth in bands, the inner teeth larger; intermaxillary tooth patch short, continuous with maxillary teeth; vomerine tooth patch elongate, reaching level of eye, median teeth somewhat enlarged, but not forming a single row, pterygoid teeth absent; colour (in formaldehyde): body light brown with darker opercular region, dorsal and anal fins black edged and fully black at end of caudal region.

Distribution: Indo-West Pacific: Comoros to Madagascar, South China Sea, Philippines, Taiwan, Hawaiian Islands, Japan & New Zealand (Smith et al. 1981; Smith 1989d; Karrer 1983; Paulin et al. 1989; Asano 1984; Machida 1984; Smith 1999e; Nakabo 2000; Shinohara et al. 2005; Mundy 2005; Ho et al. 2015b).

Indian EEZ: Andaman Sea (Sumod et al. 2016).Present study [Figure 3.41]

Remarks: Karrer (1983) recorded *N. solitarium* from Mozambique Channel, along the coast of Madagascar under the name *N. melanurum* Rafinesque, 1810. Present study reported the presence of the genus *Nettastoma* from Indian EEZ; *N. solitarium* was previously reported from the Western Pacific and Western Indian Ocean. The present record of *N. solitarium* from the Andaman Sea extends the biogeographical distribution of this species to tropical waters of the Eastern Indian Ocean. This species may be more widespread than presently known. The tooth pattern and all meristic characters of the present specimen are exactly the same as in the type specimens described by Smith et al. (1981). However, it is worthwhile pointing out that certain morphometric measurements, such as snout length, eye diameter, depth at anal origin, gill opening and interbranchial distance, differ to some extent in the present specimen. It is also noted that the body shape of the present specimen is affected by formalin preservation. A careful examination of available specimens should be made to standardize the range of morphometric and meristic characteristics of this species.

Table 3.29: Comparison of morphometric and meristic characters of *Nettastoma solitarium* Castle & Smith, 1981 with previous study.

	Smith et al. 1981 (n=4)	Present study (n=1)
Total length (mm)	-	455
Preanal length (mm)	-	190
Head length (mm)	-	73
% TL		
Preanal length	-	41.8
% PAL		
Predorsal length	35-36	36.8
Head length	37-39	38.4
Depth at gill-opening	-	7.0
Depth at dorsal-fin origin	-	0.0
Depth at anus	9-11	9.2
% HL		
Snout length	40-41	39.0
Eye diameter	9-11	7.5
Interorbital width	14-16	11.5
Upper-jaw length	-	53.0
Lower-jaw length	-	47.5
Interbranchial width	6-8	11.5
Gill-opening length	-	10.4
Meristics		
Lateral-line pores		
predorsal	-	6
Preanal	42-45	43
Head pores		
Supraorbital	6	6
Infraorbital	13-16	13
Preoperculomandubular	19	19
Supratemporal	3	3

Genus *Nettenchelys* Alcock, 1898

Type species: *Nettenchelys taylori* Alcock, 1898; off the Travancore coast, India

Diagnosis: Elongated body, slender and attenuated tail; frequently broken tail; dorsal fin commences over gill opening or slightly behind; anterior nostril tubular near tip of snout, posterior nostril positioned on dorsal surface of head or body, from a point just posterior to eye to dorsal surface of body well behind dorsal fin origin; SO 5, IO 8–10+2 –4; POM 11–16; teeth on jaws in narrow bands, vomerine tooth patch elongate, sometimes with a median series of enlarged teeth anteriorly (Smith et al. 1981; Smith et al. 2015).

The genus *Nettenchelys* comprises 10 valid species: *Nettenchelys dionisi* Brito, 1989 (Eastern Atlantic), *N. erroriensis* Karmovskaya, 1994b (Western Arabian Sea), *N. exoria* Böhlke & Smith, 1981(Atlantic), *N. gephyra* Castle & Smith, 1981(Western Pacific), *N. inion* Smith & Böhlke, 1981, *N. paxtoni* Karmovskaya, 1999 (Western Pacicfic), *N. proxima* Smith, Lin & Chen, 2015(Western Pacific), *N. pygmaea* Smith & Böhlke, 1981 (Western Atlantic), *N. taylori* Alcock, 1898 and *N. bellottii* (D' Ancona, 1928) is known only from the larvae (Red Sea) (Smith et al. 2015; Fricke et al. 2018a). In India this genus is represented by a single species *Nettenchelys taylori* Alcock, 1898.

Nettenchelys taylori Alcock, 1898

Fig. 3.39

Holotype: ZSI F 317l/1 (female, 533 mm TL, incomplete), off Travancore Coast, 7°17'30"N, 76°54'30"E, 786 m.

Diagnosis: Body elongate and deepest in the middle and round in cross section; dorsal fin commences slightly behind the gill opening; posterior nostril far behind head, midway between dorsal fin origin and anus; anterior vomerine teeth not uniserial; median ST pore absent; predorsal 34% PAL; head 33% PAL; SO 5; ST 2; IO 11–12; POM: 15 (Smith et al. 1981; Smith et al. 2015).

Description: Detailed description of this species is given by (Alcock 1898; Smith et al. 1981; Smith et al. 2015).

Distribution: Known only from, off Travancore, India (Alcock 1898).

Remarks: This species is not encountered in present study, and it has not been collected since after its original description.

Genus *Venefica* Jordan & Davis, 1891

Type species: *Nettastoma procerum* Goode & Bean, 1883 (by original designation), North Atlantic

This genus constitutes 5 valid species, *V. multiporosa* Karrer, 1983 (Indo-West Pacific); *V. ocella* Garman, 1899 (Eastern Pacific); *V. proboscidea* (Vaillant, 1888) (Atlantic); *V. procera* (Goode & Bean, 1883) & *V. tentaculata* Garman 1899 (Eastern and Western Pacicfic) (Fricke et al. 2018). Indian EEZ this genus is represented by a single species *Venefica* sp. (recorded as *Venefica Proboscidea* (vaillant, 1888) by Lloyd (1909) (status is uncertain). Present study also reports a single specimen from Arabian Sea (Specimen is in poor condition with damaged body and broken tail).

***Venefica* sp.**

Fig. 3.40, Table 3.30

Lloyd (1909) reported a single specimen from Arabian Sea from the collection of R.I.M.S Investigator at a depth of 1624 m (Reg No. 2376/1) as *Nettastoma proboscidium* Vaillant 1888 (Validity uncertain).

Collection locationss: AS: 07°51·476'N, 76°24.880'E, 1345 m, 26.07.2014, (Cr.327, St.02), HSDT-CV

Voucher specimen No.: 3270206

Diagnosis: Body elongate with slender head and deeper body; long and slender jaws; snout with a long fleshy proboscis at tip which is 4.4 times the diameter of eye; dorsal and anal fins should be continuous with caudal fin similar to other congeners; head 3.4 times to the preanal length; Eye 12.4 times snout; interorbital width 40.4 times to the head length; Interorbital lesser than eye diameter; rictus extends beyond the posterior margin of eye; anterior nostril tubular, at the base of snout tip; posterior nostril a pore in front of eye.

Description: Body elongate and slender, with damaged tail, dorsal and anal fins should be continuous with caudal fin similar to other congeners; dorsal-fin origin slightly beyond the gill opening, predorsal 31.7% PAL. anal fin commences immediately behind anus; pectoral fin absent; anus anterior to mid-body, head elongated and slender its length 29.2% PAL;

snout elongated and slender, its length 61.9% HL; tip of the snout with a fleshy proboscis, its length 21.9% HL; tongue not free; upper jaw slightly overhangs the lower jaw; flange absent on upper and lower lips; mouth large rictus ends beyond the posterior margin of eye; eye small, its horizontal diameter is 5.0% HL; anterior nostril tubular, at the base of snout tip; posterior nostril a pore in front of eye; depth at anus more than depth at gill opening, 8.2% vs. 2.8% of PAL; head pores, lateral-line pores and vertebrae not discernible; teeth granular and blunt; intermaxillary teeth in a triangular patch, maxillary and mandibular teeth triserial and commences as biserial teeth; vomerine tooth patch elongate biserial anteriorly and 4 teeth in the middle and ends as biserial teeth; colour when fresh is light brown with pale median fins and proboscis reddish brown.

Distribution: Indian EEZ: Arabian Sea, (Lloyd 1909; Present study [Figure 3.41]).

Remarks: As previously discussed present specimen is in damaged condition with broken tail hence we could not resolve the identity up to the species level. The location of collection of the present specimen is nearer to the location where Lloyd (1909) reports a species as *Venefica Proboscidae* (Villiant, 1888). His description about the species is very short to make future comparison. Even though he pointed out that his specimen is similar as Villiant (1888) specimen (Holotype: MNHN 1884-1069) collected from Atlantic waters. Later Kareer (1983) reported another 2 specimens (MNHN 1979-65; MNHN 1979-66) from Mozambique channel and Karmovskaya (2004) reported a specimen

(MNHN 1997-3799) from Vanuatu, Pacific Ocean without giving any description of the specimen. These reports of *V. proboscidae* are suspicious as this species is restricted only to Atlantic waters (Smith pers. Comm.). Considering the locality of collection Lloyd species and present collected species may represent same species. Further taxonomic and genetic data are necessary by collecting intact specimens to resolve the exact species identity.

Table 3.30: Morphometric and meristic characters of *Venefica* sp.

	Present study (n=1)
Total length(mm)	900
Preanal length	360
% PAL	
Head Length*	29.2
Predorsal length	31.7
Depth at anus	8.2
Depth at gill slit	2.8
% HL	
Proboscis length	21.9
Snout length*	61.9
Eye diameter	5.0
Interorbital width	2.5
Upper-jaw length*	74.3
Lower-jaw length	45.7
Gill-opening length	7.4
Interbranchial width	7.9

*Including proboscis length

Family Nettastomatidae

Figure 3.37: *Facciolella* sp. G: New record of genus from Indian waters; New species from Andaman Sea; New record of the genus from Indian waters

Figure 3.38: *Nettastoma solitarium*: New record of the genus from Indian waters; New record form Andaman Sea

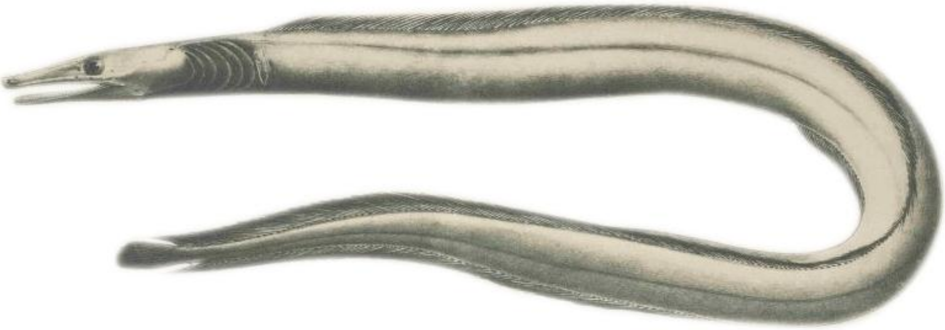

Figure 3.39: *Nettenchelys taylori*, from Alcock (1899), pl. 25, fig. 5: Not encountered in the present study

Figure 3.40: *Venefica* sp.: Species identity not resolved

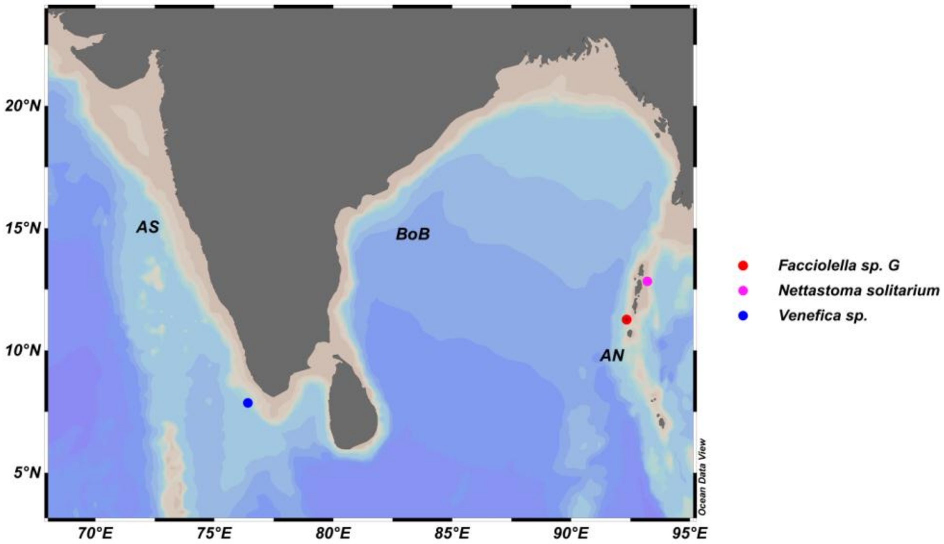

Figure 3.41: Map showing distribution of deep-sea eels of family Nettastomatidae in the Indian EEZ

VII. Family OPHICHTHIDAE Günther, 1870

Snake eels & worm eels

Ophichthid eels are the most diverse and speciose among the order Anguilliformes with 2 subfamilies the Myrophinae (69 species) and the Ophichthinae (270 species) (Fricke et al. 2018d). The presence or absence of median fins at the tail tip separates the two subfamilies. In the Myrophinae the tail tip is flexible due to the continuous median fins, whereas the tail tip is hard and the median fins are absent in the subfamily Ophichthinae (McCosker et al. 1989; McCosker & Okamoto 2016).

Ophichthid eels are distributed worldwide from tropical to warm temperate oceans. Most inhabit depths less than 200 m, from coral reefs to sand and mud substrates, entering rivers and estuaries but recent deep-sea explorations have uncovered many new species living at depths more than 200 m (McCosker et al. 1989; McCosker 1999; McCosker 2005; McCosker & Chen 2000; McCosker 2010; McCosker & Ho 2015; Tashiro et al. 2015). They are rarely captured by sampling gears due to their specialized burrowing nature. This is one reason that majority of species are known only from single specimen.

In Indian coastal waters, the family Ophichthidae is represented by 17 genera and 26 species (Gopi & Mishra 2015; Ray et al. 2015b; Mohapatra et al. 2018b). There have been no reports of snake eels from deep-waters of India. Present study reports 5 species under 3 genera (*Neenchelys* Bamber, 1915, *Ophichthus* Ahl, 1789 and *Pisodonophis*, Kaup 1856b) from deep-waters of Indian EEZ. Among them three are new to science and one is new record.

(1) Subfamily Myrophinae Kaup, 1856b

Genus *Neenchelys* Bamber, 1915

Type species: *Neenchelys microtretus* Bamber, 1915; Red Sea.

Diagnosis: Robust to elongate body, cylindrical anteriorly and laterally compressed posteriorly; dorsal-fin origin variable from anterior of trunk to slightly posterior of anus; anus positioned before the mid-length; pectoral-fin length variable from less than a eye diameter to larger than snout; lips devoid of barbels; anterior nostril tubular near tip of snout, posterior nostril an elongate slit above lip, opens wholly outside the mouth; branchial opening round and constricted; teeth conical and mostly uniserial on jaws and vomer; preopercular pores 1–4 (usually 2, the exceptions are 1 in *N. parvipectoralis* and 4 in *Neenchlyes* sp. A) (Ho et al. 2013).

Members of this genus belong to the subfamily Myrophinae. This genus contains 12 valid species. Meristic and morphometric characters clearly demonstrate two distinct groupings based on the length of their pectoral fin. A minute (less than the eye diameter) pectoral fin is characteristic of five species: *N. andamanensis* Hibino, Satapoomin & Kimura, 2015b; *N. gracilis* Ho & Loh, 2015; *N. mccoskeri* Hibino, Ho & Kimura, 2012b; *N. microtretus* Bamber, 1915 and *N. parvipectoralis* Chu, Wu & Jin, 1981.The remaining seven species have an elongate pectoral fin (longer than the snout length): *N. buitendijki* Weber & de Beaufort, 1916; *N. cheni* (Chen & Weng, 1967); *N. daedalus* McCosker, 1982; *N. diaphora* Ho, McCosker & Smith, 2015c; *N. nudiceps* Tashiro, Hibino & Imamura, 2015; *N. pelagica* Ho, McCosker & Smith, 2015c and *N. similis* Ho, McCosker & Smith, 2015c.

Two shallow-water species of *Neenchelys* were previously reported from Indian EEZ. *N. buitendijki* was reported from the Arabian Sea (Bombay and the Gulf of Kutch) from depths of 15–56 m (Bal & Mohamed 1957; Kotthaus 1968) and later Ray & Mohapatra (2016) reported *N. buitendijki and N. cheni* from the Bay of Bengal from a depth below 50 m. Present discovery of the new species adds another *Neenchelys* to Indian EEZ and upgrades the diversity of this genus to 3 species and total valid species in the world to 13. Present study reports the first deep-water species of *Neenchelys* from Indian EEZ.

***Neenchelys* sp. A (New species)**

Fig. 3.42, Table 3.31

Many-pored worm eel

Collection locations: AS: 08°20.734'N, 76°24.887'E, 544 m, 30.11.2016, (Cr.353, St.42), Naturalist dredge

Voucher specimen No.: 3534201 (CMLRE)

Diagnosis: Dorsal fin origin slightly anterior to mid trunk region; pectoral fin minute, almost equal to eye; snout conical, its center above anterior third of lower jaw; anterior nostril tubular with an elongate ventral filament; teeth numerous, slender and conical; preopercular pores 4; supratemporal pores 5. Colouration uniform grey, with a blackish tinge in branchial region; vertebral count 38/68/181.

Description: Body elongate, slender, somewhat cylindrical, with tail gradually compressed posteriorly; depth of body relatively uniform, tapering gradually to tip of tail; depth of head not greatly different than depth of body; tail moderately elongate, preanal 38.7% TL; median fins moderately elevated and continuous with caudal fin, slightly elevated before caudal fin; caudal fin flexible; dorsal-fin origin after mid trunk region, predorsal 23.1% TL; pectoral fin minute, length about equal to eye diameter, 2.9% HL; head profile terete, head length 9% of TL; snout conical, acute anteriorly, tip of snout overhanging lower jaw by diameter of eye, snout length 14.4% HL; slightly expanded in branchial region; anterior nostril tubular, directed anteroventrally with a prominent elongate filament along its posterior rim; posterior nostril above upper lip and before eye, oblique, elongate and horizontal in aspect; lower jaw included, its tip just reaching a line drawn between anterior margins of anterior nostrils; angle of gape about one eye diameter behind a vertical through posterior margin of eye ball; tongue well attached to the mouth floor; gill opening a narrow vertical slit, situated at anteroventral corner of pectoral–fin base, gill-opening length 8.3% HL; maximum depth at head 22.1% HL; head pores small: single median temporal and interorbital pores, SO 1+4, IO 5+1 (5 along the upper lip and 1 behind the eye); mandibular pores 6; preopercular pores 4 and ST 5; lateral line incomplete, pores inconspicuous, extending to about a head length before tail tip, lateral-line pores conspicuous: prepectoral 13, predorsal 41; preanal 69; vertebrae: predorsal 38, preanal 68 and total vertebrae 181; teeth slender, conical, pointed, their tips directed backward; anteriormost in each series the longest; anterior ethmovomerine block of intermaxillary teeth elongate, 3 pairs before level of anterior nostrils, followed by 2 triplets of slightly larger teeth, followed by 16 uniserial vomerine teeth, decreasing in size posteriorly; maxillary teeth uniserial, 36 on each side; mandibular teeth 58 on each side, uniserial and decreasing in size posteriorly. Colour when fresh: body uniform grey, with a blackish tinge in branchial region, sides of tail have black scattered melanophores (0.2–0.8 mm); median fins lighter in colour, becoming darker posteriorly; pectoral fins transparent; midlateral sides of posterior tail region more darkly pigmented; oral cavity white, overlaid with patches of black spots.

Distribution: Known only from the type specimen from Arabian Sea, India (present study [Figure 3.47]).

Discussion: The new species differs from all of its congeners in having four rather than two (rarely one) preopercular pores. Cephalic pore patterns are consistent within species of ophichthid and other anguilliform families (McCosker 1977). Present new species belongs to the group of Neenchelys with a minute pectoral fin. It differs from all others in the length of their pectoral fin and other morphological characters. It is similar to *N. mccoskeri* reported from Taiwan and Japan in certain morphometric characters such as shape of anterior nostril filament, origin of dorsal fin and total vertebral count. But the *Neenchelys* sp. A differs in following characters from *N. mccoskeri* such as slightly longer head (9.0% vs. 6.4–7.7% TL in *N. mccoskeri*), smaller upper jaw (24.9% vs. 27.9–37.2% HL in *N. mccoskeri*) shorter snout (14.4% vs. 15.8–23.1% HL in *N. mccoskeri*) and shorter eye (3.2% vs. 4.0–8.4% HL in *N. mccoskeri*). In addition the condition of anterior nostril filament in present new species is considerably more elongate than *N. mccoskeri* (greater than eye diameter vs. less than eye diameter in *N. mccoskeri*). Finally present species have numerous larger teeth and more no of preopercular pores than in *N. mccoskeri* or any of its congeners.

Remarks: Neenchelys sp. A is a new Species to Science.

Table 3.31: Comparison of morphometric and meristic characters of *Neenchelys* sp. A with similar congeners.

	N. mccoskeri **(n=31)**	**Ho et al. 2013** ***N. microtretus*** **(n=1)**	***N. parvipectoralis*** **(n=16)**	**Hibino et al. 2015b** ***N. andamanensis*** **(n=1)**	**Ho & Loh 2015** ***N. gracilis*** **(n=1)**	**Present study** ***Neenchelys*** **sp. A (n=1)**
Total length (mm)	283–522	183	163–302	336	429	411
% TL						
Head length	6.4–7.7	10.9	10.1–11.3	7.4	6.2	9
Predorsal length	21.1–25.6	19.1	15.7–17.5	19	16.6	23.1
Trunk length	30.9–36.6	31.1	30.6–34.0	33	32.3	29.7
Preanal length	34.6–43.7	42.1	41.4–44.4	40	38.5	38.7
Tail length	56.5–62.8	57.9	55.6–62.9	60	61.5	61.3
% Trunk length						
Gill-opening to dorsal-fin origin	43.6–53.4	26.3	15.3–22.3	35.1	32.1	47.5
Origin of dorsal-fin to anus	46–59	74	78–75	65	68	52.5
% HL						
Pectoral-fin length	1.5–3.5	–	1.4–4.2	2.4	–	2.9
Snout length	15.8–23.1	17.5	13.8–17.5	14	15.8	14.4
Eye diameter	4.0–8.4	5	5.0–7.1	5.3	5.3	3.2
Upper-jaw length	27.9–37.2	27.5	24.1–30.8	33	–	24.9
Interorbital width	10.4–16.1	–	8–13.1	4.5	9.8	5.8
Postorbital width	70.2–82.5	–	74.7–86.1	–	81.9	82.4
Gill-opening length	6.3–11.9	–	6.7–13.5	–	3.8	8.3
Depth at head	25–42	35	33.5–41.7	18.9	21.1	22.1
Depth at anus	28.7–48.7	–	31.6–44.0	16.14	21.1	19.6
Width at anus	24.2–37.4	–	24.1–34.6	13.49	18.5	17.9
Meristics						
Lateral-line pores						
Prepectoral	9–11	–	12–14	11	11	13
Predorsal	37–44	–	19–24	36	33	41
Preanal	62–	–	53–59	78	78	69
Head pores						
Supraorbital	1+4	1+4	1+4	1+4	1+4	1+4
Infraorbital	5+1	5+1	5+1	4+2	4+1	5+1
Preopercular	2	2	1–2	2	2	4
Mandibular	7	5	6–7	6	5	6
Supratemporal	3	3	3	2	3	5
Frontal	1	1	1	1	1	1
Vertebrae						
Predorsal	34–41	24	18–23	36	30	38
Preanal	62–67	56	53–57	77	78	68
Total	172–184	151	138–148	221	200	181

(2) Subfamily Ophichthinae Günther, 1870

Genus *Ophichthus* Ahl, 1789

Type species: *Muraena ophis* Linnaeus, 1758 (by original description), Mediterranean Sea.

Diagnosis: Body moderate to very elongate, cylindrical and laterally compressed posteriorly; tail longer than head and trunk combined; dorsal fin origin above or behind gill openings, well developed pectoral fin, moderate to well-developed eyes, tubular anterior nostril, posterior nostril opening into mouth or along lower edge of lip, teeth conical and numerous uniserial to multiserial on jaws and vomer, finless pointed tail tip, generally uniform colour with darker dorsal region (McCoskeret al. 2012a).

The genus *Ophichthus* is a polyphyletic assemblage with more than 70 species and numerous genera (McCosker & Ho, 2015). In Indian coastal waters the genus *Ophichthus* is recognized by 6 valid species *O. altipennis* (Kaup, 1856b); *O. apicalis* (Anonymous [Bennett] 1830); *O. cephalozona* Bleeker, 1864; *O. lithinus* (Jordan & Richardson, 1908); *O. microcephalus* Day, 1878 and *O. johnmcoskeri* Mohapatra, Ray, Mohanty & Mishra, 2018 (Talwar & Kacker, 1984; Ray et al. 2015b; Mohapatra et al. 2018b). In Indian no deep-water *Ophichthus* species were previously reported. Present study reports 2 new species (*Ophichthus* sp. A and *Ophichthus* sp. B) and one new record (*Ophichthus urolophus* Temminck & Schlegal 1846) from Western Indian Ocean.

Ophichthus sp. A (New species)

Fig. 3.43, Table 3.32

Collection locations: AN: 06°38·301'N, 93°41.082'E, 321 m, 24.09.2010, (Cr.280, St.37), EXPO; 06°37·814'N, 93°41.191'E, 337 m, 10.12.2011, (Cr.292, St.83), HSDT-CV; 10°51·520'N, 92°11.336'E, 363 m, 26.01.2015, (Cr.334, St.01), HOT; 06°35·885'N, 93°42.204'E, 332 m, 01.02.2015, (Cr.334, St.04), HOT; 12°29·719'N, 93°10.732'E, 314 m, 25.11.2017 (Cr.367 St.05), HSDT-CV

Voucher specimen No.: 2801617(CMLRE)

Diagnosis: A moderately elongate species; head 13–14% of TL, tail 54.6–56.8%, depth at gill opening 4–4.7% and predorsal 18.4–20.5% TL; eye large, its diameter almost equal to snout; pectoral fins elongate but not lanceolate, with elongate middle-most ray; rear margin of orbit in advance of rictus, with its center positioned after the midpoint of upper jaw; posterior nostril opens along upper lip, with a small anterior flap; preoperculomandibular pores 3+6; teeth numerous, small and conical, biserial on maxillary with triserial ending, uniserial anteriorly and biserial posteriorly on mandible with triserial ending, and biserial anteriorly and uniserial posteriorly on vomer. Colouration pale brown on dorsal surface and whitish below, snout tip brown with lower jaw pale; median fins and pectoral fins colourless except anal-fin base blackened posteriorly. Vertebral count 19/53/150.

Description: Body moderately elongate, cylindrical anteriorly and compressed in posterior tail region; depth at gill opening 4.0–4.7% TL; preanal 44.2–45.4%, head 13–14% and tail 54.6–56.8% TL; snout tip moderately rounded and not elongated; anterior nostril tubular, towards anteriorly but not reaching to the tip of snout; snout not bisected on underside by a groove; posterior nostril opens along upper lip with a short anterior flap that extends beyond the edge of lip; upper jaw slightly extended at its tip, upper and lower lip meets when mouth closed; eye large, approximately equal to snout, its horizontal diameter 17.1–19.4% HL; posterior margin of eye in advance of rictus; centre of eye placed slightly posterior to middle of upper jaw; branchial basket slightly wider and deeper than body; predorsal 18.4–20.5% TL; dorsal and anal fins are placed in a groove for their entire length; pectoral fin elongated but not lanceolate, its base positioned in upper half of the gill opening, pectoral-fin length 29.1–33.0% HL; dorsal and anal fins end before the tail tip by approximately half the snout length; head pores small but conspicuous: single median interorbital and temporal pores, SO: 1+4, IO 4+2, POM 3+6 and ST 3; lateral-line pores: prepectoral 9–11, predorsal 20–21, preanal 54–59; veretebra: predorsal 19, preanal 53 and total veretebrae 150; teeth small, conical, and numerous; intermaxillary with a rosette of 6–9 teeth preceded by 4–6 teeth, followed by 2–7 biserial vomerine teeth continued by 15–17 uniserial teeth; biserial maxillary teeth with triserial ending, mandibular teeth uniserial anteriorly with few isolated pairs, biserial in last quarter and ending as triserial; body colouration when fresh light brown on dorsal surface and white ventrally, including lower jaw and branchial region; dorsal surface of the head and snout brown; posterior and anterior nostrils pale; median and pectoral fins pale white, except posterior region of anal-fin base which is black.

Distribution: Known only from Andaman Sea (present study [Figure 3.47])

***Discussion**:* McCosker (2010) reviewed 19 species of the deep-water snake-eels of the genus *Ophichthus* from the Indo-Pacific region. Later, McCosker & Ho (2015) described two additional deep-water species, *O. bicolar* McCosker & Ho, 2015 and *O. shaoi* McCosker & Ho, 2015 from Taiwan waters. *Ophichthus* sp. A appears to be similar to *O. genie* McCosker, 1999 described from New Caledonia and the Maldives, in its general head and body proportions but differs in its preopercularmandibular pore condition (2+6 or 7 vs. 3+6 in *Ophichthus* sp. A), vertebral numbers (12–16 predorsal, 56–59 preanal, and total 139–147 vs. 19, 53 and 150, respectively), shape of its pectoral fin (lanceolate vs. not lanceolate) and the colour of its anal fin (colourless vs. having its anal fin margin black posteriorly).*Ophichthus* sp. A is also similar to *O. kunaloa* McCosker, 1979 from the central Pacific. It has similar head and body proportions and general colouration and a dark patch at its anal-fin base, but differs significantly in its preopercular mandibular pore condition (2+5 vs. 3+6 in *Ophichthus* sp. A), vertebral number (66–69 preanal and total 180–185 vs. 53 and 150), and mandibular tooth pattern (biserial vs. uniserial anteriorly and biserial posteriorly with triserial ending). The large eye (almost equal to snout) is an important character of *Ophichthus* sp. A which is similar to that of *O. congroides* McCosker, 2010 and *O. tomioi* McCosker, 2010, however, these species have an enlarged lanceolate pectoral fin and their dorsal-fin origin before the tip of the pectoral fin. *Ophichthus megalops* Asano, 1987 also has large eyes, a black anal fin posterior margin, and 3 preopercular pores similar to *Ophichthus* sp. A, but differs in head length (11% vs. 13–14% of total length), predorsal (29 vs. 19) and total vertebrae (160 vs. 150).

Remarks: *Ophichthus* sp. A is a species new to Science from Andaman Sea and this genus is reporting for the first time from deep-waters of Indian EEZ.

Table 3.32: Comparison of morphometric and meristic characters of *Ophichthus* sp. A (New species) with similar congeners.

	McCosker 1979; 2002	**McCosker 1999**	**McCosker 2010**		**Asano 1987**	**Present study (n=6) *Ophichthus* sp. A**		
	O. kunoloa* *(n=5)	***O. genie* *(n=6)***	***O. congroides* *(n=2)***	***O. tomioi* *(n=5)***	***O. megalops* *(n=1)***	**Range**	**Mean**	**SD**
Total length (mm)	383–473	196–337	472–522	334–447	322	331–447		
% TL								
Head length	9.6–10.1	9.3–10.1	8.3–8.4	9.1–10.0	11	13.0–14.0	13.6	0.4
Preanal length	39.8–41.0	43.9*	37.5–39.7	37.4–40.7	44.7	44.2–45.4	44.9	0.5
Trunk length	30.4–30.7	31.7–35.6	31.3–31.4	-	33.6	30.2–32.0	31.2	0.7
Tail length	59.0–60.2	55.2–58.2	60.3–62.5	59.2–62.6	55.4	54.6–56.8	55.3	0.8
Depth at gill-opening	3.5	2.4–3.2	2.7*	3.2–4.0	4	4.0–4.7	4.4	0.3
Predorsal length	13.2–14.4	12.6–15.5	13.6–13.8	12.6–13.8	25	18.4–20.5	19.5	0.7
% HL								
Pectoral fin length	31.9–47.6	38.8–47.1	42.5	39.6–45.5	32.4	29.1–33.0	31.8	1.4
Upper-jaw length	37.9–43.8	38.2–47.1	-	37.8–43.8	-	39.4–44.7	42.1	2.0
Snout length	16.8–22.3	19.7–26.6	19.7–20.5	17.5–21.1	21.3	18.2–20.5	19.1	0.8
Eye diameter	14.2–17.5	11.5–14.4	16.9–17.9	15.2–18.5	18.6	17.1–19.4	18.3	0.9
Interorbital width	16.4*	10.1–15.6	15.7–16.0	-	18.1	10.6–14.4	13.2	2.3
Meristics								
Lateral-line pores								
Prepectoral	-	-	-	-	-	9-11		
Predorsal	-	-	-	-	-	20-21		
Preanal	-	-	-	-	-	54-59		
Head pores								
Supraorbital	1+4	1+4	1+4	1+4	1+4	1+4		
Infraorbital	4+2	4+2	4+2-3	4+2	4+2	4+2		
Preoperculomandubular	2+5	2+6-7	2+6	2+6-7	3+6	3+6		
Single median ST	1	1	1	1	1	1		
Single median Interorbital	1	1	1	1	1	1		
Vertebrae								
Predorsal	15	12–16	20–22	16–18	29	19		
Preanal	66	56–59	75–77	60–67	60	53		
Total	182	139–147	204–208	166–189	160	150		

***Ophichthus* sp. B (New species)**

Fig. 3.44, Table 3.33

Collection location: BoB: 18°50·436’N, 85°23.119’E, 644 m, 29.10.2011, (Cr.291, St.03), EXPO

Voucher specimen No.: 2910309 (CMLRE)

Diagnosis: Moderately elongated body with head 10.1%, tail 59.5% and depth at gill opening 1.8% TL; dorsal-fin origin behind pectoral-fin tip of about one pectoral-fin length; predorsal distance 15.1% TL; eye moderate in size, circular and approximately half in snout length; pectoral fin moderately elongated with the middlemost ray largest, not lanceolate; upper lip devoid of barbels between the anterior and posterior nostrils; preoperculomandibular pores 6+3; teeth on vomer with 4 biserial teeth followed by 2 uniserial teeth, maxillary teeth numerous irregularly biserial and mandibular teeth almost uniserial with few random teeth in inner side. Colour (in formaldehyde) uniform dark brown to black throughout the body, median fin and pectoral fin black.Vertebral count 19/57/149.

Description: Body moderately elongated, cylindrical anteriorly and laterally compressed posteriorly towards tail region; depth at gill opening 1.8%, preanal 40.5%, head 10.1% and tail 59.5% TL; snout conical, elongated with round tip; snout not bisected on underside by a groove; anterior nostril tubular located laterally near tip of the snout, posterior nostril opening along the upper lip just in front of eye with a short flap extending slightly beyond edge of upper lip; upper jaw overhangs lower jaw; lips smooth, no barbels along upper lip; eye moderate approximately double the snout, its horizontal diameter 8.7% HL; posterior margin of eye in advance of rictus; centre of eye placed slightly posterior from middle of upper jaw; branchial region slightly enlarged; dorsal-fin origin behind pectoral-fin tip about one pectoral-fin length; pectoral fin elongated but not lanceolate, its base positioned in upper half of the gill opening; dorsal and anal fins not placed in a groove; pectoral fin moderately elongated its length 26.5% HL and its upper base is in level with the dorsal margin of gill opening; head pores small but conspicuous: single median interorbital and temporal pores, SO 1+4, IO 4+2, POM 6+3 and ST 3; lateral-line pores conspicuous: prepectoral 10, predorsal 21 and preanal 60; vertebrae: predorsal 19, preanal 57 and total vertebrae 149; teeth small and conical, intermaxillary with a rosette of 4 teeth, vomer with 4 biserial teeth proceeded by 2 uniserial teeth, maxillary irregularly biserial with 23 and mandibular teeth almost 21 mostly uniserial, with few random teeth in inner side anteriorly. Colour (in formaldehyde) uniform dark brown to black throughout the body, median fins pale and pectoral fin black.

Discussion: *Ophichthus* sp. B appears to be closely related to other deep-water congeners *O. aphotistos* McCosker and Chen, 2000 described from Taiwan, *O. cruentifer* (Goode and Bean, 1896) and *O. pullus* McCosker, 2005 from eastern Atlantic in having similar position of dorsal and anal fins, condition of pectoral fin, vertebrae (predorsal & preanal) and cephalic pore counts except POM; but differs in having larger head (10.1%. vs. 6.9–8.9% TL in others and more POM pores (6+3 vs. 6+2 in others). *Ophichthus* sp. B have total vertebral counts similar with *O.*

cruentifer and *O. pullus* (149 vs. 144-155 and 149-153 respectively) but differs from *O. aphotistos* by slightly lower total vertebral count (149 vs. 157–162) (McCosker and Chen 2000; McCosker 2005; Hibino et al. 2016). Again, *Ophichthus* sp. B has large head and position of dorsal fin origin similar to other deep-water species described from Taiwan *O. bicolor* McCosker and Ho, 2015 but differs in slightly anterior position of anus (40.5% vs. 42.4–46.2% of TL), smaller eye (8.7% vs. 10.3–13.5% of HL), lower preanal and total vertebral counts (57 and 149 vs. 61–63 and 155–163). *Ophichthus* sp. B is also distinct in having dark brown to black body colouration compared *to O. bicolor.* As the name implies it has contrasting colours, light yellow dorsally and white ventrally (McCosker and Ho 2015). In addition *Ophichthus* sp. B is similar to another deep-water species *O. obtusus* McCosker, Ide & Endo, 2012 described from Japan in their dark body coloration and vertebral counts: predorsal (19 vs. 11–19), preanal (57 vs. 52–57) and total (149 vs. 148–153) but differs in more posterior origin of dorsal fin (behind pectoral-fin tip vs. not behind in *O. obtusus*) and absence of small cauliflower shaped barbels at base of anterior nostril and beneath 2nd infraorbital pore (McCosker et al. 2012a; Chiu et al. 2013). Finally *Ophichthus* sp. B is more slender than all other congers discussed above.

Distribution: Known only from Bay of Bengal through present study [Figure 3.47].

Remarks: *Ophichthus* sp.B is a species new to science.

Table 3.33: Comparison of morphometric and meristic characters of *Ophichthus* sp. B (New species) with similar congeners.

	***O. aphotistos* (n=31)**	**McCosker 2005 *O. cruentifer (n=48)***	***O.pullus (n=33)***	**McCosker & Ho 2015 *O.bicolor (n=20)***	**McCosker et al. 2012a *O. obtusus (n=10)***	**Present study *Ophichthus* sp. B (n=1)**
Total length	480-628	249-428	451-529	489-919	540-697	457
% TL						
Head length	7.7-8.1	6.9-8.7	8.5-8.9	8.6-10.8	8.4-9.2	10.1
Preanal length	39.6-40.6	38.0-43.0	39.2-42.7	42.4-46.2	41.7-44.9	40.5
Tail length	59.4-60.4	57.0-62.0	57.3-60.8	53.1-57.2	55.1-58.3	59.5
Trunk length	_	_	_	_	_	30.4
Depth at gill-opening	2.5-2.9	2.3-3.0	2.8-2.3	_	2.7-3.5	1.8
Predorsal length	12.3-14.8	9.5-16.0	14.4-19.1	13.6-18.3	10.6-12.0	15.1
% HL						
Pectoral-fin length	20.8-32.6	20.0-30.0	22.6-24.9	21.6-34.0	27.2-33.0	26.5
Upper-jaw length	31.1-32.4	29.0-37.0	28.6-24.3	37.7-48.4	18.7-27.0	31.3
Snout length	20.4-21.6	20.0-23.0	17.4-18.8	17.2-21.5	13.8-21.1	16.5
Eye diameter	9.4-10.6	5.6-9.2	8.4-9.9	10.3-13.5	6.2-10.4	8.7
Interorbital width						10.2
Meristics						
Lateral-line pores						
Prepectoral	-	-	-	-	-	10
Predorsal	-	-	-	-	-	21
Preanal	-	-	-	-	-	60
Lateral-line pores						
Supraorbital	1+4	1+4	1+4	1+4	1+4	1+4
Infraorbital	4+2	4+2	4+2	4+2	4+2	4+2
Preoperculomandibular	6+2	6+2	6+2	6+2	5+3	6+3
Single median ST	1	1	1	1	1	1
Single median Interorbital	1	1	1	1	1	1
Vertebrae						
Predorsal	16-19	14-19	18-23	15-23	11-19	19
Preanal	58-60	56-61	55-58	61-66	52-57	57
Total	158-162	144-155	149-153	155-163	148-153	149

Ophichthus urolophus (Temminck & Schlegel, 1846)

Fig. 3.45, Table 3.34

Manetail snake eel

Synonym: *Conger urolophus* Temminck & Schlegel, 1846

Collection location: AS: 08°59·618'N, 75°55.468'E, 200 m, 10.01.2014, (Cr.322, St.07), HSDT-CV

Voucher specimen No.: 3220709 (CMLRE)

Conger urolophus Temminck & Schlegel, 1846; Nagasaki, Japan. ***Lectotype***: RMNH 3688a, ***Parolectoptype:*** RMNH 3688b.

Diagnosis: A moderately elongate species with head 13.7–15.5% TL, tail 54.7–54.9%, depth at gill opening 4.2–4.3% TL; dorsal-fin origin usually behind the tip of pectoral fins, rarely slightly ahead of pectoral-fin tip; pectoral fins spatulate and not elongated; blunt snout; large eyes; rictus ends beyond the posterior margin of eye; anterior nostril tubular near tip of snout, posterior nostril a slit along the upper lip covered by a flap; teeth small conical; maxillary teeth irregularly biserial, mandibular and vomerine teeth uniserial; head pores: SO 1+3, IO 4+2 and POM 6+3; vertebrae 134.

Description: Body cylindrical and flattened posteriorly at extreme tail tip; dorsal and anal fins low in entire stretch, and are positioned in a grove but somewhat high before the tail tip; tail tip naked and devoid of median fins; dorsal-fin origin slightly before the tip of pectoral fin, predorsal length 17.9–18.9% TL; anal fin originates just after the anus; anus positioned slightly before the mid-body, preanal length 45.1–45.3% TL; snout blunt, snout length 15.7-16.8% HL; pectoral fin well developed, not elongated and spatulate, pectoral-fin length 31–35% HL; head moderately elongated, head length 13.7–15.5% TL; tongue fixed; upper jaw and lower jaw almost equal; flanges on upper and lower lip absent; rictus ends beyond the posterior margin of eye; eye large circular in shape, covered by a membrane, its horizontal diameter 9.9–10.8% HL. anterior nostril tubular located laterally near tip of snout, posterior nostril just in front of the eye along the upper lip covered by a flap; absence of papilla in between nostrils; branchial region inflated; gill openings wide and its anterior margin is in level with upper base of pectoral fin; maximum depth at gill 4.2–4.3% TL; lateral-line pores small and inconspicuous: prepectoral 9–10, predorsal 15; preanal 52-53; vertebrae: predorsal 16, preanal 54 and total vertebra 134; head pores small and inconspicuous: SO 1+3, IO pores 4+2, POM 6+3 and ST 3; single median interorbital and temporal pores; teeth on jaws small and conical; intermaxillary in a rosette of 4–5 teeths; mandibular and vomerine teeth uniserial, maxillary teeth irregularly biserial with random teeth as inner row. Colour after preservation in formaldehyde is light brown with pale ventral region, median fins and pectoral fins pale.

Distribution: Western Pacific and Southeastern Indian Ocean (Sumida & Machida 2000; McCosker 2010; Ji & Kim 2011b; Ho et al. 2015b). Indian EEZ (Present study [Figure 3.47]).

Remarks: *Ophichthus urolophus* is reported for the first time from Western Indian Ocean (New reccord of species). There is some variation in dorsal fin origin of present specimens (slightly ahead than normal position). This variation was also evident in few Japanese specimens (Sumida & Machida 2000). Ho et al. (2015b) pointed out variation of teeth pattern from uniserial to biserial and triserial in different stages of growth in Taiwan specimens.

Table 3.34: Comparison of morphometric and meristic characters of *Ophichthus urolophus* (Temminck & Schlegel, 1846) with previous study

	Sumida & machida 2000 (n=89)	**Ji & Kim 2011b (n=8)**	**McCosker 2010 (n=99)**	**Present study materials (n=2)**		
				Range	**Mean**	**SD**
Total length (mm)	370-615	400-607	298-529	322-357		
% TL						
Preanal length	42-47	42.2-44.4	-	45.1-45.3	45.2	0.2
Predorsal length	12-22	14.6-16.6	-	17.9-18.9	18.4	0.7
Head length	11-13	8.6-12.2	11-13	13.7-15.5	14.6	1.3
Trunk length	-	-	-	29.5-31.4	30.4	1.3
Depth at gill-opening	-	4.4-4.8	4-4.8	4.2-4.3	4.3	0.1
Depth at anus	3-5	4.1-4.9	-	3.6-3.9	3.7	0.2
Tail length	53-58	55.6-58.1	53-58	54.7-54.9	54.8	0.2
% HL						
Snout length	12-19	15.2-20	-	15.7-16.8	16.2	0.8
Eye diameter	10-15	10.9-13.2	-	9.9-10.8	10.3	0.6
Interorbital width	14-20	15.6-20	-	14.2-15.1	14.7	0.7
Upper- jaw length	31-40	35.6-39.2	-	32.6-36.2	34.4	2.5
Lower- jaw length	25-37	31.3-38.5	-	30.5-35.4	33.0	3.5
Gill-opening length	12-19	15.6-19.1	-	16.5-18.8	17.6	1.6
Interbranchial width	16-30	4.3-6.6	-	20.3-20.5	20.4	0.1
Pectoral-fin length	26-37	30-36.9	-	31-35	33.2	3.2
Pectoral-fin base length	-	-	-	8.1-9.3	8.7	0.9
Meristics						
Lateral-line pores						
Prepectoral	-	-	-	9-10		
Predorsal	-	-	-	15		
Preanal	-	-	-	52-53		
Head pores						
Supraorbital	-	-	1+3	1+3		
Infraorbital	-	-	4+2	4+2		
Preoperculomandubular	-	-	2-3+6-7	6+3		
Supratemporal	1+4	-	3	3		
Single median ST				1		
Single median Interorbital				1		
Vertebrae						
Predorsal	-	-	-	16		
Preanal	-	-	-	54		
Total	-	-	134-139	134		

Genus *Pisodonophis* Kaup, 1856b

Type species: *Ophisurus cancrivorus,* Richardson 1848 by original description; Australia, Arafura Sea, Eastern Indian Ocean.

Diagnosis: Dorsal-fin origin before or behind the pectoral fin; third preopercular pore usually present; jaw teeth are conical, blunt and granular; maxillary teeth occurs in regular or irregular rows; prevomer and vomer are slightly separated from each other; Colouration is generally uniform except in *Pisodonophis daspilotus* (McCosker 1977; McCosker et al. 1989).

Currently there are 9 valid species in this genus. *P. boro* (Hamilton, 1822) (Indo-West Pacific); *P. cancrivorus* (Richardson, 1848) (Red Sea, Indo-West Pacific); *P. copelandi* Herre, 1953 (Philippines); *P. daspilotus* Gilbert, 1898 (Eastern Pacific); *P. hijala* (Hamilton, 1822) (Indian Ocean); *P. hoevenii* (Bleeker, 1853) (Indo-West Pacific); *P. hypselopterus* (Bleeker, 1851) (Western Pacific); *P. sangjuensis* Ji & Kim, 2011b (Southern Korea & Sea south of Korea); *P. semicinctus* (Richardson, 1848) (Mediterranean Sea & eastern Atlantic) (Fricke et al. 2018a). In Indian EEZ 3 species were reported *P. boro*, *P. hijala* and *P. cancrivorus*. All the aforementioned species was reported from shallow waters. Present study reports the bathymetric extension of *P. cancrivorus* to deep-waters of about 400 m depth.

Pisodonophis cancrivorus (Richardson, 1848)

Fig. 3.46, Table 3.35

Longfin snake eel

Synonyms: *Ophiurus baccidens* Cantor, 1849; *Ophisurus brachysoma* Bleeker, 1853; Ophisurus cancrivorus Richardson, 1848; *Myrophis chrysogaster* Macleay, 1881; *Ophichthys madagascariensis* Fourmanoir, 1961; *Ophisurus nigrepinnis* Liénard, 1842; *Ophisurus schaapii* Bleeker, 1852; *Ophisurus sinensis* Richardson, 1848

Collection locations: AS: 10°06·020'N, 75°37.190'E, 400 m, 14.10.2010, (Cr.281, 09), HSDT-CV

Voucher specimen No.: 2810115 (CMLRE)

Ophisurus cancrivorus Richardson, 1848, Port Essington, Northern Territory, Australia; ***Holotype:*** unknown; Additional material: BMNH 1938.12.21.1 (1) Singapore; BMNH 1938.12.21.2 (1), Philippines (non types).

Diagnosis: Body cylindrical and laterally compressed only on extreme tail tip; dorsal-fin origin almost above the middle of pectoral fin; pectoral fin well developed, its length 32.3 % HL; anus located well before mid-body, preanal 41.3% TL; upper lip with a small papilla in between the anterior nostril and posterior nostril, another barbell below the anterior margin of eye; teeth molariform and multiserial in jaws and vomer.

Description: Body cylindrical for most of the part except the tail region which is laterally compressed; dorsal and anal fins low in entire stretch, and are positioned in a grove but somewhat high before the tail tip; tail tip naked and devoid of median fins; dorsal-fin origin almost above the middle of pectoral fin, predorsal length 12.7% TL; anal fin originates just after the anus; anus positioned well before the mid-body, preanal length 41.3% TL; snout sharp and pointed, its length 18.6% HL; pectoral fin well developed and oval shaped, pectoral-fin length 32.3% of HL; head moderate, head length 11.4% TL; tongue well attached to mouth floor; upper jaw slightly overhangs the lower jaw; flanges on upper and lower lip absent; mouth inferior, rictus ends well beyond the posterior margin of eye; eye small and circular in shape, covered by a membrane, its horizontal diameter is 8.6% of HL; anterior nostril tubular located laterally near tip of snout, posterior nostril just in front of the eye and below on lip covered by a flap; small papilla in between the anterior and posterior nostril and behind the posterior nostril there is another minute papilla; branchial region enlarged; gill openings wide and its anterior margin is in level with upper base of pectoral fin; maximum depth at gill 4% TL; lateral-line pores small and inconspicuous, prepectoral 11, predorsal 13 and preanal 56; vertebrae: predorsal 14, preanal 58 and total vertebra 158; head pores small difficult to count: SO 1+4, IO 4+2; POM 5+3; ST 3; Single median interorbital and supratemporal pores; teeth on jaws and vomer molariform and multiserial; intermaxillary in a separate oval patch with 3 rows of teeth, maxillary and mandibular teeth in 3-4 rows anteriorly and ends as uniserial posteriorly, vomer starts with similar 4 irregular rows and ends as uniserial and extend further back beyond the posterior end of maxillary teeth; colour in formaldehyde is reddish brown with pale ventral region, median fins and pectoral fin brown to black and tip of the tail pale.

Distribution: Indo-Pacific: (McCosker & Castle 1986; Ji & Kim 2011b); Indian EEZ: Arabian Sea (Bijukumar & Raghaven et al. 2015 and present study [Figure 3.47]) Bay of Bengal (Venkateswarlu et al. 1998; Ray 2016).

Remarks: Present study extends the bathymetric range of this species from shallow waters (<50m) to deep-water of about 400 m depth.

Table 3.35: Comparison of morphometric and meristic characters of *Pisodonophis cancrivorus* (Richardson, 1848) with previous study

	Ji & Kim 2011b (n=5)	Present study (n=1)	
Total length (mm)	374-872	606	
	In TL		**%TL**
Preanal length	2.4-2.6	2.4	41.3
Predorsal length	7.4-9.1	7.9	12.7
Head length	8.3-9.8	8.8	11.4
Trunk length	_	3.3	29.9
Depth at gill-opening	24.7-38.5	24.9	4.0
Depth at anus	_	28.8	3.5
Tail	1.6-1.9	1.7	58.7
	In HL		**%HL**
Snout length	4.8-6.1	5.4	18.6
Eye diameter	10-13.2	11.7	8.6
Interorbital width	_	6.7	14.8
Upper- jaw length	2.6-3.3	2.8	36.1
Lower- jaw length	_	3.1	31.9
Gill-opening length	_	7	14.3
Interbranchial width	_	4.5	22.3
Pectoral-fin length	3.2-4.1	3.2	32.3
Pectoral-fin base length	9.2-10.1	9.5	9.1
Meristics			
Lateral-line pores			
Prepectoral	_	11	
Predorsal	_	13	
Preanal	56-57	56	
Head pores			
Supraorbital	_	1+4	
Infraorbital	_	4+2	
Preoperculomandubular	_	5+3	
Supratemporal		3	
Single median ST	_	1	
Single median Interorbital	_	1	
Vertebrae			
Predorsal	17	14	
Preanal	52-58	58	
Total	153-164	158	

Family Ophichthidae

Figure 3.42: *Neenchelys* sp. A: New species from Arabian Sea

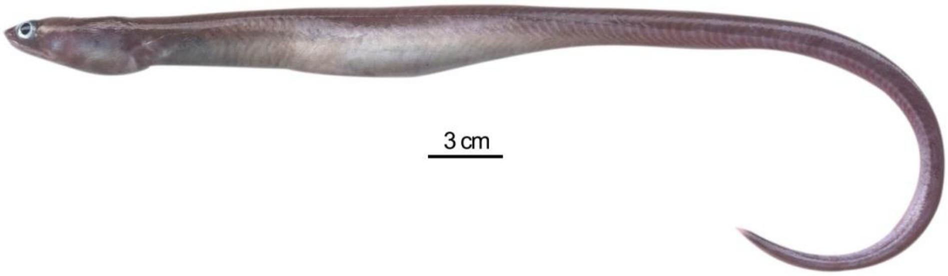

Figure 3.43: *Ophichthus* sp. A**:** New species from Andaman Sea

Figure 3.44: *Ophichthus* sp. B: New species from Bay of Bengal

Figure 3.45: *Ophichthus urolophus:* New record from Western Indian Ocean

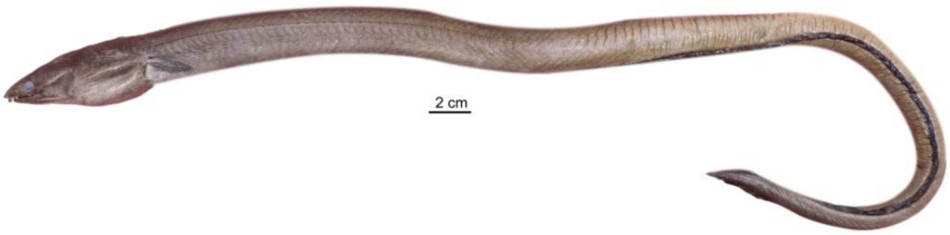

Figure 3.46: *Pisodonophis cancrivorus*: First report from deep-waters of Indian EEZ, previously reported from shallow-waters

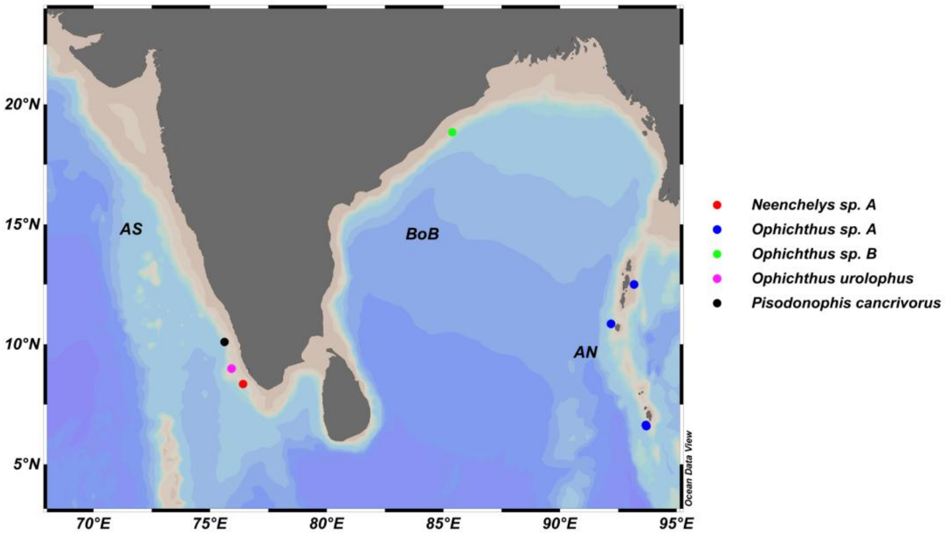

Figure 3.47: Map showing distribution of deep-sea eels of family Ophichthidae in the Indian EEZ

VIII. Family SERRIVOMERIDAE Trewavas, 1932

Sawtooth eels

Serrivomerids are midwater eels found usually at depths ranging from 500–1000 m in temperate and tropical regions of the world Oceans (Smith 1999f). This family represents 2 genera *Serrivomer* Gill & Ryder, 1883 with 10 species and *Stemonidium* Gilbert, 1905 with a single species. Only one genus (*serrivomer*) has been reported from this family in India.

Genus *Serrivomer* Gill & Ryder, 1883

Type species: *Serrivomer beanii* Gill & Ryder 1883, off Northeastern USA, Atlantic Ocean.

Diagnosis: Body cylindrical, slightly compressed with a tapering tail; jaws attenuated and occlusive; anterior and posterior nostrils located close together; dorsal-fin origin slightly posterior to anus; anus well in front of mid-body; cephalic pores restricted to 3 pores; lateral line reduced to single series of papillae (Tighe 1989).

This genus represents 10 valid species: *S. beanii* Gill & Ryder, 1883 (North Atlantic, Indian Ocean, Western Pacific); *S. bertini* Bauchot, 1959 (Indo-West Pacific & off Chile); *S. garmani* Bertin, 1944 (Indian Ocean); *S. jesperseni* Bauchot, 1953 (cosmopolitan); *S. lanceolatoides* (Schmidt, 1916); (cosmopolitan); *S. neocaledoniensis* Bauchot, 1959 (Southwestern Pacific: New Caledonia); *S. samoensis* Bauchot, 1959 (Southwestern Pacific); *S. schmidti* Bauchot, 1953 (South eastern & southwestern Atlantic); *S. sector* Garman, 1899 (Indo-West Pacific) (Fricke et al.

2018a). In addition to the above said species there is one more valid species *Gavialiceps microps* (based on description it belongs to *Serrivomer* genus) described by Alcock (1889a) along with *Gavialiceps taeniola*. Lloyd (1909) reported another species under the name *Serrivomer sector* from Arabian Sea (validity uncertain). Due to the damaged condition of the specimens we could not clarify which species represent this genus in Indian EEZ. Nevertheless, we are giving some partial data of the specimen collected.

***Serrivomer* sp.**

Fig. 3.48, Table 3.36

Collection locations: AS: 08°21·601'N, 76°10.171'E, 995 m, 12.10.2010, (Cr.281, St.03), HSDT-CV; 08°24·837'N, 75°53.151'E, 1241 m, 17.07.2013, (Cr.316, St.09), HSDT-CV; 08°00·845'N, 76°25.914'E, 1152 m, 10.12.2013, (Cr.321, St.16), HSDT-CV

Voucher specimen No.: 3211623 (CMLRE)

Diagnosis: Lower jaw slightly longer than the upper jaw; anterior and posterior nostril close to each other; cephalic pores restricted to 3; head 19% TL; preanal 27.6% TL; predorsal 33.8 % total length; snout 34.9 % HL; eye 4.1% of head length; lateral-line pores absent.

Description: Body slender, cylindrical and slightly compressed with tapering tail; dorsal and anal fins continuous with caudal fin; dorsal-fin origin slightly behind the anus, predorsal 33.8% of TL; pectoral fin present but small and slender, 2.9% HL; anus well before mid-body, preanal 27.6% TL; anal fins start just behind the anus; head moderately elongated, head 19% TL; snout slender, 34.9% of HL; eye fairly well developed, oval in shape, horizontal diameter 4.1% HL; anterior and posterior nostril close to each other as small slits in front of eye; jaws strong beak like with pointed tips, lower jaw slightly longer than upper jaw; no flanges on upper and lower lip; mouth large, rictus ends slightly behind posterior margin of eye; gill opening located very low with less interbranchial width, gill height 8.3% HL; lateral-line pores absent; cephalic pores inconspicuous 3 in numbers located in between the anterior and posterior nostrils, maxillary teeth in 2–3 rows increasing its size from outer to inner; mandibular teeths in 3–4 rows, inner row small sized and isolated from other rows; next row with 30–45 enlarged teeth similar to maxillary teeth; vomer with 2 alternating rows of laterally compressed teeth, each 3–4 times as long as wide. Colour when fresh is blackish with silvery sheen on head, fins pale.

Distribution: Indian EEZ: Arabian Sea: (Alcock 1889a; Lloyd 1909; Present study [Figure 3.49); Bay of Bengal (Alcock 1889a); Andaman Sea (Hashim 2012).

Remarks: Alcock reported *Gavialiceps microps* from Bay of Bengal, Arabian Sea and Andaman Sea (actually a species of genus *Serrivomer*) (Alcock 1889a; 1899). Later Lloyd (1909) reported a specimen from Arabian Sea and defined as *Serrivomer sector* Garman, 1899. However he said “It also agrees with the shorter description of *Serrivomer beanii* Gill and Ryder, 1883. Hashim (2012) reported *S. beanii* from Andaman Sea. Alcock’s name microps has priority over Garman’s *Serrivomer sector* (1899) if both are same species the valid name will be *Serrivomer* *microps*. Present study reports a species of *Serrivomer* but is unable to reach a conclusion up to species level due to the damaged condition of the specimens. There are no proper descriptions or illustrations on the species reported from Indian EEZ. Most of the specimens of *Serrivomer* sp. we got were in damaged conditions without a full body. or the specimen with whole body was in a damaged condition. The measurements we have made are therefore approximations only. A detailed study is essential by collecting intact specimens from India and critically comparing it with the valid species to confirm the real identity of Indian *Serrivemer* species.

Table 3.36: Morphometric and meristic characters of *Serrivomer* sp.

	Present study (n=1)
Total length	420
% TL	
Preanal length	27.6
Head Length	19.0
Predorsal length	33.8
Depth at anus	1.8
Depth at gill-opening	2.7
% HL	
Snout length	34.9
Eye diameter	4.1
Interorbital width	4.8
Upper- jaw length	44.9
Lower- jaw length	47.0
Gill-opening length	8.3
Pectoral-fin length	2.9

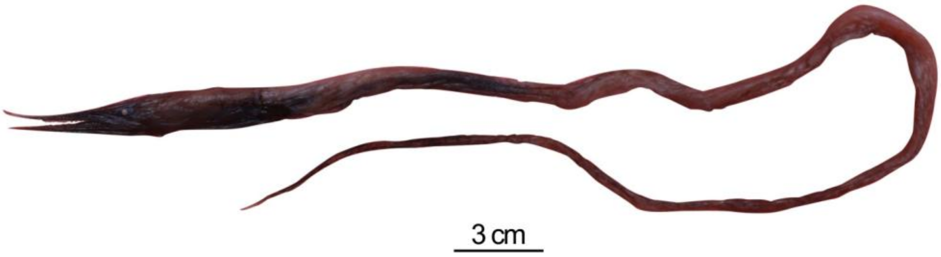

Figure 3.48: *Serrivomer* sp.: Species identity not resolved

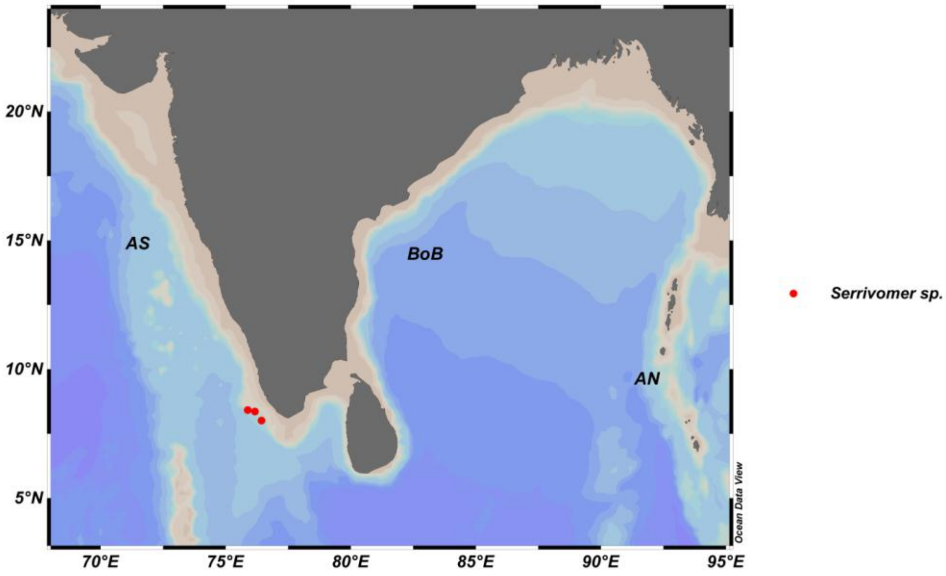

Figure 3.49: Map showing distribution of deep-sea eels of family Serrivomeridae in the Indian EEZ

IX. Family SYNAPHOBRANCHIDAE Johnson, 1862

Cutthroat eels

Synaphobranchids are benthopelagic eels, widely distributed in the upper continental slope to the abyssal depths of the temperate, tropical and subpolar regions of the world Oceans (Sulak & Shcherbachav 1997; Karmovskaya 2003). Currently 46 valid species under 12 genera were recognized (Fricke et al. 2018a).

Synaphobranchidae is divided into 3 subfamiles: Simenchelyinae, Synaphobranchinae and llyophinae. Distinguishing characteristics are as follows: Simenchelyinae: Peculiar snub nosed appearance with short head and extremely short jaws; anus slightly before the midbody; well-developed fins; presence of small embedded scales. Synaphobranchinae: Lower jaw longer than upper, teeth small and numerous, multiserial on upper and lower jaws, patch of teeth on intermaxillary and weak teeth in 1–2 rows on vomer; gill opening on each side converge towards the ventral mid line. Ilyophinae: Great variation in body shape, dentition, presence or absence of pectoral fins, ornamentation of snout, most species devoid of scales; lower jaw shorter than upper jaw; in some species anus located far forward under the pectoral fins (Robins & Robins 1989; Smith 1999i; Smith 2002c).

In Indian EEZ 4 species under 2 genera (*Synaphobranchus* & *Dysomma*) belongs to 2 subfamilies have been reported during the Investigator surveys (Alcock1899; Lloyd 1909). Presently two names under the genus *Synaphobranchus* have been found to be invalid, is discussed elsewhere in this chapter.

Venu (2009) reported 2 species *S. Kaupii*, Johnson, 1862 and *Histiobranchus bathybius* (Günther, 1877) and Hashim (2012) reported another 2 species *Ilyophis brunneus* Gilbert, 1891 and *S. affinis* Günther, 1877. The Identity of these species is suspicious. Due to the absence of voucher specimens, illustration and proper description of the specimens confirmation of these species is not possible. Hence we are not able to consider these species to Indian deep-sea eel fauna. Present study reports 4 species under 2 genera (*Synaphobranchus* and *Dysomma*) which include 3 new records from Arabian Sea and one new species from Arabian Sea and Andaman Sea.

(1) Subfamily Ilyophinae Jordan & Davis, 1891

Genus *Dysomma* Alcock, 1889a

Type species: *Dysomma bucephalus* Alcock, 1889a, Bay of Bengal waters, India.

Diagnosis: Body stout to moderately elongate, slightly compressed in head and trunk; dorsal-fin origin in front of anus; snout slightly project beyond the lower jaw (except for *D. melanurum*); enlarged compound teeth on dentary and vomer; intermaxillary teeth present or absent; gill opening well separated; pectoral fin present or absent, and absence of scales (Ho et al. 2015a).

There are currently 17 valid species in this genus. *D. alticorpus* Fricke, Golani, Appelbaum-Golani & Zajonz, 2018b; *D. anguillare* Barnard, 1923; *D. brevirostre* (Facciolà, 1887); *D. bucephalus* Alcock, 1889a; *D. dolichosomatum* Karrer, 1983; *D. fuscoventralis*

Karrer & Klausewitz, 1982; *D. goslinei* Robins & Robins, 1976; *D. longirostrum* Chen & Mok, 2001*; D. melanurum* Chen & Weng, 1967; *D.muciparus* (Alcock, 1891); *D. opisthoproctus* Chen & Mok, 1995; *D. polycatodon* Karrer, 1983; *D. taiwanensis* Ho, Smith & Tighe, 2015a and *D. tridens* Robins, Böhlke & Robins, 1989; *D. brachygnathos* Ho & Tighe 2018; *D. formosa* Ho & Tighe, 2018; *D. robinsorum* Ho & Tighe, 2018 (Fricke et al. 2018a). In Indian EEZ this genus is represented by 2 species *D. bucephalus* and *D. muciparus* both was previously reported only from Bay of Bengal waters. Present study reports both these species from Arabian Sea.

Dysomma bucephalus Alcock, 1889a

Fig. 3.50, Table 3.37

Collection locations: AS: 11°57·317'N, 74°26.081'E, 200 m, 09.01.2014, (Cr.322, St.05), HSDT-CV

Voucher specimen No.: 3220511 (CMLRE)

Holotype: ZSI F11675, 210 mm TL, Bay of Bengal, Eastern Indian Ocean, 20°17'30"N, 88°51'E, Investigator station 14, 353 m.

Diagnosis: Dorsal-fin origin approximately one pectoral-fin length ahead of its base; anus far forward, immediately behind the gill opening; eye small; branchial region inflated; pectoral fin present; intermaxillary teeth present; vomerine with 4 compound teeth; maxillary teeth triserial with 45-46 teeth, mandibular teeth uniserial with 35-37 smaller teeth; vertebrae 107.

Description: Body moderately elongate, slightly compressed with a tapering tail; dorsal fin and anal fins continuous with caudal fin; dorsal-fin origin approximately one pectoral fin length ahead from its base, predorsal 19.2–19.5% TL; anal fin commences just behind the anus; anus far forward under the base of pectoral fin, just behind the gill opening, preanal length 24.1–24.9% TL; pectoral fin slender and elongated, its length 16.7–17% HL; head broad with slightly inflated branchial region, head length 23.6–24.4% TL; snout moderate, broad, its tip tapers acutely and ornamented with papillae and plicae, snout length 17.7–18% HL; eye small and circular, its horizontal diameter 4–4.2% HL; anterior nostril tubular placed laterally on tip of snout, posterior nostril a large slit with a slightly raised rim placed as it just touches the anterior lower margin of eye; flanges on upper and lower lip absent; mouth elongated, rictus extends far behind the posterior margin of eye; gill opening moderate, situated infront of pectoral base, gill-opening length 9.4–11.6% HL; maximum depth at anus 7.5% of TL. Lateral-line pores small conspicuous: predorsal 5, prepectoral 12, preanal 13; vertebrae: predorsal 6, preanal vertebrae 14 and total vertebrae 107; head pore small and conspicuous: SO 3, IO 5, POM 5, ST 0; intermaxillary teeth 2 in numbers arranged transversely; vomerine teeth uniserial with 4 compound teeths; maxillary tooth small and triserial arranged 45-47 in numbers, mandibular teeth uniserial with 35-40 widely spaced small teeth's; Colour when fresh is greyish brown, with pale ventral region, median fins and pectoral fins pale brown, caudal fin blackish.

Distribution: Northern Indian Ocean (No records other than from Indian EEZ); Bay of Bengal (Alcock, 1889a); Arabian Sea (Present study [Figure 3.54]).

Remarks: *Dysomma bucephalus* was previously known only from the type material colleted from Western Bay of Bengal, Northeastern Indian

Ocean during the Investigator survey more than a century ago. Present study reports this species from South Eastern Arabian Sea thus extending their distribution to the Northwestern Indian Ocean.

Table 3.37: Comparison of morphometric and meristic characters of *Dysomma bucephalus* Alcock, 1889a with previous study

	Robins & Robins 1976 (n=1)	**Present study (n=2)**		
		Range	**Mean**	**SD**
Total length	210	203-205	?	?
% TL				
Preanal length	-	24.1-24.9	24.5	0.5
Predorsal length	20	19.2-19.5	19.4	0.2
Head length	22	23.6-24.4	24.0	0.5
Trunk length	-	0.5	0.5	0
Depth at gill-opening	-	6.6-7.6	7.1	0.7
Depth at anus	-	7.5	7.5	0.0
% HL				
Snout length	18	17.7–18	17.9	0.2
Eye diameter	4	4–4.2	4.1	0.2
Interorbital width	14	12.9-14	13.5	0.8
Upper- jaw length	-	34.2-36.7	35.4	1.7
Lower- jaw length	-	32.4-34.2	33.3	1.2
Gill-opening length	-	9.4-11.6	10.5	1.6
Interbranchial width	-	13.1-13.4	13.3	0.2
Pectoral-fin length	17	16.7–17	16.8	0.2
Pectoral-fin base length	-	5.4-6	5.7	0.5
Meristics				
Lateral-line pores				
Prepectoral	-	12		
Predorsal	-	5		
Preanal	-	13		
Head pores				
Supraorbital	3	3		
Infraorbital	5	5		
Preoperculomandubular	5	5		
Supratemporal	-	0		
Vertebrae				
Predorsal	-	6		
Preanal	-	14		
Total	107	107		

***Dysomma muciparus* (Alcock, 1891)**

Fig. 3.51, Table 3.38

Synonym: *Dysommopsis muciparus* Alcock, 1891

Collection locations: AS: 12°22·150’N, 74°32.570’E, 242 m, 21.08.2012, (Cr.305, St.05), HSDT-CV; 09°17·958’N, 75°39.942’E, 392 m, 02.11.2014, (Cr.331, St.01), HSDT-CV

Voucher specimen No.: 3050509 (CMLRE)

Lectotype: ZSI F13107 ca. 257 mm TL. ***Paralectotype****:* ZSI F13106 ca. 217 mm TL; Southeast of Machilipatnam, Andhra Pradesh, India, Bay of Bengal, 15°56'50"N, 81°33'30"E, Investigator station 120, 439-505 m.

Diagnosis: Pectoral fin absent; predorsal 20.6–22.2% TL; anus positioned a snout length behind the dorsal-fin origin, preanal 23.3–25% TL; two intermaxillary teeth; five vomerine teeth; four enlarged mandibular teeths followed by small uniserial teeths.

Description: Body cylindrical anteriorly and laterally compressed posteriorly; dorsal and anal fin continuous with caudal fin; Caudal fin not attenuated; dorsal fin origin about two third head length behind gill opening, predorsal 20.6-22.2% TL; anal fin commences just behind the anus; anal fin origin a snout length behind the dorsal fin origin, preanal 23.3–25% TL; pectoral fin absent; head moderate with slightly expanded branchial region, head length 13.5–15.5% TL; snout tip tapered and fleshy with less ornamentation, slightly downturned at anterior region, snout length 19.1–20% HL; eye small and circular, its horizontal diameter 5.6–7.3% HL; anterior nostril tubular located laterally near tip of the snout; posterior nostril an oval slit located anteroventrally at lower half of eye, with a slightly raised rim, anterior portion of rim more expanded; flanges on upper and lower lip absent; mouth elongated, rictus extends far behind the posterior margin of eye; upper jaw slightly overhangs the lower jaw with the intermaxillary teeth exposed; tongue well attached to mouth floor; gill opening is positioned obliquely on lower side of the body, gill-opening length 8–10.5% HL; maximum depth at gill % 4.6–6.5% TL; lateral- line pores small but discernible: pregill 12–13, predorsal 18–20 and preanal 25–26; vertebrae predorsal 20, preanal 25 and total vertebrae 156; head pores conspicuous: SO 3; IO 5; POM 8 and ST 0; teeth on jaws conical; intermaxillary teeth in 2 transverse rows which is exposed when mouth closed; vomer with 5 large compound teeth in a single row; maxillary teeth small irregularly uniserial anteriorly and biserial till the level of second vomerine teeth; mandibular dentition uniserial with 4 large widely spaced teeth with a thick tissue on its base followed by small conical closely arranged teeths; color after preservation in formaldehyde: body dark brown, median fins are pale on anterior half and blackish in posterior region including the caudal tip.

Distribution: Northern Indian Ocean (No records other than from Indian EEZ); Bay of Bengal (Alcock 1891); Arabian Sea (Present study [Figure 3.54]).

Remarks: *Dysomma muciparous* was previously known only from the type material collected from the Investigator more than a century ago from Western Bay of Bengal, Northeastern Indian Ocean. Present study reports this species from South Eastern Arabian Sea thus extending their distribution to the Northwestern Indian Ocean. The report of *Dysomma muciparous* from Hawaii by Smith & Castle (1981) is based on a misidentification and the specimen may be *Dysomma dolichosomatum* Karrer, 1983 described from Mozambique channel (was undescribed in 1981) or an undesribed species (Pers. Comm. with D. G. Smith & Kenneth A. Tighe, Smithsonian Institution).

Table 3.38: Comparison of morphometric and meristic characters of *Dysomma muciparus* (Alcock, 1891) with previous study.

	Robins & Robins 1976 (n=2)	**Present study (n=4)**		
		Range	**Mean**	**SD**
Total length (mm)	218-249	223-252		
% TL				
Preanal length	24	23.3-25	24.5	0.8
Predorsal length	19-20	20.6–22.2	21.7	0.7
Head length	12-13	13.5-15.5	14.4	0.8
Trunk length	-	9.5-11.1	10.1	0.5
Depth at gill-opening	-	4.6-6.5	5.6	0.8
Depth at anus	4	4.5-5.7	5.1	0.5
% HL				
Snout length	19-20	19.1–20	19.4	0.4
Eye diameter	5.7-9.2	5.6-7.3	6.8	0.5
Interorbital width	9.4-16	9-13.5	12.0	2.1
Upper- jaw length	48	40-45	42.0	2.3
Lower- jaw length	-	36.9-41	38.7	2.1
Gill-opening length	-	8–10.5	8.6	1.3
Interbranchial width	-	6.9–7.9	7.5	0.5
Meristics				
Lateral-line pores				
Prepectoral	-	12-13		
Predorsal	-	18-20		
Preanal	-	25-26		
Head pores				
Supraorbital	3	3		
Infraorbital	5	5		
Preoperculomandubular	8	8		
Supratemporal	-	0		
Vertebrae				
Predorsal		20		
Preanal		25		
Total	157	156		

(2) Subfamily Synaphobranchinae Johnson 1862

Genus *Synaphobranchus* Johnson, 1862

***Type species**: Synaphobranchus Kaupii,* Johnson, 1862; off Maderia, Eastern Atlantic Ocean.

Diagnosis: Body elongated and laterally compressed, tapering from anus towards both the end; Scales oval, irregularly oval, or sub circular; Gill opening ventral, horizontal, opening through a single medially divided opening or separate but with anterior ends close together, diverging posteriorly or separated by about the length of gill slit and diverging posteriorly (Robins & Robins 1989)

A total of 6 valid species were recognized in the genus. *S. affinis* Günther, 1877; *S. brevidorsalis* Günther, 1887; *S. kaupii* Johnson, 1862; *S. oregoni* Castle, 1960b; *S. calvus* Melo, 2007 and *S. oligolepis* Ho, Hong & Chen 2018 (Ho et al. 2018d). Another species *S dolichorhynchus* (Lea, 1913) is listed by (Fricke et al. 2018a) is known only from Leptocephalus larvae and its validity is suspicious. In Indian EEZ this genus is represented by 2 species *Synaphobranchus pinnatus* (Gornov.) Gntr. reported by Alcock, 1899 and *Synaphobranchus pinnatus* var. *brevidorsalis* reported by Lloyd (1909) both the names are now inavalid. Prsesent study reports 2 species from this genus, *Synaphobranchus* sp. A (new species) and *S. oregoni* Castle, 1960b (new record) from Indian EEZ.

Synaphobranchus oregoni Castle, 1960b

Fig. 3.52, Table 3.39

Shortdorsal cutthroat eel

Collection locations: AS: 09°53·600'N, 75°31.907'E, 975 m, 08.08.2010, (Cr.278, St.02), HSDT-CV; 07°47·482'N, 76°27.317'E, 1338, 15.07.2013, (Cr.316, St.02), HSDT-CV; 08°53·593'N, 75°27.288'E, 1000 m, 11.01.2014, (Cr.322, St.08), HSDT-CV; 08°04·969'N, 76°07.335'E, 1400 m, 20.10.2017, (Cr.366, St.02), HSDT-CV

Voucher specimen No.: 3160212 (CMLRE)

Holotype: USNM 185605, 380 mm TL, Gulf of Mexico off Alabama, USA, 29°01'N, 88°24'W, Oregon station. 640, 649–869 m; ***Paratypes****:* FMNH 47911(6) NMNZ P.4514 [ex FMNH] (2), collected with the type.

Diagnosis: Dorsal-fin origin behind the anus, predorsal 34.3–40.1% TL; snout slightly projects beyond the lower jaw; scales present on most of the body except snout, lower jaw and fins; scales are rounded to sub triangular in appearance and arranged in paving stone manner and embedded in a thin epidermis; predorsal vertebrae 42–43, preanal vertebrae 30–32 and total vertebrae 134–136.

Description: Body moderately elongated, not greatly compressed anterior to anus but progressively more compressed posteriorly along the tail; tail tip somewhat blunt, not greatly attenuated; dorsal and anal fins continuous with caudal fin; dorsal-fin origin behind the anus, predorsal 34.3–40.1% TL; anus placed well before mid-body, preanal 25.5–29.2% TL; anal fin commences just after the anus, anal fin is higher than the dorsal fin; pectoral fin elongated and well developed, pectoral-fin length 36.4–43.2% HL; head conical and not appreciably differentiated from trunk, head length 13.3–14.4% TL; snout moderate slightly projects beyond the lower jaw, snout length 25.8–31.3% HL; mouth terminal, gape extends beyond the posterior margin of eye, approximately less than an eye diameter behind the posterior margin of eye; flanges absent on both jaws; tongue attached to the mouth floor; anterior nostril tubular and positioned laterally near tip of the snout, posterior nostril an oval slit with slightly raised rim in front of eye at mid-level. Eye large and circular in shape, its horizontal diameter 10.6–15.5% HL; gill opening placed horizontally on ventral side of the body, just before the pectoral fin, nearly confluent at surface as a common aperture but separated distinctly inside, length of the gill opening 16.5–21.4% HL; maximum depth at anus 6.7–8.2% TL; scales present on most of the body except snout, lower jaw and fins; scales are rounded to sub triangular in appearance and arranged in paving stone manner and embedded in a thin epidermis. Lateral-line pores conspicuous, prepectoral 10–11, predorsal 41–42, and preanal 29–32; vertebrae: predorsal 42–43, preanal 30–32 and total vertebrae 134–136; head pores conspicuous: SO 6; IO 8; POM 11; ST 3 and frontal pores 2; teeth conical and slightly recurved, intermaxillary teeth in an oval patch, separated from maxillary teeth by a small gap; vomerine teeth uniserial without any enlarged teeth anteriorly, largest teeth only sub equals to the smallest of intermaxillary tooth; vomerine teeth extends up to the posterior margin of eye; maxillary and mandibular teeth numerous, biserial anteriorly with inner teeth larger than outer, posteriorly ends as numerous small teeths; colour when fresh dark brown and torned skin area appears as white, branchial opening black, pectoral fins and median fins black.

Distribution: Circumglobal (Fricke et al. 2018a); Indian EEZ: Arabian Sea (Present study [Figure 3.54]).

Remarks: Present study reports this species for the first time from Indian EEZ. Lloyd (1909) reported a specimen from Arabian Sea as *Synaphobranchus pinnatus var. brevidorsalis* and the name is now invalid. That specimen may be most propably *S. oregoni* which was undescribed at that time.

Table 3.39: Comparison of morphometric and meristic characters of *Synaphobranchus oregoni* Castle,1960b with previous study.

	Melo 2007 (n= 11)	**Present study materials (n=7)**		
		Range	**Mean**	**SD**
Total length (mm)	233-814	435-641		
% TL				
Preanal length	25.3-29.9	25.5-29.2	27.6	1.2
Predorsal length	30.6-43.7	34.3-40.1	37.3	1.9
Head length	11.1-13.4	13.3-14.4	13.8	0.3
Trunk length	13.3-18	12.2-15.1	13.8	1.1
Depth at pectoral	-	5.8-7.5	6.7	0.7
Depth at anus	3.5-7.7	6.7-8.2	7.5	0.6
% HL				
Snout length	24.3-28.9	25.8-31.3	28.5	2.0
Eye diameter	12.8-18.1	10.6-15.5	13.2	1.9
Interorbital width	13.2-22.1	14.2-17.6	15.9	1.2
Upper- jaw length	44.3-58.6	48.6-54.7	52.4	1.9
Lower- jaw length	47.8-64.7	48.1-54	51.3	1.9
Gill-opening length	9.6-22.7	16.5-21.4	19.0	1.9
Pectoral-fin length	-	36.4-43.2	40.2	2.6
Pectoral-fin base length	-	7.8-9.4	8.7	0.5
Meristics				
Lateral-line pores				
Prepectoral		10-11		
Predorsal	37–49	41-42		
Preanal	27-33	29-32		
Head pores				
Supraorbital	4-6	6		
Infraorbital	7	8		
Preoperculomandubular	9-12	11		
Supratemporal	3	3		
Frontal	2	2		
Vertebrae				
Predorsal		42-43		
Preanal		30-32		
Total	121-149	134-136		

***Synaphobranchus* sp. A**

Fig. 3.53, Table 3.40

Indian longhead cutthroat eel

Collection locations: AS: 08°21·601'N, 76°10.171'E, 995 m, 12.10.2010, (Cr.281, St.03), HSDT-CV; 08°53·593'N, 75°27.288'E, 1000 m, 11.01.2014, (Cr.322, St.08), HSDT-CV;

AN: 11°17·465'N, 92°47.886'E, 907 m, 16.01.2015, (Cr.334, St.12), HOT; 07°28·734'N, 93°24.510'E, 650 m, 04.04.2016, (Cr.349, St.02), HSDT-CV; 13°15.902'N, 93°15.827'E, 635 m, 26.11.2017, (Cr.367, St.08), HSDT-CV; 11°47.889'N, 92°05.437'E, 646 m, 28.11.2017, (Cr.367, St.15), HSDT-CV

Voucher specimen No.: 3671511 (CMLRE)

Diagnosis: Slender body; dorsal-fin origin slightly before the origin of anal fin; scales oval, not greatly elongated in shape; head length 14.3–15.1% TL; gill-opening length 16.8–24.8% HL; lateral-line pores: prepectoral 9–11; predorsal 26–30, preanal 28–31; vomerine teeth uniserial without any enlarged teeth anteriorly, largest teeth only sub equals to the smallest of intermaxillary tooth.

Description: Body slender, moderately elongated, laterally compressed, with somewhat blunt tail not attenuated; dorsal and anal fins continuous with caudal fin; dorsal fin lower than anal fin; dorsal-fin origin just before the origin of anal fin, predorsal length 23.4–28% TL; pectoral fin longer than snout 5.3–7% TL; short trunk 12.5–14.3% TL; anal fin originates just near to anus; anus placed at anterior third of the body, preanal length

27.2–28.9% TL; head conical, compressed not clearly distinguished from trunk, head length 14.3–15.1% TL; snout moderately elongated and pointed with its fleshy tip turned downwards and not extends in front of lower jaw, snout length 26.9–31.5 HL; tongue not free; lower jaw slightly protrudes than upper jaw; lips absent; mouth moderate and terminal, rictus extends beyond the posterior margin of eye; eye moderate and spherical in shape, its horizontal diameter 12.5–15.4% HL; anterior nostril tubular located laterally near tip of the snot, posterior nostril an oval slit, with slightly raised rim located in front of eye at mid-level; gill opening almost confluent anteriorly and posteriorly, appear to open in a common shallow aperture, its length 16.8–24.8% HL; scales oval, not greatly elongate absent on fins; depth at anus 5.7–7.7% TL; lateral-line pores conspicuous: prepectoral 9–11, predorsal 26–30 and preanal 28–31; vertebrae: predorsal 31, preanal 32 and total not dicsernable; head pores small conspicuous: SO 5; IO 8; POM 11; ST pores 3; frontal 2; Teeth conical and slightly recurved, Intermaxillary teeth in an oval patch of about 10–12 with larger teeth in medial row, and separated from maxillary and vomerine teeth by a small gap; vomerine teeth uniserial without any enlarged teeth, largest teeth is only sub equals to the smallest of intermaxillary tooth which extends beyond the posterior margin of eye; maxillary and mandibular teeth numerous, biserial anteriorly much smaller than others and posteriorly becoming multiserial and villiform; colour when fresh is whitish with greyish fins.

Distribution: Known only from Arabian Sea and Andaman Sea of Indian EEZ (Present study [Figure 3.54])

Remarks: New species described from Indian EEZ.

Discussion: *Synaphobranchus s*p. A can be distinguished from *S. affinis,* in having greater head length 14.3–15.1% vs. 11.2–12.8% TL, longer gill-opening 16.8–24.8 vs. 12.3–19.2 % HL, less predorsal lateral-line pores 26–30 vs. 30–32, more preanal lateral-line pores 28–31vs. 28–30, more number of IO pores 8 vs.7 in *S. affinis*. *Synaphobranchus s*p. A can be differentiated from *S. kaupii* in its greater head length 14.3–15.1% vs. 11.4–12.4% TL, shorter trunk 12.5–14.3 vs. 14.4–17.4% TL, lesser predorsal length 23.4–28 vs. 30.9–36.9% TL, higher body depth at anus 5.7–7.7 vs. 4–4.5% TL, slightly longer sout 26.9–31.5 vs. 23.5–29% HL, longer upper jaw 52.9–57.8 vs. 45.2–51.6% HL, longer gill-opening 16.8–24.8 vs. 10.6–13.3% HL, less predorsal lateral-line pores 26–30 vs. 35–46, lesser preanal pores 28–31 vs. 28–35, more no of IO pores 8 vs.7 in *S. kaupii*. *Synaphobranchus s*p. A can be distinguished from *S. brevidorsalis* by its larger head length, shorter trunk, lesser predorsal and preanal length, larger body depth and pectoral-fin length, larger jaw lengths, lesser predorsal and preanal lateral-line pores. Present new species also differs from *S. oregoni* in larger head length, shorter trunk, lesser predorsal length, slightly larger snout and eye diameter, lesser pre-dorsal lateral-line pores and more IO pores. *Synaphobranchus s*p. A can be distinguished from another congener *S. clavus* by its larger head length, snout and gill-opening length, smaller predorsal length, lesser predorsal lateral-line pores and ST pores. *Synaphobranchus s*p. A is similar in most body proportions and head pores with a recently described species, *S. oligolepis* but differs in lesser interorbital width 15.8–16.4 vs. 9.9–24% HL, more prepectoral pores 9–11 vs. 5–10, lesser predorsal (26–30 vs. 21–33) and preanal lateral-line pores (28–31 vs. 24–33).

Table 3.40: Comparison of morphometric and meristic characters of *Synaphobranchus* sp. A with congeners.

	Melo 2007					Ho et al. 2018d	Present study (n=5) *Synaphobranchus* sp. A		
	***S.affinis* (n=5)**	***S. kaupii* (n=5)**	***S. brevidorsalis* (n=10)**	***S. oregoni* (n=11)**	***S. clavus* (n=24)**	***S. oligolepis* (n=20)**	**Range**	**Mean**	**SD**
Total length (mm)	382-561	291-548	329-890	233-814	312-660	128-540	327-525		
% TL									
Head Length	11.2-12.8	11.4-12.4	11.3-13.5	11.1-13.4	10.3-12.9	11.7-15.2	14.3-15.1	14.7	0.3
Trunk length	10.1-15.9	14.4-17.4	16.1-20.7	13.3-18	11.3-20	11.3-17.8	12.5-14.3	13.4	0.7
Preanal length	24.9-27.8	25.9-28.7	29.6-33.5	25.3-29.9	21.4-31.2	24.5-33	27.2-28.9	28.1	0.8
Predorsal length	26.3-33	30.9-36.9	42.2-54.6	30.6-43.7	31.9-45.5	24.4-35.8	23.4-28	26.2	1.9
Body depth at anus	4.6-7.4	4-4.5	4.3-7.7	3.5-7.7	4.1-6	3.4-8.2	5.7-7.7	6.5	0.7
Pectoral-fin length	4.2-6.4	4.5-5.9	3.9-5.1	4.0-6.0	3.9-6	4-6.5	5.3-7	6.1	0.7
% HL									
Snout length	22.6-32.6	23.5-29	23.5-28.3	24.3-28.9	22-27.2	23.1-35.4	26.9-31.5	28.9	1.7
Eye diameter	13.4-15.7	12.5-15.7	10.1-14.4	12.8-18.1	11.5-16.4	11.8-19.5	12.5-15.4	14.4	1.2
Upper-jaw length	42.3-63	45.2-51.6	45-52.1	44.3-58.6	44.2-59.6	46.6-62.3	52.9-57.8	55.8	2.0
Lower-Jaw length	45.8-57.2	49.2-68.7	48.1-56.9	47.8-64.7	48-63.6	-	51.9-58.8	55.1	2.6
Interorbital width	14.8-20.7	13.7-18.7	14.9-23.9	13.2-22.1	11.1-18.5	9.9-24	15.8-16.4	16.1	0.2
Gill-opening length	12.3-19.2	10.6-13.3	16.1-24.5	9.6-22.7	8.2-18.2	14.5-23.5	16.8-24.8	20.7	3.2
Depth at pectoral	-	-	-	-	-	-	35.2-50	41.0	5.8
Meristics									
Laterel-line pores									
prepectoral	-	-	-	-	-	5-10	9-11		
predorsal	30-32	35-46	47-64	37-39	41-53	21-33	26-30		
Preanal	28-30	28-35	30-37	27-33	26-33	24-33	28-31		
Total	109-134	140-150	128-132	121-149	131-145	-	-		
Head pores									
Supraorbital	4 – 5	5	4 – 5	4 – 6	5 – 6	5	5		
IO	7	7	6 – 8	7	6 – 8	8	8		
POM	11 -13	11 – 14	11 – 13	9 – 12	12 - 15	10-13	11		
Ethmoid	1	1	1	1	1	1	1		
Supratemporal	3	3	3	3	5	3	3		
Frontal	2	2	2	2	2	2	2		
Adnasal	1	1	1	1	1	1	1		

Family Synaphobranchidae

Figure 3.50: *Dysomma bucephalus*: New record from Western Indian Ocean

Figure 3.51: *Dysomma muciparus*: New record from Western Indian Ocean

Figure 3.52: *Synaphobranchus oregoni*: New record from Northern Indian Ocean

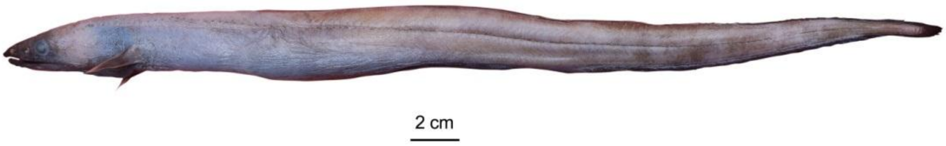

Figure 3.53: *Synaphobranchus* sp. A: New species from Arabian Sea and Andaman Sea

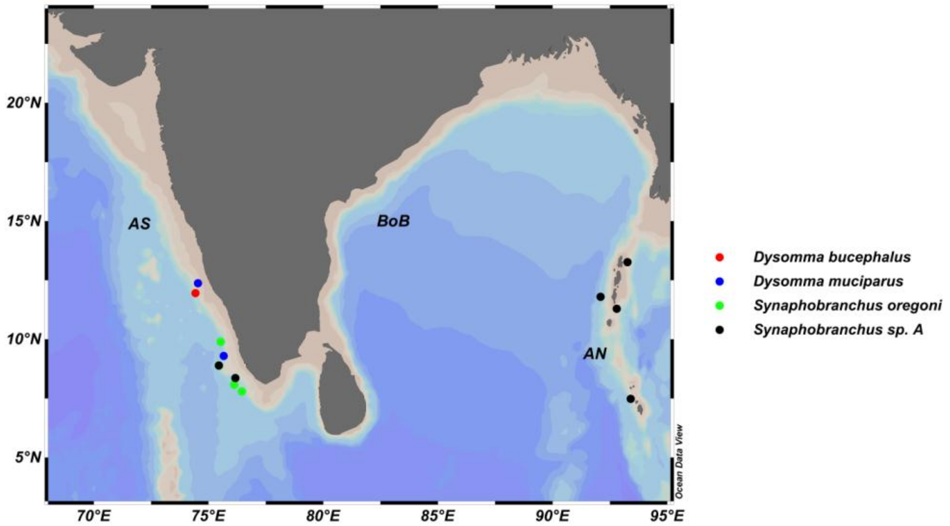

Figure 3.54: Map showing distribution of deep-sea eels of family Synaphobranchidae in the Indian EEZ

B. Suborder MURAENOIDEI

Include 4 Families; Family Chopsidae, Myrocongidae, Muraenidae and Protanguillidae. Of the 4 families, Muraenidae is the most speciose (218 valid species) under subfamilies Uropteryginae (31 species) and Muraeninae (174 species). Family Protanguillidae is represented by a single species. Only the family Muraenidae has deep-sea eels as its representatives.

X. Family MURAENIDAE Refinesque, 1815

Moray eels

Diagnosis: Elongate muscular and laterally compressed body; well developed eyes; long fang like teeth; gill openings restricted to small roundish lateral slits; lateral-line pores restricted only to head; fourth branchial arch strengthened for supporting pharyngeal jaws; pectorals absent and posterior nostril high on head (Böhlke et al. 1989; Smith 2012).

Family Muraenidae is one of the most diverse and species rich among the order Anguilliformes, only ophichthids exceeds them. Currently 210 valid species of moray eels under 16 genera are recognized (Fricke et al. 2018a). They are cryptic, found mostly in shallow waters and as rock/ coral reef inhabitants. However, many species live in offshore waters on sand and mud bottoms at greater depths up to 500 m (Smith 2012). They show wide variation in their colour patterns from nearly uniform to distinctive patterns of spots, blotches, bars and reticulations. Muraenidae is divided into two subfamilies based on their extent of fins, Uropterygiinae with median fins restricted to the posterior tip of the tail and Muraeninae with long dorsal fin, beginning on or just behind the head and the anal fin beginning just behind the anus (Böhlke et al. 1989, Böhlke & Randall 2000).

Most of the morays described from Indian EEZ are from coastal regions, mostly below 50 m depth. Present study reports 2 species of deep-sea (depth >200 m) moray eels belonging to the subfamily Muraeninae; genus *Gymnothorax* Bloch, 1795 which is the first observation of moray eels from a greater depth of about 200 m from Indian EEZ.

(1) Subfamily Muraeninae Rafinesque, 1815

Genus *Gymnothorax* Bloch, 1795

Type species: *Gymnothorax reticularis* Bloch, 1795, Coromandel Coast, India

Diagnosis: Elongated, laterally compressed body with tapering tail; anus shortly before, at, or shortly behind mid body; dorsal-fin origin shortly before gill opening to nearly over the anus; head moderately short to elongate; one to three branchial pores; jaws and dentition vary from short jaws with short almost molariform teeth to long jaws with caniniform teeth and colouration variably uniform to highly spotted or patterned (Böhlke & Randall 2000).

This genus represents more than half of the world's moray eels (124 species) (Smith 2012). Indian EEZ represents 27 species including a new discovery in the present study. Present study reports 2 species of the genus *Gymnothorax* from deep-waters of India.

Gymnothorax reticularis Bloch, 1795

Fig. 3.55, Table 3.41
Dusky-banded moray

Holotype: ZMB 3986, 302 mm TL, Tranquebar, Coromandel Coast, India.

Collection locations: AS: 09°59·575'N, 75°35.768'E, 214 m, 08.08.2010, (Cr.278, St.01), HSDT-CV; 09°59·935'N, 75°36.086'E, 200 m, 10.08.2011, (Cr.288, St.17), HSDT-CV

Voucher specimen No.: 2780137 (CMLRE)

Diagnosis: Body with 17–18 vertical bars; head with numerous spots, drawn out longitudinally with their pale interspaces giving an impression of horizontal lines, especially in branchial region; continuous spots on the body, restricted to the dorsal half; total vertebrae 117.

***Description**:* Body moderately elongated with almost cylindrical head and laterally compressed tail; caudal fin rounded, not attenuated; dorsal and anal fins continuous with caudal fin; dorsal-fin origin slightly ahead of gill opening, predorsal 12.4–13.2% TL; anus placed slightly before mid-body; anal fin originates immediately behind anus; preanal 48.2–50.3% TL; head with a smooth dorsal profile, not raised 15.1–16.5% TL; snout blunt 16.5–17.5% HL; upper jaw and lower jaw almost equal; rictus extends far behind the posterior margin of eye; eye spherical, covered by membrane, its horizontal diameter is 10.2–11.6% HL; all teeth concealed when mouth closed; tongue well attached to floor of mouth; anterior nostril tubular placed near the tip of the snout, posterior nostril oval slit with slightly raised rim positioned above the anterior margin of eye; gill opening cresentic in shape, placed at mid-level of the body; depth at gill opening is greater than depth at anus (6.4–8 vs. 4.3–5.3% TL); head pores small but conspicuous: branchial pores 2, SO 3; IO 4; mandibular pores 6; teeth on jaws are pointed, canine and slightly serrated; intermaxillary teeth 5, maxillary teeth 6–7, mandibular teeth 11–12; vomerine teeth, molariform 5–6; vertebrae: predorsal 6, preanal vertebrae 48, total vertebrae 117; colour (in formaldehyde): head and chin with closely arranged brown spots separated by pale interspace giving an appearance of horizontal lines, especially in the branchial region, 17–18 dark brown bars on a light cream to white background commencing behind the gill opening, well discerned ventrally and diffused dorsally, continuous series of small brown round to irregular spots on dorsal side.Vventral side is devoid of spots.

Distribution: Indian Ocean and Mediterranean Sea (Smith & Böhlke 1997; Stern & Goren 2013; Psomadakis et al. 2015, Moazzam & Osmani 2015; Lin et al. 2018); Indian EEZ: Arabian Sea: (Bijukumar & Deepthi 2009; Bijukumar & Raghavan 2015; Present study [Figure 3.57]) Bay of Bengal: (Bloch 1795; Day 1889; Krishnan & Mishra 1993; Nagabhushanam & Krishnan 1993; Mishra & Krishnan 2003; Yennawar et al. 2013; Ray 2016).

Remarks: Present study reports this species from 200–214 m depth which is greater depth than ever reported. Maximum depth of earlier observance of this species was 100 m (Froese & Pauly 2018). This species is distributed from shallow waters to upper continental shelf in Indian EEZ. *G. reticularis* has long been confused with *G. minor* (Temminck & Schlegel, 1846). Smith & Böhlke (1997) studies on banded moray eels clarified that the records of *G. reticularis* from Pacific Ocean are misidentification of a similar species *G. minor* and also pointed out that the Red Sea specimen has more vertebrae than Indian specimens 114-120 vs. 126 in Red Sea. Our specimen also has less vertebral count (118) than Red Sea specimen . Species clarification is based on Smith & Böhlke (1997). Our specimens have slightly longer head and upper jaw compared to holotype, but similar specimens with longer head were reported by Yennawar et al. 2013 from Bay of Bengal waters.

Table 3.41: Comparison of morphometric and meristic characters of *Gymnothorax reticularis* Bloch, 1795 with previous study.

	Smith & Böhlke 1997 (n=1)	**Yennawar et al. 2013 (n=2)**	**Present study (n=4)**		
			Range	**Mean**	**SD**
Total length (mm)	302	288-304	309-344		
% TL					
Preanal length	47	47-50	48.2-50.3	49.2	1.1
Predorsal length	-	-	12.4-13.2	12.8	0.4
Head length	12.2	16.3-17.2	15.1-16.5	15.7	0.7
Trunk length	34.7	32.2	32-35.5	34.0	1.7
Depth at gill-opening	-	7.6–7.9	6.4-8	7.2	0.8
Depth at anus	-	-	4.3-5.3	4.9	0.5
% HL					
Snout length	-		16.5-17.5	16.8	0.5
Eye diameter	9.8	10.7-13.9	10.2-11.6	11.2	0.7
Interorbital width	-	-	14.3-15.8	15.0	0.6
Upper-jaw length	43.5	-	35.9-40.8	38.3	2.4
Lower-jaw length	-	-	34.5-38.6	36.8	2.0
Gill-opening length	-	-	9-11.5	10.2	1.3
Interbranchial width	-	-	25.4-36.5	32.4	6.1
Meristics					
Pores					
Preoperculomandubular	6	-	6		
Infraorbital	4	-	4		
Supraorbital	3	-	3		
Supratemporal	Absent	-	Absent		
Branchial	2	-	2		
Vertebrae					
Predorsal	6	5–6	6		
Preanal	49	48–49	48		
Total	118	115–119	117		

Gymnothorax sp. A (New species)

Fig. 3.56, Table 3.42

Indian white spotted moray eel

Collection locations: AS: 09°59·935’N, 75°36.086’E, 200 m, 10.08.2011, (Cr.288, St.17), HSDT-CV

Voucher specimen No.: 2881718 (CMLRE)

Diagnosis: Moderate sized body with greyish brown colour overlain with small irregular white spots; anus slightly behind mid-point of body; head broad with short jaws; snout tip blunt and short; eyes small and closer to rictus than to snout tip; pointed and serrated teeth; vomerine teeth start as uniserial for a short run and then extend as biserial and ends in uniserial teeth; two branchial pores and vertebral count 3/57/130.

Description: Moderate sized eel with cylindrical to laterally compressed head and laterally compressed tail; dorsal and anal fins continuous with caudal fin; dorsal fin commences slightly before gill opening, predorsal 9.9% TL; anal fin origin immediately behind anus; anus located slightly after mid-body, preanal length 53.2% TL; head broad and gently sloping towards the snout, head length 16.7% TL; snout blunt and short, snout length 16.3% HL; upper jaw slightly overhangs lower jaw; all teeth concealed when mouth closed; tongue well attached to the floor of mouth; flange absent on upper and lower lip; eyes small, covered by membrane and closer to snout tip than rictus, horizontal eye diameter 7.9% HL; anterior nostril tubular at tip of snout, and posterior nostril above anterior margin of eye; gill opening a diagonal slit at mid-body, gill opening 10% HL; depth at gill opening more than depth at anus, 8.1% vs. 4.4% TL.; head pores small but discernible: branchial pores 2, located above and well before gill opening closer to dorsal-fin origin than gill opening; SO 3, first pore at tip of snout above lip, second above base of anterior nostril, third between anterior and posterior nostrils; IO 4, first pore just behind base of anterior nostril, second between anterior nostril and anterior margin of eye, third below anterior margin of eye, and fourth after posterior margin of eye; mandibular pore 6, first five before rictus and sixth at level of rictus; Vertebrae: predorsal 3, preanal 57 and total 130; teeth on jaws serrated and uniserial except in vomer and anterior dentary; maxillary and mandibular teeth conical and sharp, whereas vomerine teeth blunt and smaller; intermaxillary teeth 6 on both sides, followed by 9 maxillary teeth on both sides, median intermaxillary teeth 2, inner maxillary teeth 1 on each side, just before vomerine teeth; vomer with 4 uniserial teeth anteriorly, followed by 4 biserial teeth and 3 uniserial teeth posteriorly; mandibular teeth 17 on each side, anterior 4 teeth little enlarged with 4 smaller outer teeth on each side, remaining teeth decreasing in size posteriorly; colour (in formaldehyde) is greyish brown body overlain with white spots of irregular shape; snout, lower jaw and ventral portion of the body pale; in enlarged view under microscope there is small brown pigmentation inside the white spots; margin of gill openings with similar brown pigmentation; spots very small and more closely spaced in head region and becoming large and more widely spaced in posterior region; tail end is almost devoid of spots with duskish greyish brown colour; dorsal fin greyish brown overlain with white spots similar to those on body; anal fin dusky greyish brown colour with few isolated spots; caudal fin ends with small white margin, visible only on close inspection; mouth white colour overlain with grey patches.

Distribution: Known only from type specimen collected from off Kochi, South Eastern Arabian Sea, India. Present study [Figure 3.57]

Discussion: There are several white-spotted morays described worldwide. The white-spotted morays *G. intesi* (Fourmanoir & Rivaton, 1979), *G. johnsoni* (Smith, 1962) and *G. neglectus* Tanaka, 1911 differ from the new species in having more vertebrae (more than 137 total vertebrae). *Gymnothorax miliaris* (Kaup, 1856a) a spotted moray, which may be confused with the present species in colouration, however, differs from the *Gymnothorax* sp. A in having yellow dots in place of white dots, biserial maxillary dentition and having fewer vertebrae (117–126) than the *Gymnothorax* sp. A, and its distribution is restricted only to Atlantic waters. *Gymnothorax nuttingi* Snyder, 1904 another spotted moray reported from almost similar depth range has more vertebrae (157–165) than the *Gymnothorax* sp. A.

There are three spotted morays in India which can be confused with *Gymnothorax* sp. A. *Gymnothorax meleagris* (Shaw, 1795) has the total vertebrae (127–132) close to *Gymnothorax* sp. A, but differs in predorsal (4–6 vs. 3 in the new species) and preanal vertebrae (48–53 vs. 57 in the new species). In addition, *G. meleagris* can be differentiated from the present new species by the presence of a black spot on the gill opening, a distinct white patch at the tip of the tail and in its biserial maxillary dentition. *Gymnothorax tile* (Hamilton, 1822), a species described from

India, has irregular small pale spots, but it has more predorsal vertebrae (9–11). *Gymnothorax punctaus* Bloch and Schneider, 1801 is another white-spotted moray eel described from India, having similar uniserial dentition. It can be easily differentiated by more vertebrae (MVF, 5, 54, 136), tan colouration of head, and white spots commencing only after the origin of dorsal fin. *Enchelycore nycturanus* Smith, 2002 is another white-spotted moray described from the east coast of South Africa similar in colour pattern to the new species but differs from the new species in having arched jaws which cannot be closed completely, placing this species in another genus *Enchelycore* rather than *Gymnothorax*. It also differs in higher vertebral count (147–148 vs. 130 in *Gymnothorax* sp. A) and lesser preanal length (40–42 vs. 53.2% TL vs. new species). Further, all the above said similar species have smooth teeth in comparison to the serrated teeth in the new species. The serrated teeth, body colouration and pattern of new species, closely resembles a deep-water species *Gymnothorax sokotrensis* Kotthaus, 1968 described from Socotra Island, southwestern Arabian sea. But *G. sokotrensis* can be distinguished in having more vertebrae (8/62/140–143 vs. 3/57/130 in *Gymnothorax* sp. A) and lesser pre-anal length (46–50% vs. 53%) in comparison to the new species.

Remarks: New to science

Table 3.42: Morphometric and meristic characters of *Gymnothorax* sp. A (New species)

	Present study(n=1)
Total length (mm)	342
% TL	
Preanal length	53.2
Predorsal length	9.9
Head length	16.7
Trunk length	36.5
Depth at gill-opening	8.1
Depth at anus	4.4
% HL	
Snout length	16.3
Eye diameter	7.9
Interorbital width	12.8
Upper-jaw length	34.4
Lower-jaw length	33.9
Gill-opening length	10.0
Interbranchial width	22.8
Meristics	
Pores	
Supraorbital	3
Infraorbital	4
Mandibular	6
Supratemporal	Absent
Branchial	2
Vertebrae	
Predorsal	3
Preanal	57
Total	130

Family Muraenidae

Figure 3.55: *Gymnothorax reticularis*: First report from deep-waters of Indian EEZ, previously reported from shallow-waters

Figure 3.56: *Gymnothorax* sp. A: New species from Arabian Sea

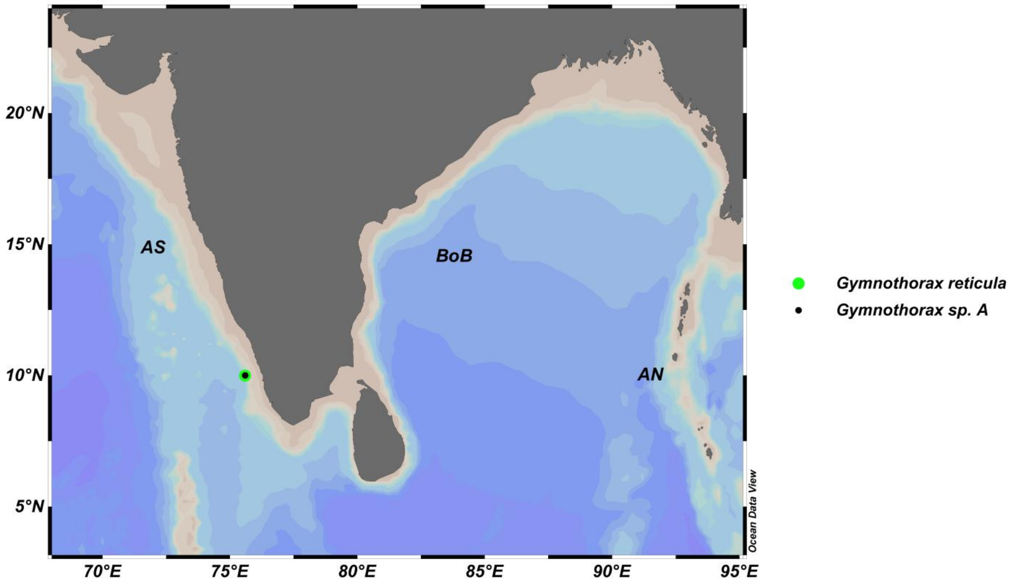

Figure 3.57: Map showing distribution of deep-sea eels of family Muraenidae in the Indian EEZ

3.4 Otolith morphology of selected species of deep-sea Anguilliformes

Otoliths or ‘earstones’ are complex paired polycrystalline structures composed of calcium carbonate and other inorganic salts located in the labyrinth of the inner ear of teleost fishes (Campana et al. 1997; Campana 2004; popper et al. 2005). The inner ear consist of three chambers saccula, utricle and legna containing 3 pairs of otoliths; sagittae, lapillae and asterisci respectively (Degens et al. 1969; Platt & Popper 1981; Secor et al. 1991; Tuset et al. 2008). These otoliths are responsible for acoustic (sound detection) and vestibular (balance) function in fishes (Popper & Fay, 1993; Campana 1999; Popper & Lu 2000; popper et al. 2005). Otoliths are the only calcified structures known to grow throughout the lifetime of fish in a continual way without any resorption (Bilton 1974; Mendoza 2006). The otoliths are three-dimensional structures with fast growth along the anteriorposterior axis and slow accretion along the distal-proximal direction (Shiao et al. 2005). The three otolith pairs in teleosts show large morphological variability (Lombarte & Cruz 2007) and in most adult fish the variability is especially true for sagittae (Platt & Popper, 1981; Compana 2004; Tuset et al. 2008). In fishery analysis saccular otoliths (sagittae) are most studied due to their larger size and distinct growth rings (Boehlert 1985, Sumerfelt & Hall 1987). There is almost certainly no other biological structure that is more important to fishery researchers than otolith because of the information they contain (Begg et al. 2005).

Otolith morphology is a valuable parameter in the species identification of teleost fishes (Adams 1940, Smale et al. 1995; Compana

2004; Ponton 2006; Tuset et al. 2006, 2008; 2011). Their species specific morphology is extensively used in identification and discrimination of species (Cardinale et al. 2004). The morphology of the otoliths is determined by genetic characteristics of the species, and is influenced by ontogenical and environmental factors (Vignon & Morat 2010; Vignon 2012). In addition to their traditional use in taxonomy otoliths have been used in wide array of studies such as diet studies of piscivorous predators (Fitch & Brownell, 1968; Pitcher 1980; Hecht & Appelbaum1982; Pierce et al. 1991; Tollit et al. 1997; Harvey et al. 2000; Zan et al. 2015), stock identification (Campana & Casselman, 1993; Cardinale et al. 2004; Cadrin & Friedland, 2005; Stransky, 2005; Jónsdóttir et al. 2006; Mérigot et al. 2007; Burke et al. 2008), age determination (Donkers 2004), environmental histories (Campana & Thorrold 2001; Izzo et al. 2016), ecological interpretation (Tuset et al. 2016) migratory pattern using otolith microchemistry (Kennedy et al. 2002) etc. The application of otolith is not only restricted to ichthyology, but also extended widely for some aspects of palaeontology, stratigraphy, archaeology and zoogeography (Tuset et al. 2008). Otolith atlases of fishes have been generated by various authors from different parts of the world (Hecht 1987; Smale et al.1995; Harvey & Yoklavich 1996; Rivaton & Bourret 1999; Volpedo & Echeverría 2003; Campana 2004; Furlani *et al*. 2007; Tuset et al. 2008; Lin & Chang 2012; Sadighzadeh & Tuset 2012, Bremm & Schulz 2014; Kasapoglu, & Duzgunes 2015) which helps in taxonomic identification of fishes. In India no atlases have been developed yet, however some initiative have been taken by CMLRE to produce an atlas of deep-sea fishes of India on the basis of collections from FORV *Sagar Sampada*. Recently few works have been published as part of the same (Kumar et al.2016a, 2016b). Present study provides baseline information on morphological characteristics of sagitta otolith of Anguilliformes which helps in taxonomic identification of the species.

3.4.1 Materials and methodology

Otoliths of five species under 5 genera and two families [Congridae (3) and Muraenesocidae (2)] were analysed for the present study. The sagittal otoliths were collected by making an incision on lower part of the cranium. The ventral side of the eel was placed in an upward direction in order to remove the lower jaw and to get the lower part of the cranium fully exposed. Total length (TL) of the eels was measured to nearest millimeter and total weight (TW) to the nearest milligram. The otoliths extracted were rinsed using distilled water to remove the particulate matter and stored in plastic vials after proper drying. Only the right otoliths were taken for further analysis as both right and left otoliths are considered as mirror images to each other (Stransky & MacLellan 2005; Bilge & Filiz 2018). Each otolith were photographed using a stereo zoom trinocular microscope (Leica modal No. S8APO camera, Leica DFP-425). Left otolith was placed in such away that sulcus acustics orientated towards the observer. Each otolith was weighed to an accuracy of 0.001 gm on a digital electronic weighing balance (Metler Toledo, ML 503). The shape parameters of the otoliths such as length (OL, mm), height (OH, mm), perimeter (OP, mm) and area (OA, mm^2) were taken from the photographs using the image analyzing software (Imaje J) following the terminology of Avigliano et al. (2014, 2016). Afterwards few shape indices: Aspect ratio (OH/OL %), Roundness or Inverse aspect ratio ($4 \times OA/3.14 \times OH^2$) and Circularity ($4\pi \times OA/ OP^2$) were calculated following Leguá et al. (2013). Terminology of describing the morphology (Figure 3.58) of otolith follows (Smale et al. 1995; Tuset et al. 2008).

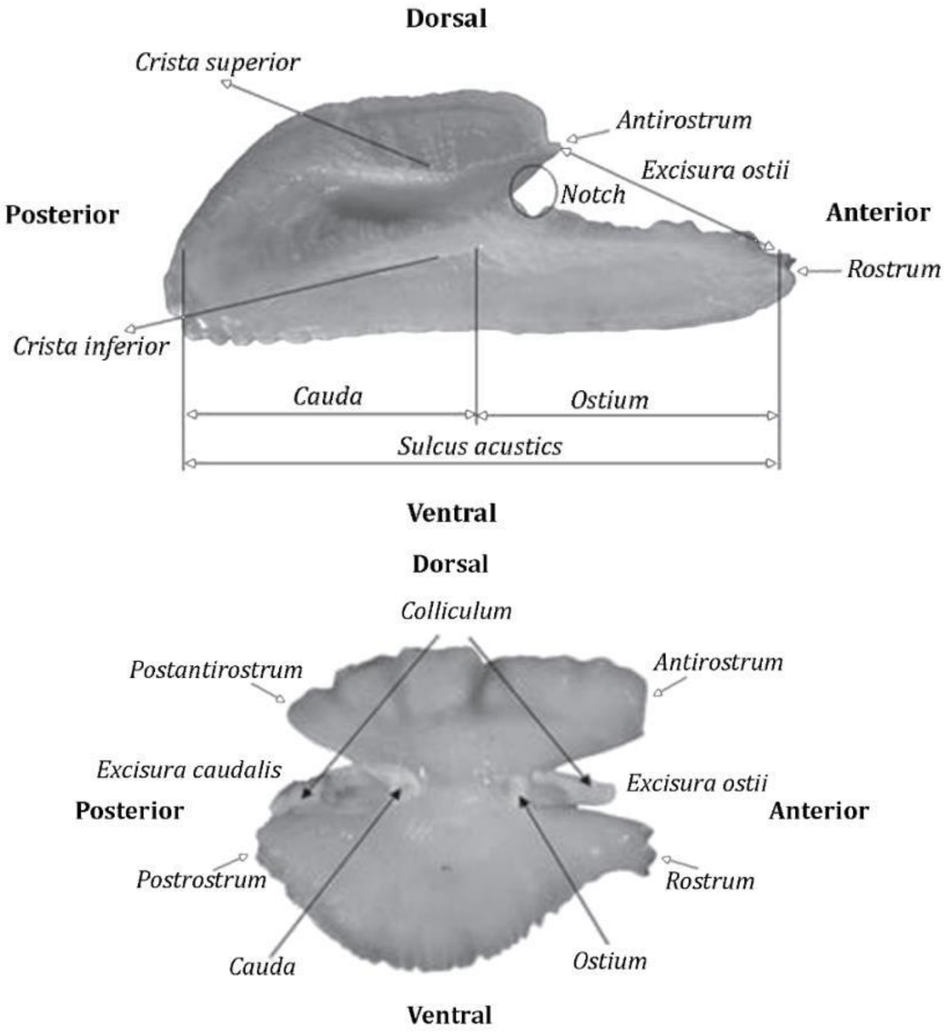

Figure 3.58: Showing morphological features of sagittal otolith adopted from (Tuset et al. 2008)

3.4.2 Results

Family: CONGRIDAE

Bathyuroconger vicinus (Vaillant, 1888)

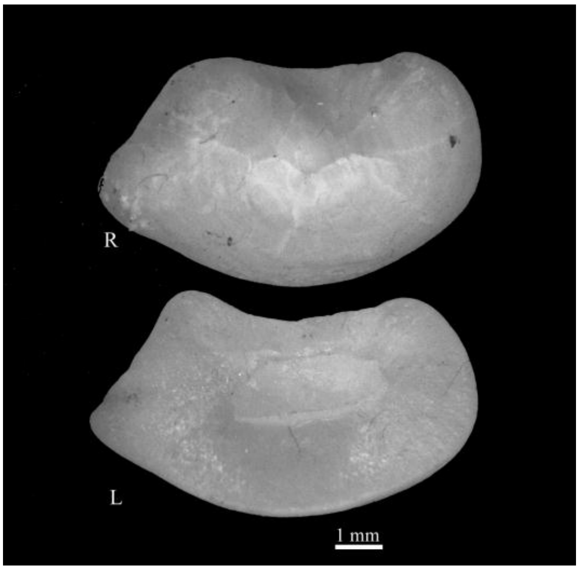

Figure 3.59: Sagittal otolith of *Bathyuroconger vicinus*; L–showing mesial surface

Morphological description–*Shape*: elliptic to oval, dorsal and ventral margin entire; *Sulcus acusticus*: archaesulcoid, caudal, median in position; *Ostium*: straight, broader than cauda; *Cauda*: narrow, *Anterior region*: narrow rounded; rostrum poorly defined; antrirostrum absent, *Posterior region*: broad rounded (Figure 3.59).

FTL: 570 mm, Area: Andaman Sea; Depth: 647 m

Shape parameters: OL: 7.07, OH: 4.49, OP: 18.7, OA: 23.03 Shape indices: AR: 1.64, roundness: 0.61 and circularity: 0.83

Gavialiceps sp. A

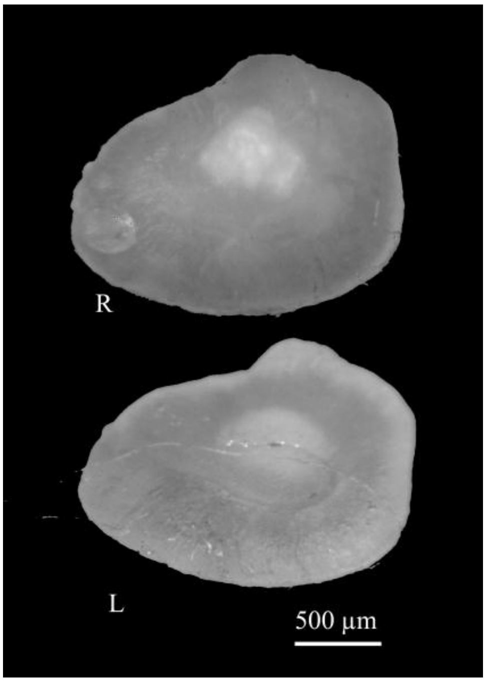

Figure 3.60: Sagittal otolith of *Gavialiceps* sp. A; L–showing mesial surface.

Otolith description–*Shape*: Elliptic to oval, dorsal and ventral margin entire, *Sulcus acusticus*: archaesulcoid, caudal, median in position, *Ostium*: straight broader than cauda, *Cauda*: narrow, *Anterior region*: narrow rounded, rostrum poorly defined, antrirostrum absent, *Posterior region*: broad rounded (Figure 3.60).

FTL: 712 mm, Area: Andaman Sea, Depth: 646 m

Shape parameters: OL: 1.97, OH: 1.56, OP: 5.64, OA: 2.27 Shape indices: AR: 1.40, roundness: 0.71 and circularity: 0.90

Xenomystax trucidans Alcock, 1894

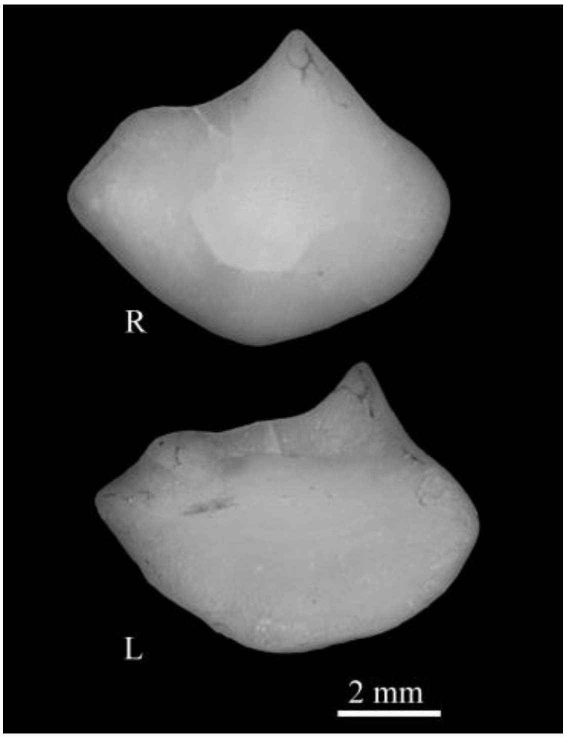

Figure 3.61: Sagittal otolith of *Xenomystax trucidans*; L–showing mesial surface

Morphological description of otolith–*Shape*: rhomboidal, dorsal margin irregular and ventral margin entire; *Sulcus acusticus*: archaesulcoid, mesial, median in position; *ostium:* narrow tube like, *Cauda*: also tube like but broader than ostium, *Anterior region*: pointed, rostrum slightly differentiated, antirostrum poorly differentiated, *Posterior region*: round but slightly pointed (Figure 3.61).

FTL: 593 mm, Area: Andaman Sea ; Depth: 635 m

Shape parameters: OL: 8.04, OH: 6.12, OP: 21.59, OA: 30.20 Shape indices: AR: 1.45, roundness: 0.69 and circularity: 0.81

Ariosoma sp. A

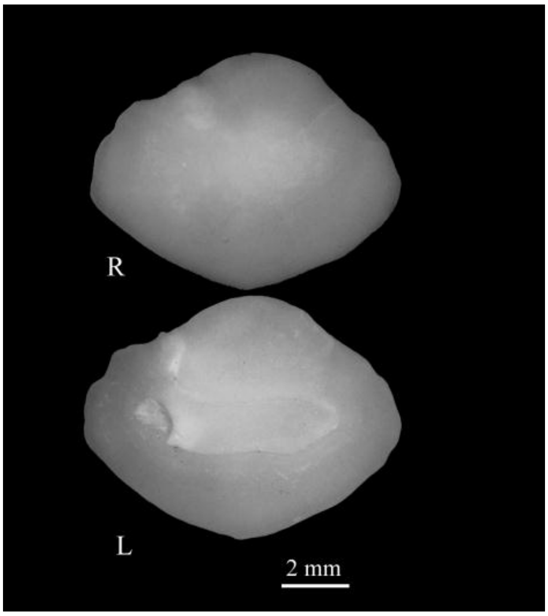

Figure 3.62: Sagittal otolith of *Ariosoma* sp. A; L–showing mesial surface.

Morphological description of otolith–Shape: oval to discoidal, entire margins, *Sulcus acusticus*: heterosulcoid, para-ostial, median in position, *Ostium*: shorter than the cauda, opening in the lateral-dorsal margin, *Cauda*: tubular, straight, *Anterior region*: round, rostrum and antirostrum asbent, *Posterior region*: angled (Figure 3.62).

FTL: 360 mm, Area: Arabian Sea ; Depth: 200 m
Shape parameters: OL: 9.34, OH: 7.28, OP: 25.48, OA: 47.24 Shape indices: AR: 1.33, roundness: 0.75 and circularity: 0.99

Family MURAENESOCIDAE

Sauromuraenesox vorax Alcock, 1889a

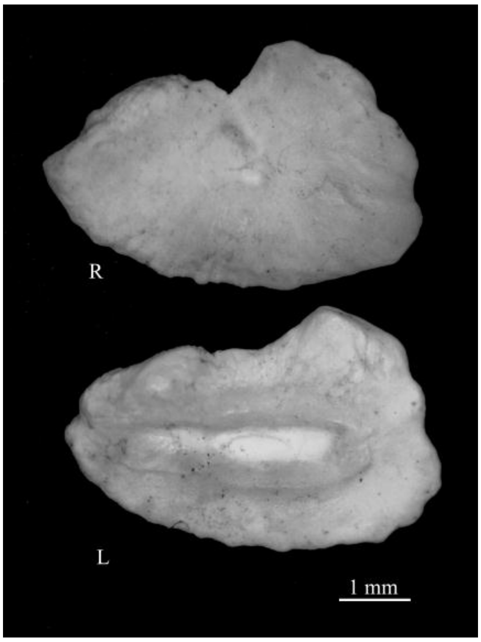

Figure 3.63: Saggital otolith of *Sauromuraenesox vorax*; L–showing mesial surface.

Morphological description of otolith –*Shape*: elliptic, with ventral margin crenate, dorsal margin irregular and ventral margin crenate, *Sulcus acusticus*: heterosulcoid, ostial, median in position, *Ostium*: funnel-like, shorter than the cauda, *Cauda*: tubular, straight but broad, *Anterior* region: round but notched, rostrum and antirostrum poorly differentiated, *Posterior* region: blunt, irregular (Figure 3.63).

FTL: 485 mm, Area: Bay of Bengal; Depth: 567 m

Shape parameters: OL: 5.28, OH: 3.47, OP: 14.34, OA: 12.81 Shape indices: AR: 1.6.5, roundness: 0.61 and circularity: 0.78

The information on otolith morphology serves as an additional character to support the taxonomic identification in fishes. In the present study we described the morphology of otolith with the adult specimens as there are reports on similar shape otoliths in larval and metamorphosis stages of Anguilliformes (Appelbaum & Hecht 1978; Hecht & Appelbaum1982). Otolith of Anguilliformes are least studied. How ever otolith descriptions of few Anguilliformes are given by authors from various parts of the world. Hech & Appelbaum (1982) has described the otolith morphology of 6 species of deep-sea mesopelagic eels belonging to two families. Smale et al. (1995) described otoliths of 26 species under 9 families. Tuset et al. (2008) described otoliths of 20 species of Anguilliformes under 8 families. Chulin et al. (2013) described 6 species under 3 families. How ever there are no works on otolith morphology of Anguilliformes from India. Present study describes the otolith morphology of four species (*Xenomystax trucidans*, *Ariosoma* sp. A, *Sauromuraenesox vorax* and *Gavialiceps* sp. A) for the first time. The remaining one species (*Bathyuroconger vicinus*) was previously described from collections outside India which is well matching with the present description. The study reveals that there are great variations in sagittal otolith structure of the 5 species of deep-sea eels described. Hence specific morphology of sagittal otolith of Anguilliformes can be used as an additional tool for supporting the taxonomy, especially to clear taxonomic ambiguities. It is equally useful in prey-predator studies and to provide a better understanding of marine food web dynamics.

3.5 Molecular taxonomy of selected species of deep-Sea Anguilliformes

3.5.1 Introduction

Fishes are traditionally identified by using morphological and meristic characters (Takahara et al. 2013). Some fishes and their different developmental stages are difficult to identify by traditional taxonomy due to high diversity and morphological plasticity (Victor et al. 2009; Zhang & Hanner 2011). In such cases DNA (Deoxyribo Nucleic Acid) barcoding technique adopted as a tool for taxonomic identification of fishes helps to resolve such taxonomic ambiguities. The molecular taxonomy helps in characterization, revealing evolutionary relationships and discovery of new and cryptic species, thereby facilitating biodiversity studies (Hebert et al. 2003; Teletchea 2009; Bhattacharya et al. 2016). Earlier days electrophoresis was used for the identification of species (Manwell & Baker 1963). Afterwards single gene sequence analysis of ribosomal DNA was used for evolutionary studies. The concept of DNA barcode was put forward by Professor Paul and collaborators from University of Guelph, Canada Hebert in the year 2003. Mitochondrial *cytochrome c oxidase* subunit 1 (COI) gene was suggested as unique barcode region for animals (Hebert et al. 2003) and was certified at the first conference on DNA Barcode of Life. A. DNA barcoding should be used in combination with conventional taxonomy for the effective conservation efforts. Molecular taxonomy can be taken up as pragmatic approach for resolving unambiguous identification of the fish fauna which can play a vital role in biodiversity assessment and conservation of marine ecosystem (Basheer et al. 2016).

Molecular taxonomy of eels has been done by various authors to study evolutionary relationships (Inoue et al. 2004; 2010; Johnson et al. 2012; Tang & Fielitz 2012, Chen et al. 2014, 2015; Santini et al. 2013; Dornburg et al. 2015). The inter relationship between various deep-sea eels have yet to be established and phylogenetic works is still continuing for a better classification. Majority of the molecular works on fishes in India are based on commercially important fishes (Lakra et al. 2007, 2009, 2010, 2011; Basheer et al. 2014). Molecular works on deep-sea fishes in India is scarce. However, recently Bineesh (2015) developed barcodes of 82 deep-sea fishes from southern coast of India. Molecular studies on eels in India is restricted to the work of Peninal et al. (2017) which include 6 species of moray eels, all of which are shallow water inhabitants. Present study provides baseline information on molecular taxonomy of deep-sea eels of India which helps to establish the evolutionary relationship among various species.

3.5.2 Materials and Methodology

a) Sample collection

Deep-sea eel specimens were collected onboard FORV *Sagar Sampada* from various regions of Indian EEZ. The samples were thoroughly washed and a portion of muscle was dissected from each species and preserved in 70% ethanol in sterile vials and stored at $^{-}20\ ^{o}$C for further molecular analysis. The species were identified using traditional taxonomy by referring standard journals. Present sampling includes 11 species of deep-sea eels under 5 families.

b) DNA isolation

Genomic DNA from the samples was isolated following the protocol of Miller et al. (1988) with slight modifications. DNeasy (Qiagen) kit, following manufacturer's instruction, was used to extract DNA. The quality of DNA was checked through runs in 0.8% agarose gel. The concentration of isolated DNA was diluted to a final concentration of100 ng/µl after checking with UV spectrophotometer. Mitochondrial DNA, cytochrome C oxidase I (COI) was amplified by using specific universal primers. For COI, more than one set of primers (varied primers) were used based on the compatibility. Annealing temperature was adjusted according to the melting temperature of the respective primers used.

Each PCR procedure included a negative control (no DNA template). Success of amplification was assessed by 1.5% agarose gel electrophoresis. After successful PCR amplification of the target fragments, amplified products were purified before the template was sequenced in both directions. The cleaned up PCR products were used as the template for sequencing PCR to increase the amount of product linearly with the number of cycles. Nucleotide sequencing was performed by the dideoxy chain-termination method (Sanger et al. 1977) using ABI Prism Big Dye Terminator v3.1 Cycle Sequencing kit, (Applied Biosystems, USA). Terminators are dideoxy nucleotides labeled with different coloured fluorescent dyes that will present different emission spectra on an electrophoresis gel illuminated by laser. Each PCR product was sequenced using both forward and reverse amplification primers. The resulting DNA fragments were cleaned before sending for sequencing.

c) Amplification and sequencing

PCR amplification reactions were carried out in 25 µl reaction volume containing 2 mMMgCl$_2$, 0.25mM each dNTPs, 4 µl DNA, 1.25U DNA polymerase enzyme, and 2.5mM of forward and reverse primers. The partial sequence of cytochrome c oxidase 1 (*CO1*) was amplified using primers fish F1 (5'-TCA ACC AAC CAC AAA GAC ATT GGC AC -3') and fish R1 (5'-TAG ACT TCT GGG TGG CCA AAG AAT CA -3') (Ward *et al*., 2005). The fragments of *co1* were amplified with the following thermo profile: 94 °C for 2 min, 35 cycles at 94 °C for 45 sec., 50 °C for 45 sec., 72 °C for 1 min and with a final extension at 72 °C for 8 min., followed by indefinite hold at 4 °C. The PCR products were visualized on 1.5% agarose gels. Samples with intense bands were selected for sequencing. Sequencing reactions used a BigDye Terminator V.3.1 Cycle sequencing Kit (Applied Biosystems, Inc). All samples were sequenced bidirectionally using an ABI3730 capillary sequencer following the manufacture's protocol.

d) Sequence analysis

The raw DNA sequences were edited and aligned using BioEdit sequence alignment editor version 7.0.5.2 (Hall 1999). The extent of sequence differences between species was calculated by averaging pair-wise comparisons of sequence differences across all individuals. The genetic distance within and between species were calculated using Kimura2-parameter (K2P) distance model implemented in MEGA 7

(Tamura et al. 2011) software. The number of polymorphic sites, monomorphic sites, singleton variable sites and parsimony informative sites were calculated using DnaSpver 3 (Rojas et al. 2006). Average percentage of different nucleotides were also determined. Neighbor-joining (NJ) trees of K2P distance were created to provide graphic representation of divergence with 1000 replications.

3.5.3 Results

A total of 11 sequences data developed from 11 species of deep-sea eels belonging to 11 genera and 5 families were used for partial sequence analysis of COI (Table 3.45). All sequences were compared with NCBI GenBank and BOLD for identification confirmation. The partial sequences of mtDNA generated in this study were deposited in the GenBank public database. All the 11 sequences generated through this study are generated for the first time. Among them 5 of the taxa (*Gavialiceps* sp. A, *Japonoconger* sp. A, *Ophichthus* sp. A, *Neenchelys* sp. A and *Synaphobranchus* sp. A) were confirmed as putative new species. The other four taxa (*Xenomystax trucidans*, *Bathymyrus echinorynchus*, *Sauromuraenesox vorax* and *Dysomma muciparus*) are generated for first time i.e. no sequences are available for these species till now. The remaining two species (*Nemichthys scolopaceus* and *Bathyuroconger vicinus*) sequences were already available in NCBI databank but our sequence shows significant intraspecific K2P distance between NCBI sequences which is discussed in detail elsewhere. All amplified sequences were >655 bp with no insertions, deletions, stop codons and NUMTs. The shortest sequence observed was 551 bp in

Sauromuraenesox vorax and the longest was 715 bp in *Nemichthys scolopaceus*. Sequences were aligned and multiple alignments resulted in consensus length of 655 bp per taxon was used for analysis. Out of the total 655 sites obtained; 178 were constant, 102 sites were variable, 7 singleton and 95 parsimony informative sites. A total of 26 haplotypes were observed across the taxa.

Table 3.43: Details of deep-sea eel species included for the molecular identification.

Sl.No.	Species	Genera	Family
1.	*Xenomystax trucidans*	*Xenomystax*	Congridae
2.	*Bathymyrus echinorynchus*	*Bathymyrus*	Congridae
3.	*Japonoconger* sp. A	*Japonoconger*	Congridae
4.	*Bathyuroconger vicinus*	*Bathyuroconger*	Congridae
5.	*Gavialiceps* sp. A	*Gavialiceps*	Congridae
6.	*Sauromuraenesox vorax*	*Sauromuraenesox*	Muraenesocidae
7.	*Ophichthus* sp. A,	*Ophichthus*	Ophichthidae
8.	*Neenchelys* sp. A	*Neenchelys*	Ophichthidae
9	*Dysomma muciparus*	*Dysomma*	Synaphobranchidae
10	*Synaphobranchus* sp. A	*Synaphobranchus*	Synaphobranchidae
11	*Nemichthys scolopaceus*	*Nemichthys*	Nemichthyidae

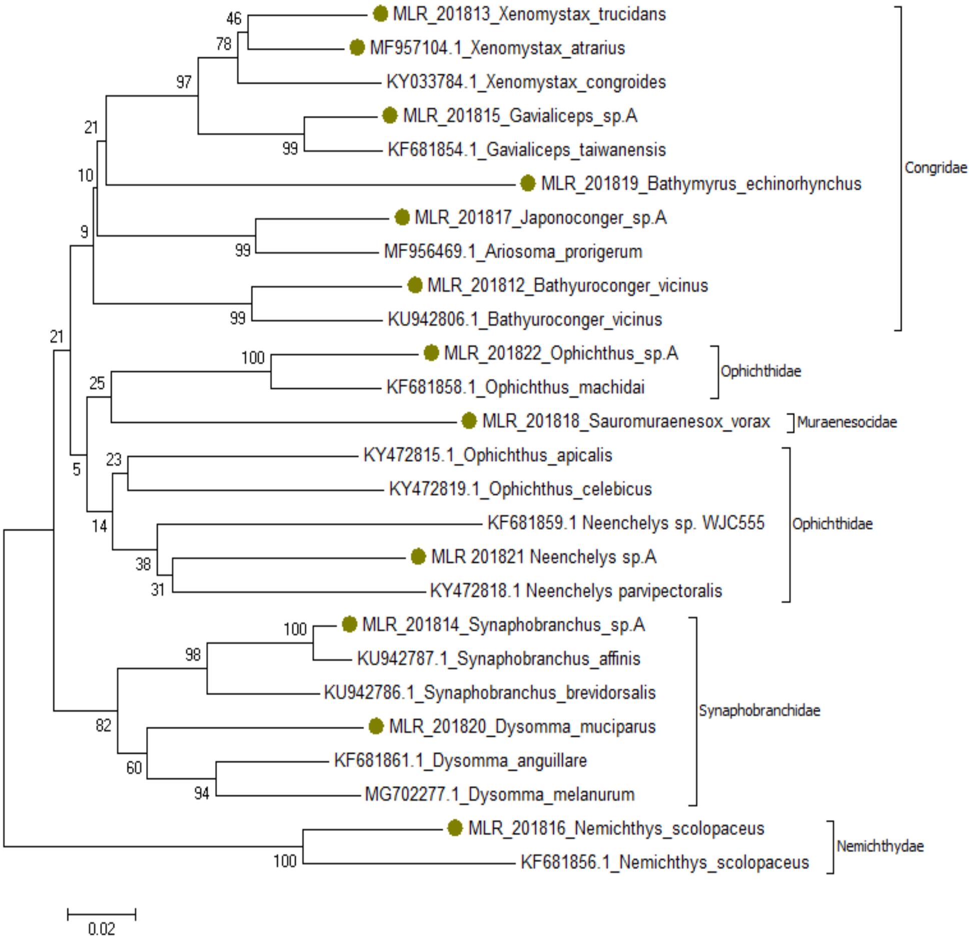

Figure 3.64: Neighbor Joining (NJ) phylogenetic tree of deep-sea Anguilliformes based on mitochondrial COI sequence

The Neighbor joining phylogenetic tree (Figure 3.64) developed with COI sequences of 11 taxa of deep-sea eels from CMLRE collection (indicated with green dots) and others (non marked) represents COI sequences adopted from NCBI for comparison. The Neighbor Joining phylogenetic tree shows 4 different clades.

Clade 1 is formed of 10 species (5 species belonging to 5 genera from our collection and 5 species belonging to 4 genera adopted from NCBI GenBank). *B. echinorynchus* has the longest sequence (655 bp) and *Japonoconger* sp. A has the shortest sequence (633bp). 366 constant sites, 186 variable sites, 54 singleton sites and 132 parsimony informative sites are present in this clade. *B. echinorynchus* has the longest sequence (655 bp) and *Japonoconger* sp. A has the shortest sequence (633bp). This clade has 366 constant sites, 186 variable sites, 54 singleton sites and 132 parsimony informative sites. The maximum interspecific (Kimura 2 parameter) K2P distance was 0.083 (8.3%) between *X. trucidans and X. congroides* and minimum was 0.044 (4.4%) between *Gavialiceps* sp. A and *G. taiwanensis*. The intraspecific distance observed in *B. vicinus* was 0.082 (8.2%) which reveal the presence of multiple taxa. *X. trucidans* have shortest genetic distance with *X. atrarius* 0.06 (6%) and *X. congroides* 0.083 (8.3%). *Ariosoma prorigerum* is a senior synonym of *Japonoconger proriger* (Fricke et al. 2018).The genetic distance between *Japonoconger sp. A* and *Ariosoma prorigerum* is 0.075 (7.5%). *B. echinorynchus* have shortest K2P distance with *Gavialiceps sp.* A 0.204 (20.4%) and *Japonoconger* sp. A 0.2 (20%). A total of 10 haplotypes were observed across the taxa. The average nucleotide frequencies were also investgated, T= 28.3 %, C= 26.8%, A= 26.6%, G= 18.3%.

The Clade 2 was formed of 8 species belonging to 2 families (Ophichthidae and Muraenesocidae). Three species belonging to 3 genera and 2 families (*Ophichthus* sp.A, *Neenchelys* sp. A and *S. vorax*) represents our collection and 5 species belonging to 2 genera is adopted from NCBI GenBank. *Ophichthus* sp. A and *Neenchelys* sp. A have the longest sequence (655 bp) and *S. vorax* has the shortest sequence (642bp). This clade has 406 constant sites, 202 variable sites, 72 singleton sites and 130 parsimony informative sites. The species *S. vorax* of the family Muraenesocidae shows genetic affinity towards the *Ophichthus* sp. of family Ophichthidae than any other species. Previous phylogenetic studies also show close relation between the members of these two families (Tang & Fielitz 2012, Santini et al. 2013). *S. vorax* have shortest K2P distance with *O. apicalis* 0.181 (18.1%) followed by *Ophichthus* sp. A *and O. machidai* 0.185 (18.5%). In this clade the maximum interspecific K2P distance was 0.181 (18.1%) between *Ophichthus* sp. A *and O. celebicus* and minimum was 0.075 (7.5%) between *Ophichthus* sp. A *and O. machidai*. *Neenchelys* sp. A have shortest genetic distance with *N. parvipectoralis* 0.142 (14.2%) and shows longest genetic distance with *Neenchelys* sp. WJC555. A total of 8 haplotypes were observed across the taxa. The average nucleotide frequencies were also investigated, T= 28.1%, C= 27.1%, A= 26.0%, G= 18.8%.

The Clade 3 was formed of 6 species belonging to 2 genera and single family Synaphobranchidae. Two species belonging to 2 genera represents our collection and 4 species belonging to 2 genera was adopted from NCBI GenBank. *Dysomma muciparus* has the longest sequence (655 bp) and *Synaphobranchus* sp. A has the shortest sequence (647bp). This clade contains 223 constant sites, 57 variable sites, 20 singleton sites and 37 parsimony informative sites. In this clade the maximum interspecific K2P distance was 0.121 (12.1%) between *D. muciparus and D. anguillare* and minimum was 0.018 (1.8%) between *Synaphobranchus* sp. A *and S. affinis*. *D. muciparus* have shortest genetic distance with *S.*

brevidorsalis (0.117) and D. *melanurum* (0.120). *Synaphobranchus* sp. A have shortest K2P distance with *S. affinis* 0.018 (1.8%) *and* shows 0.071 (7.1%) with *S. brevidorsalis*. A total of 6 haplotypes were observed across the taxa. The average nucleotide frequencies were also investgated, T= 26 %, C= 29.7%, A= 25.8%, G= 18.5%.

The clade 4 was formed of members of family Nemichthyidae. Of the two *Nemichthys scolopaceus* samples one is our specimen and the other is adopted from NCBI GenBank. The intraspecific K2P distance was 0.103 (10.3%) in *Nemichthys scolopaceus*. This clade has 570 constant sites, 71 variable sites, 71 singleton sites and 0 parsimony informative sites . A total of 2 haplotypes were observed across the taxa. Both sequences of the species were supported by high bootstrap values. The average nucleotide frequencies were also investigated, T= 28.5 %, C= 28.6%, A= 21.9%, G= 21%.

3.6 Revalidation of deep-sea Anguilliformes from Indian waters

The Order Anguilliformes comprises 3 suborders Anguilloidei, Congroidei and Muraenoidei. The suborder Anguilloidei includes 3 families Anguillidae, Heterenchelyidae & Moringuidae. Members of family Anguillidae are freshwater or estuarine species and migrate to sea only for breeding. Members of family Heterenchylidae are marine inhabitants and not been reported from Indian Ocean. Members of family Moringuidae are marine inhabitants rarely seen in freshwater. These 3 families under the suborder Anguilloidei has not been reported from deep-waters of Indian EEZ. The suborder Congroidei includes 9 families all of them have been reported from deep-waters of Indian EEZ. The suborder Muraenoidaei includes 3 families Chlopsidae, Myrocongridae and Muraenidae. Only Muraenidae has been reported from deep-waters of Indian EEZ, the other two families (Chlopsidae & Myrocongridae) have not been reported from Indian waters.

Table 3.44: Comparison of previous and present status of deep-sea Anguilliformes

Sl.no	Suborder/family	Previous study		Present study		Updated	
		Genera	Species	Genera	Species	Genera	Species
I	**Suborder Congroidei**						
1.	Colocongridae	1	1	1	1	1	1
2.	Congridae	8	10	13	20	14	21
3.	Derichthyidae	0	0	1	1	1	1
4.	Muraenesocidae	1	1	2	2	2	2
5	Nemichthyidae	2	2	2	2	2	2
6.	Nettastomatidae	2	2	3	3	4	4
7.	Ophichthidae	0	0	3	5	3	5
8.	Serrivomeridae	1	1	1	1	1	1
9.	Synaphobranchidae	1	2	2	4	2	4
	Total	**16**	**19**	**28**	**39**	**30**	**41**
II	**Suborder Muraenoidei**						
10	Muraenidae	0	0	1	2	1	2
	Grand total	**16**	**19**	**29**	**41**	**31**	**43**

Table 3.45: Updated checklist of deep-sea Anguilliformes of Indian EEZ.

Sl.No.	Family/ Species	Area	Previousreport	Present report	Depth range	References	Remarks
A	**Suborder Congroidei**						
I	**Family Colocongridae Smith, 1976**						
1	*Coloconger raniceps* A lcock, 1889	AS	✓	✓		10, 11, 14,17, 18,22	Widely distributed in Indian EEZ
		BoB	✓	✓	201–1400	2, 11, 22	
		AN	✓	✓		2, 16, 22	
II	**Family Congridae Kaup, 1856**						
(1)	**Subfamily Bathymyrinae Böhlke, 1949**						
1	*Ariosoma gnanadossi* Talwar & Mukherjee, 1977	AS					
		BoB	✓	✓	225–307	20, 22	
		AN					
2	*Ariosoma* sp. A	AS		✓		22	New species from Arabian Sea
		BoB			200–214		
		AN					
3	*Bathymyrus echinorhynchus* Alcock, 1889a	AS					
		BoB	✓	✓	174–238	1, 22	
		AN					
(2)	**Subfamily Congrinae Kaup 1856a**						
4	*Bathycongrus macrocercus* (Alcock, 1894b)	AS					
		BoB	✓		332–635	10	
		AN	✓	✓		7, 16, 22	

5	*Bathycongrus nasicus* (Alcock, 1894a)	AS					
		BoB	✓		234–514	6	
		AN		✓		22	New record from Andaman Sea
6	*Bathycongrus* sp. A	AS		✓		22	New species from Arabian Sea
		BoB			200–214		
		AN					
7	*Bathycongrus* sp.B	AS		✓		22	New species from Arabian Sea
		BoB			975–1338		
		AN					
8	*Bathycongrus trimaculatus* Karmovskaya & Smith, 2008	AS					
		BoB			411		
		AN		✓		22	New record from Indian Ocean
9	*Bathyuroconger vicinus* (Vaillant, 1888)	AS	✓	✓		8, 11, 12, 18, 21,22	
		BoB	✓	✓	210–1345	5, 11, 22	Widely distributed in Indian EEZ
		AN		✓		22	New record ftom Andamn Sea
10	*Congrhynchus talabonoides* Fowler, 1934	AS					
		BoB			314–441		
		AN		✓		22	New record from Indian Ocean
11	*“Congromuraena” musteliceps* Alcock, 1894b	AS					
		BoB	✓		265–457	7	Not encountered in the present Study
		AN					Genus not assigned
12	*Gavialiceps* sp. A	AS					
		BoB			323–812		
		AN		✓		22	New species from Andaman Sea
13	*Gavialiceps taeniola* Alcock, 1889b	AS	✓	✓		11, 12,17,18, 21,22	
		BoB	✓	✓	201–1131	4, 11,15, 22	Widely distributed in Indian EEZ
		AN	✓			2, 16	

14	*Gnathophis* sp. A	AS		✓		22	New species from Arabian Sea
		BoB			200		First report of the Genus from Indian EEZ
		AN					
15	*Gnathophis* sp. B	AS					
		BoB			363–441		First report of the Genus from Indian EEZ
		AN		✓		22	New species from Andaman Sea
16	*Japonoconger* sp. A	AS					
		BoB		✓	430	22	New species from Bay of Bengal
		AN					First report of the Genus from Indian EEZ
17	*Macrocephenchelys sp. A*	AS		✓		22	New species from Arabian Sea & Andaman Sea
		B0B			323–392		First report of the Genus from Indian EEZ
		AN		✓		22	
18	*Promyllantor purpureus* Alcock, 1890	AS	✓	✓		3, 21, 22	
		BoB			501–1829		
		AN					
19	*Rhynchoconger squaliceps* (Alcock, 1894b)	AS		✓	200–445	22	New record from Arabian Sea
		BoB	✓	✓		7, 22	
		AN					
20	*Uroconger lepturus* (Richardson, 1845)	AS		✓		22	
		BoB			214		Previously reported from shallow waters (Bathymetric range extension)
		AN					
21	*Xenomystax trucidens* Alcock, 1894b	AS	✓	✓		7, 11, 12, 18 ,21,22	Widely distributed in Indian EEZ
		BoB		✓	201–1315	22	New record from Bay of Bengal & Andaman Sea
		AN		✓		22	

III	**Family Derichthyidae Gill, 1884**						
1	*Nessorhamphus danae* Schmidt, 1931	AS		✓		22	New record from Arabian Sea
		BoB			942		First report of family Indian EEZ
		AN					
IV	**Family Muraenesocidae Kaup, 1859**						
1	*Muraenesox bagio* (Hamilton, 1822)	AS		✓		22	
		BoB			214		Previously reported from shallow waters (Bathymetric range extension)
		AN					
2	*Sauromuraenesox vorax* Alcock, 1889b	AS	✓	✓		21, 22	
		BoB	✓	✓	200–653	2, 20, 22	
		AN		✓		22	New record from Andaman Sea
V	**Family Nemichthyidae Kaup, 1859**						
1	*Avocettina infans* (Günther, 1878)	AS	✓	✓		13,22	Widely distributed in Indian EEZ
		BoB		✓	200–1345	22	New record from Bay of Bengal
		AN	✓			16	
2	*Nemichthys scolopaceus* Richardson, 1848	AS	✓	✓		10,11,12,17,18,21,22	
		BoB	✓	✓	282–1397	7, 11, 22	Widely distributed in Indian EEZ
		AN	✓	✓		2, 11, 22	
VI	**Family Nettastomatidae Kaup, 1859**						
		AS					
1	*Facciolella* sp. G	BoB			392		New record of genus from Indian EEZ
		AN		✓		22	New species from Andaman Sea
2	*Nettastoma solitarium* Castle & Smith, 1981	AS					
		BoB			441		New record of genus from Indian EEZ
		AN		✓		22	New record from Eastern Indian Ocean

		AS	✓			9	Not encountered in the present study
3	*Nettenchelys taylori* Alcock, 1898	BoB			786		This species has not been collected since after the original discovery
		AN					
		AS	✓	✓		14, 22	
4	*Venefica* sp.	BoB			888–1345		Species identity not resolved due to damaged condition of the specimen
		AN					
VII	**Family Ophichthidae Günther, 1870**						
(1)	**Subfamily Myrophinae Kaup, 1856b**						
1	*Neenchelys* sp. A	AS		✓		22	New species from Arabian Sea
		BoB			544		
		AN					
(2)	**Subfamily Ophichthinae Günther, 1870**						
2	*Ophichthus* sp. A	AS					
		BoB			314–363		
		AN		✓		22	New species from Andaman Sea
3	*Ophichthus* sp. B	AS					
		BoB		✓	644	22	New species from Bay of Bengal
		AN					
4	*Ophichthus urolophus* (Temminck & Schlegel, 1846)	AS		✓		22	New record from Western Indian Ocean
		BoB			200		
		AN					
		AS		✓		22	Previously reported from shallow waters (Bathymetric range extension)
5	*Pisodonophis cancrivorus* (Richardson, 1848)	BoB			400		
		AN					

VIII	**Family Serrivomeridae Trewavas, 1932**						
		AS	✓	✓		2, 14, 22	
1	*Serrivomer* sp.	BoB	✓		1589–1911	2	Species identity not resolved due to damaged condition of specimens
		AN	✓			2, 11	
IX	**Family Synaphobranchidae Johnson, 1862**						
(1)	**Subfamily Ilyophinae Jordan & Davis, 1891**						
1	*Dysomma bucephalus* Alcock, 1889b	AS		✓		22	New record from Western Indian Ocean
		BoB	✓		205–457	2	
		AN					
		AS		✓		22	New record from Western Indian Ocean
2	*Dysomma muciparus* Alcock, 1889b	BoB	✓		242–494	4	
		AN					
(2)	**Subfamily Synaphobranchinae Johnson, 1862**						
		AS		✓		22	New record from Northern Indian Ocean
3	*Synaphobranchus oregoni*	BoB			975–1400		
		AN					
		AS		✓		22	New species from Arabian Sea and Andaman Sea
4	*Synaphobranchus* sp. A						
		BoB			635–1000		
		AN		✓		22	
B	**Suborder Muraenoidei**						
X	**Family Muraenidae Rafinesque, 1815**						
1	*Gymnothorax reticularis* Bloch,1795	AS		✓		22	Previously reported from shallow waters (Bathymetric range extension)
		BoB			200–214		
		AN					

2	*Gymnothorax* sp. A	AS BoB AN	✓	200	22	New species from Arabian Sea

1	Alcock 1889a	12	Jayaprakash et.al 2006
2	Alcock 1889b	13	Kotthaus 1968
3	Alcock 1890	14	Lloyd 1909
4	Alcock 1891	15	Nair and Madhusoodanan 1982
5	Alcock 1892	16	Rajan et al.2013
6	Alcock 1894a	17	Sajeevan et al. 2009
7	Alcock 1894b	18	Sudhakar et al.2013
8	Alcock 1899	19	Talwar 1977
9	Alcock 1898	20	Talwar & Mukherjee 1977
10	Alcock 1899	21	Venu 2009
11	Hashim 2012	22	Present study

3.7 Discussion

Sampling sufficiency of the three regions (Arabian Sea, Bay of Bengal and Andaman Sea) were tested using species accumulation plots. Results indicate that all the regions have attained sampling sufficiency greater than 72 %. These studies also show that upon more intensified sampling more number of species are likely to be obtained from these regions.

The present study reports 10 families, 29 genera and 41 species of deep-sea Anguilliformes from Indian EEZ. Among them 1 family (Derichthyidae) and 7 genera (*Congrhynchus, Gnathophis*, *Japonoconger, Macrocephenchelys*, *Nessorhamphus*, *Facciolella* and *Nettastoma*) reported through this study are new reccords for the Indian EEZ. Present study has contributed a total of 14 new species and 6 new record of species from Indian EEZ. (Area wise 15 new records AS: 6, BoB: 2 and AN: 7). Six genera (*Gymnothorax, Muraenesox, Neenchyles, Ophichthus, Pisodonophis & Uroconger*) are reported for first time from deep-waters of Indian EEZ, eventhough they were previously reported from shallow waters. Thirteen species (*Bathycongrus trimaculatus*, *B. nasicus, Bathymyrus echinorhynchus*, *Gnathophis* sp. A, *Japonoconger* sp. A, *Promyllantor purpureus*, *Nessorhamphus danae*, *Gymnothorax* sp. A, *Facciolella* sp. G, *Nettastoma solitarium, Venefica* sp., *Neenchelys* sp. A *and Ophichthus* sp. B) are rare global collections, represented mostly by single specimens. Family Congridae (12 genera and 18 species) is the most speciose group with a contribution near to half of the total diversity, followed by Ophichthidae (3 genera and 5 species). The least speciose families are Colocongridae, Derichthyidae and Serrivomeridae represented by single species each. (Table 3.44). Area wise diversity of deep-sea Anguilliformes in the present study is highest in Arabian Sea (10 families, 24 genera and 28 species) followed by Andaman Sea (7 families, 14 genera and 16 species) and Bay of Bengal (5 families, 12 genera and 12 species). Two species (*Congromuraena mustuliceps* & *Nettenchelys taylyori*) previously reported (Alcock 1894b; 1898) were not encountered in the present study. *Congromuraena mustuliceps* have been reported recently by Smith et al. (2017) from Oman Sea after a long gap of more than a Century and the other species *Nettenchelys taylori* has not been collected after its original discovery. Present study has updated the diversity of deep-sea eels of Indian EEZ to 10 families, 31 genera and 43 species from the previous Indian records of 7 families, 16 genera and 19 species (Table 3.45).

The information on otolith morphology provides additional support to the taxonomic identification in fishes. In the present study we describe the morphology of otolith with the adult specimens as there are reports on similarity in shape of otoliths between various species in larval and metamorphosis stages of Anguilliformes (Appelbaum & Hecht 1978; Hecht & Appelbaum1982). Otolith of Anguilliformes were least studied however otolith descriptions of few Anguilliformes were given by Hecht & Appelbaum (1982) who described the otolith morphology of 6 species of deep-sea mesopelagic eels belonging to two families; Smale et al. (1995) for 26 species under 9 families, Tuset et al. (2008) described 20 species of Anguilliformes under 8 families. Chulin et al. (2013) described 6 species under 3 families. However there are no previous works on otolith morphology of Anguilliformes from India. Present study describes the otolith morphology of four species (*Xenomystax trucidans*, *Ariosoma* sp. A, *Sauromuraenesox vorax* and *Gavialiceps* sp. A) for the first time in the world. The remaining one species (*Bathyuroconger vicinus*) was previously described from collections outside India. The study reveals that there are great variations in sagittal otolith structure of 5 species of deep-sea eels described. Hence specific morphology of sagittal otolith of Anguilliformes can be used as an additional tool for supporting the taxonomy especially during taxonomic ambiguities. It is equally useful in prey-predator studies which will provide a better understanding of marine food web dynamics.

Barcoding of deep-sea eels of order Anguilliformes is attempted for the first time in species from Indian waters. DNA barcoding, based on the sequencing of Cytochrome C Oxidase type I (COI) gene, has received significant interest in species identification, authentication, and phylogenetic analysis (Bhattacharya et al. 2016). In this study we successfully generated COI barcode sequences for 11 deep-sea eels belonging to 11 genera and 5 families.

Inferences from the present NJ phylogenetic tree indicate that most of the species were clustered into different clades with respective families. However it was noted that the families Ophichthidae and Muraenesocidae falls into a single clade which reveals that the members of Muraenesocidae has closer genetic relationship with the members of Ophichthidae. This relationship between the two families corroborates well with the previous studies (Tang & Fielitz 2013, Santini et al. 2013).

The first clade (family congridae) was formed with 10 species. Among them the placement of genus *Gavialiceps* was questionable for long time and the issue was solved only recently. Smith (1989j) first placed the genus *Gavialiceps* in the family Congridae, later Karmovskaya (1993) included this genus in family Muraenesocidae. Smith (2017) again commented that *Gavialiceps* should be removed from Muraenesocidae due to their resemblance with the genus *Xenomystax* of the family Congridae. Recently Lin & Ho (2018) followed Smith's comment in their work and later Ho et al. (2018a) placed back this genus to the family Congridae. Our phylogenetic tree also show close relationship of *Gavialiceps* genera to the *Xenomystax* genera of Congridae family as commented by Smith (2017) and well agrees the recent placement of genus *Gavialiceps* to the family Congridae. Another genus *Japonoconger* sp. A shows genetic relationship with *Ariosoma prorigerum* which is a senior synonym of *Japonoconger proriger*. In the present phylogenetic analysis we have identified 5 putative new species belonging to the families Congridae (2 sp.), Ophichthidae (2 sp.) and Synaphobranchidae (1 sp.). We have already confirmed the above 5 species as new to science by taxonomic identification. The results obtained from molecular studies well supports our traditional taxonomic identification. The sequence data for the two genes (*Bathymyrus* & *Sauromuraenesox*) is made available for first time through this study. The present phylogenetic study also reveal the presence of two cryptic species (*Bathyuroconger vicinus* & *Nemichthys scolopaceus*) belonging to the families Congridae and Nemichthyidae. These two species shows high intraspecific distances 8.2% in *Bathyuroconger vicinus* and 10.3% in *Nemichthys scolopaceus*.

These two species are known to have circumglobal distribution but our study reveals that they have similar morphological characteristics, but shows clear genetic variation between the species. Hence our data support the statement of Smith et al. (2018a) in the case of *B. vicinus* and Gaither et al. (2015) in the case of *N. scolopaceus*. Both the authors have pointed about the presence of likely species complex in these two circumglobal species. Few species earlier considered circumglobal have been now considered as multiple taxa. An exceptional example is Bonefish *Albulla vulpes* which was previously considered as circumglobal species has now been differentiated into 12 or more lineages (Bowen et al. 2008; Hidaka et al. 2008). All the sequences of deep-sea eels developed through the present study are generated for the first time in the world and will be useful for the ongoing global phylogenetic classification studies.

* * *

Chapter 4

DISTRIBUTION, DIVERSITY & ABUNDANCE OF DEEP-SEA ANGUILLIFORMES IN INDIAN EEZ

Contents

4.1 Introduction

The distribution, diversity and abundance of fish species depends on various biotic and abiotic factors. In deep-sea the abiotic factors are rather uniform, the major limiting factor regulating the distribution and diversity of deep-sea fauna is the food availability (Rex 1976; Thiel 1979; Haedrich 1996; Vinogradova 1997). There are only limited studies on deep-sea fish distribution and diversity from Indian waters (Silas 1969; Raghuprasad & Ramachadran Nair 1979; Sivakami 1989; Sudarsan & Somavanshi 1998; Venu & Kurup 2002; Venu 2009; Sreedhar et al. 2007; Sudhakar et al. 2013; Hashim 2012; Vinu 2017).

Order Anguilliformes are cosmopolitan in distribution and comprises 16 families, 156 genera and 967species. Pacific Ocean has highest diversity with (630 species) followed by Indian Ocean (322 species) and Atlantic Ocean (248 species). Among the 16 families, the three most diverse families are Ophichthidae (337 species), Congridae

(218 species) and Muraenidae (210 species) and the least diverse families are Protanguillidae (single species) and Derichthyidae (3 species). The abundance, distribution and diversity of deep sea Anguilliformes are least studied globally. The diversity of Anguilliformes from Taiwan waters has been well studied (Chen 2012, Ho et al. 2015, 2018) and is believed to have the highest diversity of the eels in the world (13 families, 79 genera & 231 species). Deep-sea Anguilliformes of Brazilian waters (western South Atlantic Ocean) was studied by Melo et al. (2009) who reported 6 families 22 genera & 30 species. Knowledge regarding the abundance, distribution and diversity of deep-sea eel fauna of Indian waters remain scanty (Alcock 1899; Venu 2009; Hashim 2012; Sudhakar et al. 2013). Previous studies from Indian waters have reported 7 families 17 genera and 19 species of deep-sea eels.

This chapter discusses various aspects of deep-sea eels such as their regional, bathymetric trend in abundance as well as contribution of various families to the abundance, geographic and bathymetric trend of distribution; diversity and distribution pattern. In the present study, the Indian EEZ is delineated into three regional seas (Arabian Sea, Bay of Bengal & Andaman Sea) as well as two depth zones Upper Bathyal Zone (UBZ: 200–800 m) and Lower Bathyal Zone (LBZ: 800–1400 m). The similarity and dissimilarity between the Anguilliform species in these regional seas as well as similarity and dissimilarity between Anguilliform species within the two depth zones are detailed.

4.2 Methodology

A total of 93 random sampling stations were surveyed for deep-sea Anguilliformes in various regions of Indian EEZ at a depths ranging from 200–1400 m. Their abundance from each station were recorded and standardized to $1Km^2$ area using swept area method (detailed in chapter 2). Abundance data was used for various data analysis, square root transformed abundance data was used for multivariate analysis (Cluster analysis). Analysis was performed using Plymouth Routines in Multivariate Ecological Research package-6 (PRIMER 6) (Clarke and Warwick 2001a). Further details of data analysis are discussed in chapter 2.

4.3 Results

4.3.1 Geographic and bathymetric distribution of deep-sea Anguilliformes in Indian EEZ

The geographic and bathymetric ranges in distribution of deep-sea eels observed from the present study are evaluated to assess geographic and bathymetric variations in distribution of the Order, within Indian EEZ. (Figure 4.1 & Figure 4.2).

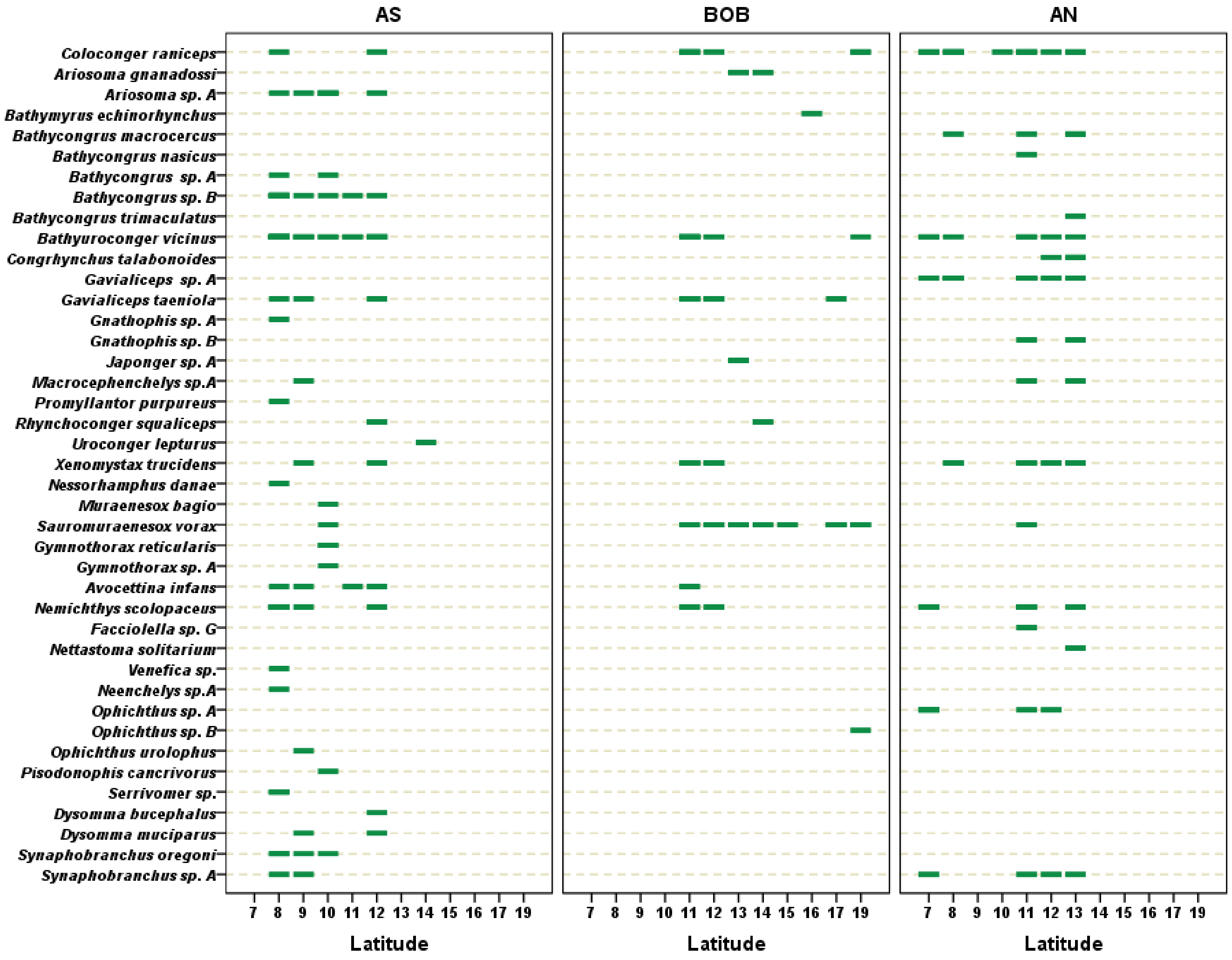

Figure 4.1: Geographic distribution of deep-sea Anguilliformes from 3 regions of Indian EEZ.

Present study reports 41 species, 29 genera and 10 families of deep-sea Anguilliformes from Indian waters. Among the 10 families reported, 5 families (Colocongridae, Congridae, Muraenesocidae, Nemichthyidae & Ophichthidae) shows wide distribution within Indian EEZ. All the 10 families (Colocongridae, Congridae, Derichthyidae Muraenesocidea, Muraenidae, Nemichthyidae, Nettastomatidae, Ophichthidae, Serrivomeridae, Synaphobranchidae) reported from Indian waters were observed from AS. However, Bay of Bengal represents only 5 families (Colocongridae, Congridae, Muraenesocidea, Nemichthyidae, Ophichthidae) and AS represents 7 families (Colocongridae, Congridae, Muraenesocidea, Nemichthyidae, Nettastomatidae, Ophichthidae, Synaphobranchidae). Three families (Derichthyidae, Muraenidae, Serrivomeridae) are restricted to AS only.

Among the 29 genera reported from Indian waters, 7 genera (*Coloconger, Bathyuroconger, Xenomystax, Gavialiceps, Sauromuraenesox, Nemichthys, Ophichthus*) are common for all the three regions, 10 genera (*Coloconger, Ariosoma, Bathyuroconge*r, *Xenomystax, Rhynchoconger, Gavialiceps, Sauromuraenesox, Avocettina, Nemichthys, Ophichthus*) are distributed both in AS and BoB. Eleven genera (*Coloconger, Bathycongrus, Bathyuroconger, Gnathophis, Macrocephenchelys, Xenomystax, Gavialiceps, Sauromuraenesox, Nemichthys, Ophichthus, Synaphobranchus*) are common to AS and AN and 7 genera (*Coloconger, Bathyuroconger, Xenomystax, Gavialiceps, Sauromuraenesox, Nemichthys, Ophichthus*) are common to both BoB and AN. Nine genera (*Promyllantor, Uroconger, Nessorhamphus, Gymnothorax, Serrivomer, Venefica, Neenchelys, Pisodonophis, Dysomma*) are restricted to AS only. Similarly 2 genera (*Bathymyrus*, *Japonoconger*) are restricted to BoB only and 2 genera (*Congrynchus*, *Facciolella*) are restricted only to AN.

Among the 41 species reported by the present study, 5 species belonging to 5 genera and 4 families (*C. raniceps*, *B. vicinus*, *X. trucidans*, *S. vorax* and *N. scolopaceus*) shows wide distribution in all three regions (AS, BoB & AN). Some species shows restricted distribution in particular region with in the Indian EEZ. Fourteen species belonging to 12 genera and 7 families (*Arisoma* sp. A, *Bathycongrus* sp. A, *Bathycongrus* sp. B, *Gnathophis* sp. A, *Promyllantor purpureus*, *Nessoramphus danae*, *Gymnothorax* sp A., *Venefica* sp., *Neenchelys* sp. A *Ophichthus urolophus*, *Serrivomer* sp., *Dysomma bucephalus*, *Dysomma muciparus* and *Synaphobranchus oregoni*) are distributed only in AS and 4 species belonging to 4 genera and 2 families (*Ariosoma gnanadossi*, *Bathymyrus echinorhynchus*, *Japonoconger* sp. A and *Ophichthus* sp. B) are distributed only in the BoB**.** Similarly 9 species under 7 genera and 3 families (*Bathycongrus macrocercus*, *Bathycongrus nasicus*, *Bathycongrus trimaculatus*, *Congrhynchus talabonoides*, *Gnathophis* sp. B, *Gavialiceps* sp. A, *Facciolella* sp. G, *Nettastoma solitarium* and *Ophichthus* sp. A) are distributed only in AN**.** Eight species belonging to 8 genera and 4 families (*C. raniceps*, *B. vicinus*, *Rhynchoconger squaliceps*, *X. trucidans*, *G. taeniola*, *S. vorax*, *Avocettina infians* and *N. scolopaceus*) are distributed in both Arabian Sea and Bay of Bengal. Seven species under 7 genera and 5 families (*C. raniceps*, *B. vicinus*, *Macrocephenchelys sp.* A, *X. trucidans*, *S. vorax*, *N. scolopaceus* and *Synaohobranchus* sp. A) are distributed in both AS and AN. Similarly 5 species belonging to 5genera and 4 families (*C. raniceps*, *B. vicinus*, *X. trucidans*, *S. vorax* and *N. scolopaceus*) are distributed in both BoB and AN.

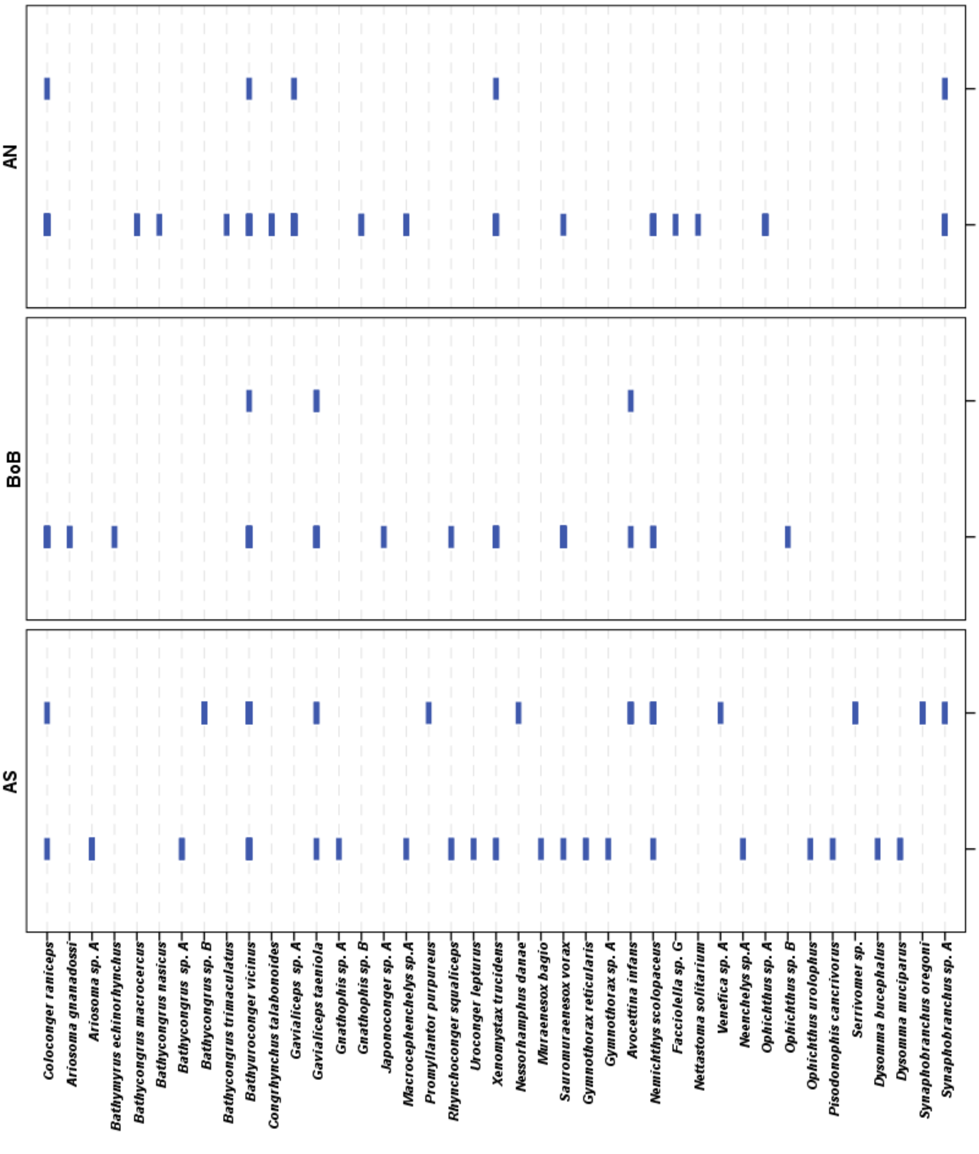

Figure 4.2: Bathymetric distribution of deep-sea Anguilliformes from two depth zones of Indian EEZ

Analysis of the geographical distribution of Anguilliforme species within the 3 regions reveals that in the Arabian Sea 7 species (*Arisoma* sp. A, *Bathycongrus* sp. A, *B. vicinus*, *A. infians*, *G. taeniola*, *N. scolopaceus*, *C. raniceps*) are widely distributed from 8°N to 12°N, 2 species (*Bathycongrus* sp.A, *S. oregoni*) distributed between 8°N to 10°N, 1 species (*Synaphobranchus* sp. A) between 8°N to 9°N, 2 species (*X. trucidans*, *D. bucephalus*) between 9°N to 12°N, I species (*G. reticularis*) was only found at 10°N and rest of the 15 species are represented from single collection and therefore their distributional range could not be ascertained. In Bay of Bengal 3 species (*C. raniceps*, *B. vicinus*, *S. vorax*) have wide distribution between 11° N to 19°N, 1 species (*G. taeniola*) distributed between 11°N to 17°N, 2 species (*X. trucidans*, *N. scolopaceus*) between 11°N to 12°N, 1 species (*Ariosoma gnanadossi*) between 12°N to 13°N and rest of the 5 species (*C. raniceps*, *B. vicinus*, *Gavialiceps* sp. A, *N. scolopaceus*, *Synaohobranchus* sp. A) were represented in single collection. In Andaman Sea 5 species are widely distributed between 7° N to 13°N, 1 species (*Ophichthus* sp. A) distributed between 7°N to 12°N, 2 species (*B. macrocercus*, *X. trucidans*) between 8°N to 13°N, 2 species (*Gnathophis* sp. B, *Macrocephenchelys sp.* A) between 11°N to 13°N, 1 species (C. talabanoids) between 12°N to 13°N and rest of the 5 species are represented by single collection.

Among the 28 species reported from AS in the present study, 20 species belonging to 18 genera and 7 families (*C. raniceps*, Ariosoma sp. A, *Bathycongrus* sp. A, *B. vicinus*, *Gnathophis sp. A*, *Macrocephenchelys* sp. A, *R. squaliceps*, *Uroconger lepturus*, *X. trucidans*, *G. taeniola*, *Muraenesox* bagio, *S. vorax*, *Gymnothorax reticularis*, *Gymnothorax* sp.

A, *N. scolopaceus*, *Neenchelys* Sp. A, *O. urolophus, Pisodonophis cancrivorus, D. muciparus, D. buephalus*) are distributed in UBZ and 12 species under 11 genera and 7 families (*C. raniceps*, *Bathycongrus* sp. B, *B. vicinus, P. purpureus, N. danae, G. taeniola, A. infans, N. scolopaceus, Venefica* sp., *Serrivomer* sp., *S. oregoni, Synaphobranchus* sp. A) are distributed in LBZ. Sixteen species (*Ariosoma* sp. A, *Bathycongrus* sp. A, *Gnathophis* sp. A, *Macrocephenchelys* sp. A, *R. squaliceps, U. lepturus, X. trucidans,, M. bagio, S. vorax, G. reticularis, Gymnothorax* sp. A, *Neenchelys* sp. A, *O. urolophus, P. cancrivorus, D. bucephalus, D.muciparus*) are distributed only in UBZ and 8 species (*Bathycongrus* sp. B, *P. purpureus, N. danae, A. infans, Venefica* sp., *Serrivomer* sp., *S, oregoni, Synaphobranchus* sp. A) are distributed only in LBZ. Four species (*C. raniceps, B. vicinus, G. taeniola, N. scolopaceus*) were found to be distributed in both the zones.

Among the 12 species reported from BoB in the present study, all (*B. vicinus, G. taeniola, A. infans, C. raniceps, A. gnandossi, B. echinorhynchus, Japonoconger* sp. A, *R. squaliceps, X. trucidans, S. vorax, N. scolopaceus, Ophichthus* sp. B) are distributed in UBZ and 3 (*B. vicinus, G. taeniola, A. infans*) species are distributed in LBZ. Nine species (*C. raniceps, A. gnandossi, B. echinorhynchus, Japonoconger* sp. A, *R. squaliceps, X. trucidans, S. vorax, N. scolopaceus, Ophichthus* sp. B) are distributed only in UBZ and no species is exclusive to LBZ. Three species (*B. vicinus, G. taeniola, A. infans*) are commonly distributed in both the zones.

All the sixteen species reported from AN in the present study (*C. raniceps, B. vicinus, X. trucidans, Gavialiceps* sp. A, *Synaphobranchus* sp. A, *B. macrocercus, B. nasicus, B. trimaculatus, C. talabonoides, Gnathophis* sp. B, *Macrocephenchelys* sp. A, *S. vorax, N. scolopaceus, Facciolella* sp. G, *N. solitarium, Ophichthus* sp. A) are distributed in UBZ and 5 species (*C. raniceps, B. vicinus, X. trucidans, Gavialiceps* sp. A, *Synaphobranchus* sp. A) are distributed in LBZ. Eleven species (*B. macrocercus, B. nasicus, B. trimaculatus, C. talabonoides, Gnathophis* sp. B, *Macrocephenchelys* sp. A, *S. vorax, N. scolopaceus, Facciolella* sp. G, *N. solitarium*, *Ophichthus* sp. A) are distributed only in UBZ and there is no species distributed exclusively in the LBZ. Five species (*C. raniceps, B. vicinus, X. trucidans, Gavialiceps* sp. A, *Synaphobranchus* sp. A) are distributed in both the zones.

4.3.1.1 Discussion

Present study examines the geographic & bathymetric distribution of deep-sea Anguilliformes from Indian waters from depths ranging from 200-1400 m. The study recorded 10 families, 29 genera & 41 species from Indian waters. From previous studies it was observed that Alcock (1899) reported 7 families, 14 genera, 17 species; Jayaprakash et al. (2006) 4 families, 7 genera, 7 species; Venu (2009) 5 families, 12 genera, 12 species; Hashim (2012) 5 families, 9 genera, 10 species and Sudhakar et al. (2013) 6 families, 7 genera and 9 species. Five families in the present study show wide distribution within Indian EEZ. Alcock (1899) reported 2 families and Hashim (2012) reported one family with wide distribution in Indian waters. In the present study, all the 10 families reported from Indian waters were represented in the AS. Among them family Derichthyidae is new to Indian waters. BoB represents 5 families and AN represents 7 families. Three families were restricted only to AS. Two families (Ophichthidae and Muraenidae) earlier reported only from shallow waters, are reported fo the first time from deep waters of Indian EEZ.

A total of 29 genera of deep sea Anguilliformes are reported from Indian waters in the present study. Regional wise distribution of various genera shows that AS represents 24 genera, of which, 11 genera (*Ariosoma*, *Gnathophis, Macrocephenchelys, Nessorhamphus, Gymnothorax, Muraenesox, Neenchelys, Uroconger, Rhynchoconger*, *Ophichthus*, *Pisodonophis*) new reports from this region. Among the 11 genera, 4 genera (*Rhynchoconger*, *Gnathophis, Macrocephenchelys*, *Nessorhamphus*) were already reported by earlier workers from shallow waters, and the present study have extended their distributional range to deep waters. Three genera *Gnathophis*, *Macrocephenchelys* and *Nessorhamphus* reported in the present study are new to Indian waters.

BoB represents 12 genera, of which 4 genera (*Xenomystax*, *Ophichthus*, *Avocettina*, *Japonoconger*) are new reports from the region. However, genus *Ophichthus* was previously reported from shallow waters but is reported for the first time from deep waters. The genus *Japonoconger* reported in the present study is new to Indian waters.

Andaman Sea represents 14 genera, of which 10 genera (*Bathyuroconger*, *Congrhynchus*, *Gnathophis*, *Macrocephenchelys*, *Xenomystax*, *Sauromuraenesox*, *Facciolella*, *Nettastoma*, *Ophichthus*, *Synaphobranchus*) are new reports. However, genus *Ophichthus* was previously reported from shallow waters but is new to deep waters. Among the 14 genera, five genera (*Congrhynchus*, *Gnathophis*, *Macrocephenchelys*, *Facciolella*, *Nettastoma*) are new reports from Indian waters. Seven genera were found common for all the regions, 10 genera were distributed both in AS and BoB, 11 genera were common to AS and AN, 7 genera were common in BoB and AN. Nine genera were restricted to AS only. Similarly 2 genera were restricted only to BoB and 2 genera were restricted only to AN.

Regional wise distribution shows that more species are distributed in AS (28 species belongs to 24 genera & 10 families), followed by AN (16 species belongs to 14 genera & 7 families) and BoB (12 species belongs to 12 genera & 5 families). Five species belonging to 5 genera and 4 families are widely distributed in all the three regions. Few species are common to two regions. Eight species belonging to 8 genera, 4 families are distributed in both AS & BoB, 7 species under 7 genera, 5 families are distributed in both AS & AN and 5 species belonging to 5 genera, 4 families are distributed in both AN & BoB. Number of species restricted to particular region is high in AS (14 species belonging to12 genera & 7 families) and least in BoB (4 species under 4 genera & 2 families) whereas in AN restricted species accounts for 9 species (belongs to 7 genera & 3 families). Common species were high in AS and BoB (8 species) and least between BoB and AN (5 species) whereas 7 species were common between AS & AN.

Alcock (1899) reported that more species were distributed in BoB (12) followed by AS (9) and AN (4) whereas Hashim (2012) reported more species from AS (8) followed by BoB (6) and AN (2). Results of our study are different from the above two studies in such a way that more distribution of species was observed in AS (28) followed by AN (16) and BoB (12). However, our results are consistent with the observation of Hashim (2012) in that maximum number of species are found in the AS.

Analysis of the geographical distribution of Anguilliforme species within the 3 regions reveals that in the Arabian Sea 7 species are widely distributed from 8°N to 12°N, 2 species distributed between 8°N to 10°N, 1 species between 8°N to 9°N, 2 species between 9°N to 12°N, I species was only found at 10°N and rest of the 15 species are represented from single collection and therefore their distributional range could not be ascertained. In Bay of Bengal 3 species have wide distribution between 11° N to 19°N, 1 species distributed between 11°N to 17°N, 2 species between 11°N to 12°N, 1 species between 12°N to 13°N and rest of the 5 species were represented in single collection. In Andaman Sea 5 species are widely distributed between 7° N to 13°N, 1 species distributed between 7°N to 12°N, 2 species between 8°N to 13°N, 2 species between 11°N to 13°N, 1 species between 12°N to 13°N and rest of the 5 species are represented by single collection.

Among the 28 species reported from AS in the present study, 20 species, 18 genera and 7 families are distributed in UBZ and 12 species, 11 genera and 7 families are distributed in the LBZ. Sixteen species are distributed only in UBZ and 8 species are distributed only in LBZ. Four species are distributed in both the zones. Four species previously reported from shallow-waters of AS shows bathymetric extension towards deeper-waters. In BoB, 12 species were reported, all distributed in UBZ of which 3 species were also distributed in LBZ. Nine species were distributed only in UBZ and there is no species distributed exclusively in LBZ. All the 16 species reported from AN were distributed in UBZ and only 5 species had distributional range in LBZ. Eleven species were distributed only in UBZ and there is no species distributed exclusively LBZ. Present study reports more species from UBZ compared to LBZ. Similar trend was reported by Venu (2009), Hashim (2012) and Sudhakar et al (2013) from Indian waters and this trend was also reported by several authors from different regions of the world which is in turn explained by decrease in food production towards the greater depths (Rex 1976; Thiel 1979).

Previous studies from Indian waters have reported 7 families 16 genera and 19 species of deep-sea eels. Area wise diversity shows that Bay of Bengal has highest diversity (6 families, 12 genera1 & 4 species) followed by Arabian Sea (6 families, 11 genera, 11 species) and Andaman Sea (4 families, 6 genera & 6 species). Present study reports 10 families 29 genera and 41 species. Area wise diversity shows that Arabian Sea has highest diversity (10 families, 24 genera, 28 species) followed by Andaman Sea (7 families, 14 genera & 16 species) and Bay of Bengal (5 families, 12 genera & 12 species). Updated diversity of deep-sea Anguilliformes is given below in table 4.1.

Table 4.1: Updated species diversity of deep-sea Anguilliformes in various regions of Indian EEZ

Sl.No.	**Family**	**Area**	**Previous study**		**Present study**		**Updated**	
			Genera	**Species**	**Genera**	**Species**	**Genera**	**Species**
1	Colocongridae	AS	1	1	1	1	1	1
		BoB	1	1	1	1	1	1
		AN	1	1	1	1	1	1
2	Congridae	AS	4	4	10	11	10	11
		BoB	7	8	7	7	9	10
		AN	2	2	7	9	7	9
3	Derichthyidae	AS			1	1	1	1
		BoB						
		AN						
4	Muraenesocidae	AS	1	1	2	2	2	2
		BoB	1	1	1	1	1	1
		AN			1	1	1	1
5	Nemichthyidae	AS	2	2	2	2	2	2
		BoB	1	1	2	2	2	2
		AN	2	2	1	1	2	2
6	Nettastomatidae	AS	2	2	1	1	2	2
		BoB						
		AN			2	2	2	2
7	Ophichthidae	AS			3	3	3	3
		BoB			1	1	1	1
		AN			1	1	1	1
8	Serrivomeridae	AS	1	1	1	1	1	1
		BoB	1	1			1	1
		AN	1	1			1	1
9	Synaphobranchidae	AS			2	4	2	4
		BoB	1	2			1	2
		AN			1	1	1	1
10	Muraenidae	AS			1	2	1	2
		BoB						
		AN						
	Total	**AS**	**11**	**11**	**24**	**28**	**25**	**29**
		BoB	**12**	**14**	**12**	**12**	**16**	**18**
		AN	**6**	**6**	**14**	**16**	**16**	**19**

4.3.2 Diversity and distribution pattern of deep-sea Anguilliformes in the Indian EEZ

Diversity indices are mathematical functions that combine the effects of richness and evenness in a community (Colwell 2009). Type of diversity indices used here are Shannon-Wiener index (H’) to measure species diversity of the region, Simpson's index (**λ’**) to measure species richness and evenness in a community, Margalef’s index (d) to measure richness of the species and Pielou's evenness index (J’) to measure evenness of the species. Diversity indices are calculated separately for the three regions and two depth zones using deep-sea Anguilliformes abundance matrix in PRIMER. Further details on diversity indices and their derivations are discussed in Chapter 2.

Region wise diversity indices (Table 4.2) reveal that the indices of species richness, evenness, and diversity of deep-sea Anguilliformes are high and dominance is low in AS. In the case of BoB, indices of species richness and dominance are less while evenness and diversity are higher than AN. Where as in AN indices of species, richness is higher but having less evenness and diversity than BoB and also show much higher dominance index than the other two regions. Indices of species richness, diversity and evenness are high in AN with dominance index lower than BoB. Among the two depth zones (UBZ & LBZ) (Table 4.3), in UBZ indices of species richness, evenness and diversity are high.

Table 4.2: Diversity indices of deep-sea Anguilliformes from three regions (AS, BoB & AN)

Area	No.of species (S)	Margalef's index (d)	Pielou's evenness index (J')	Shannon-Wiener index (H')	Simpson's Index (λ')
AS	28	7.54	0.55	1.83	0.21
BOB	12	2.13	0.43	1.06	0.41
AN	16	3.07	0.14	0.40	0.86

Table 4.3: Diversity indices of deep-sea Anguilliformes from two depth zones (UBZ & LBZ)

Depth Zones	No.of species (S)	Margalef's index (d)	Pielou's evenness index (J')	Shannon-Wiener index (H')	Simpson's index (λ')
UBZ	35	6.93	0.47	1.66	0.25
LBZ	14	4.17	0.35	0.94	0.60

Table 4.4: Diversity indices of deep-sea Anguilliformes from two depth zones of AS,BoB & AN.

Area	Depth Zones	No. of species (S)	Margalef's index (d)	Pielou's evenness index (J')	Shannon-Wiener index (H')	Simpson's index (λ')
AS	UBZ	19	4.56	0.53	1.56	0.29
	LBZ	12	3.43	0.30	0.75	0.67
BoB	UBZ	12	2.10	0.43	1.06	0.41
	LBZ	3	0.79	0.48	0.53	0.70
AN	UBZ	16	3.03	0.14	0.39	0.87
	LBZ	5	2.23	0.94	1.52	0.08

Diversity indices of deep-sea Anguilliformes obtained for two depth zones of AS, BoB & AN are given in Table 4.4. In the UBZ of AS, indices of species richness, evenness and diversity are high dominance index is low, compared to LBZ. In UBZ of BoB, indices of species richness, dominance and diversity are high whereas evenness is low, compared to LBZ. UBZ of AN have less evenness and diversity indices but shows high species richness and dominance indices compared to LBZ. While comparing the UBZ of all the three regions, the UBZ of AS shows high species richness as well as diversity indices, LBZ of AN have high evenness and low dominance indices whereas UBZ of AN have lower evenness, diversity and high dominance indices. Very low richness was observed along LBZ of BoB.

The cumulative abundance (*K*-dominance) curve is a powerful tool introduced by Lambshead et al. (1983) which is widely used to determine abundance trends in communities over time and in environmental assessment as graphical means for studying diversity (Warwick & Clarke, 1991; Fulton et al. 2004; Warwick et al. 2008). *K*-dominance curves provides graphical representation of the intrinsic diversity pattern of deep-sea Anguilliformes in which X- axis represents species rank in the order of abundance against their corresponding cumulative dominance on Y-axis. The *K*-dominance plot of three regions (Figure 4.3) reveals that the dominance curve of AN start very high in Y-axis with first species contributing as much as 92% of total abundance. Similarly first species contributed about 48% and 33% of the total abundance in BoB and AS respectively. The curves which run close to the base of the plot have high evenness and low dominance. Hence AS have high evenness and low dominance followed by BoB and curves at the top of the plot reveals least evenness and high dominance which was observed for AN

K-dominance curves of two depth zones (UBZ & LBZ) (Figure 4.4A) was also plotted which reveals that LBZ have high dominance with first species contributing about 78% of total abundance and UBZ have low dominance with first species contributing to about 39% of total abundance.

K-dominance curves of two depth zones (UBZ & LBZ) with in three regions (AS, BoB & AN) (Figure 4.4B) indicate that in AN first species accounted for 92% of the UBZ abundance and 33% for LBZ abundance. In AS first species accounted for UBZ abundance of 44% and 82% in LBZ. In BoB first species accounted for UBZ abundance of 48% and 84% in LBZ. Dominance curves of UBZ of three regions shows that the first species contributed to total abundance is 44%, 48% and 92% in AS, BoB and AN respectively. Similarly dominance curves of LBZ of three regions shows that first species accounted to total abundance is 82%, 84% and 33% in AS, BoB and AN respectively.

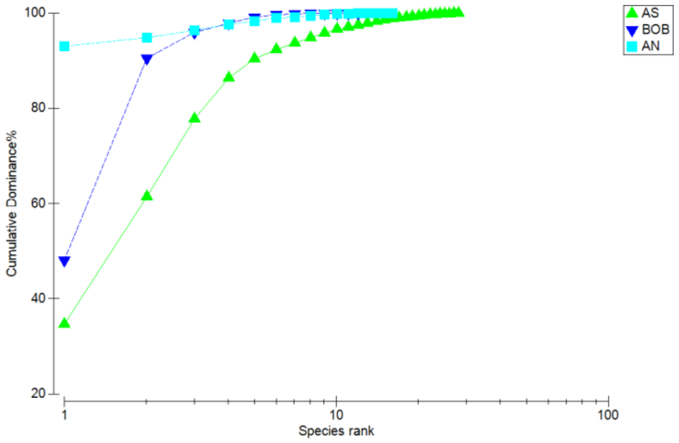

Figure 4.3: *K*-dominance curve for deep-sea Anguilliformes of three regions

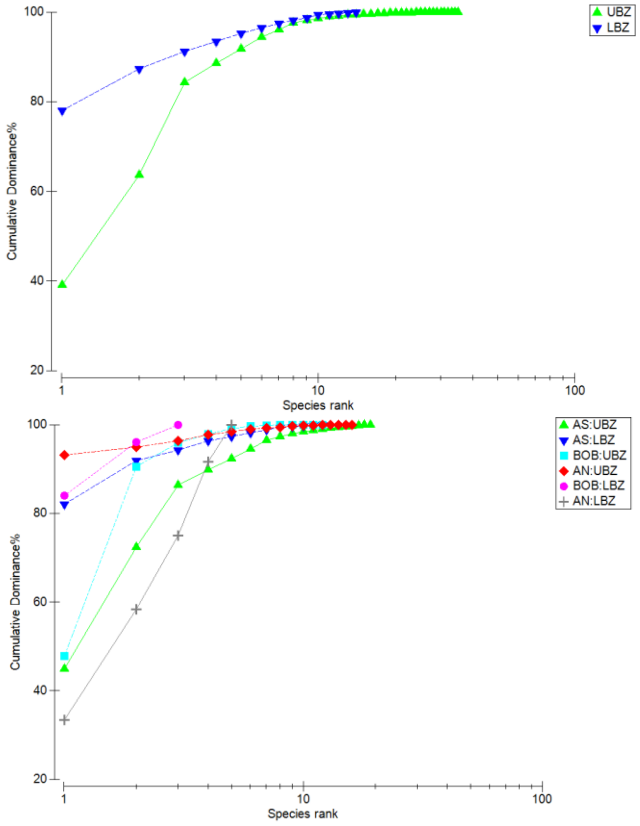

Figure 4.4: *K*-dominance plots for deep-sea Anguilliformes A) For two depth zones (UBZ & LBZ) B) For two depth zones within in three regions

Analysis of similarity (ANOSIM) in PRIMER 6 software (Figure 4.5) was done to test the differences in species composition between the regional groups (AS, BoB & AN), using species distribution data and the Bray-Curtis similarity. The result reveals that there are significant differences in species composition between the three regions studied (Table 4.5).

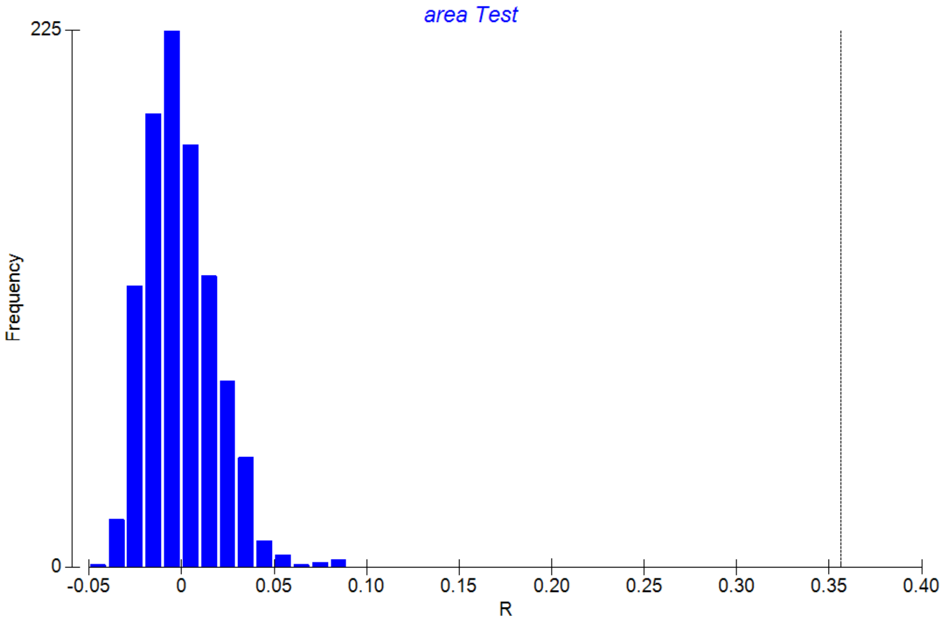

Figure 4.5: ANOSIM showing distinction in three regional groups (AS, BoB & AN)

Table 4.5: Results of ANOSIM between three regional groups

Region	ANOSIM (R)	Significance (P)
AS-BoB	0.29	0.1
AS-AN	0.34	0.1
BoB-AN	0.48	0.1

Deep-sea Anguilliformes species distribution pattern of Indian EEZ was tested using cluster analysis based on Bray-Curtis similarity on abundance data (square root transformed). The result reveals the existence of 3 regional groups (Figure 4.6), Arabian Sea (AS), Bay of Bengal (BoB) and Andaman Sea (AN) as well as two bathymetric Zones, viz. Upper Bathyal Zone (UBZ: 200–800 m) and Lower Bathyal Zone (LBZ: 800–1400 m) within the regional groups with few outliers.

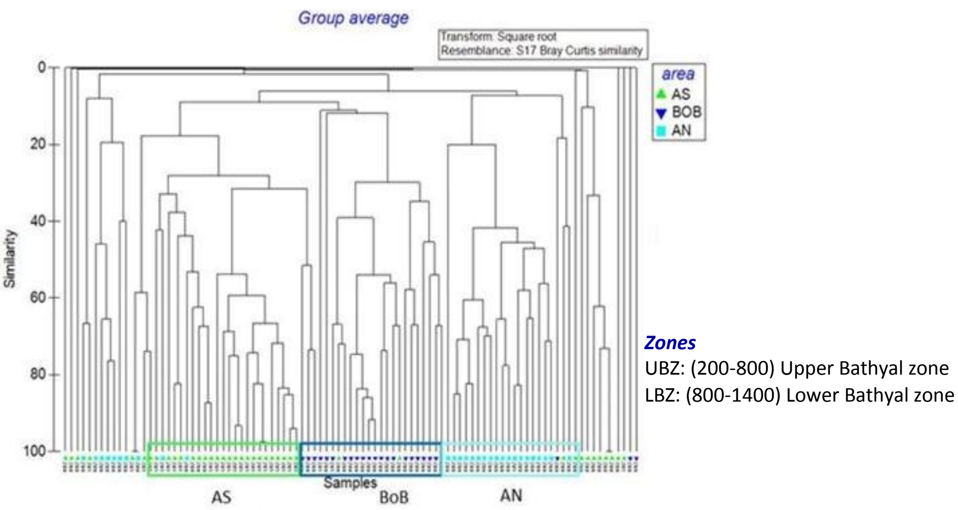

Figure 4.6: Cluster showing deep-sea Anguilliformes species assemblage in Indian EEZ.

Similarity Percentage (SIMPER) analysis was carried out using PRIMER 6 softwwere to find the species which are contributing to the similarity within the regional groups (Table 4.6) and dissimilarity between the groups. The simper analysis interprets the species contributing to the differences between regions. The SIMPER results 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. Three species contributing average similarity of 24% in AS were *Bathyuroconger vicinus*, *Bathycongrus* sp. B and *Nemichthys scolopaceus*, with a cumulative contribution of 91%. Similarly in BoB, the 4 species contributing average similarity of 38% were *Gavialiceps taeniola*, *Sauromuraenesox vorax*, *B. vicinus and Xenomystax trucidans* with a cumulative contribution of 95%. Similarly in AN, 5 species contributing average similarity of 28% were *Gavialiceps* sp. A, *Coloconger raniceps, Ophichthus* sp. A, *N. scolopaceus and B. vicinus* with a ccumulative contribution of 92%.

Table 4.6: Results of SIMPER showing species contributing to similarity within the three regional groups of Indian EEZ

Region / **Species**	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
AS Average similarity: 23.46					
Bathyuroconger vicinus	0.66	18.14	0.78	77.31	77.31
Bathycongrus sp. B	0.24	2.02	0.24	8.63	85.94
Nemichthys scolopaceus	0.2	1.21	0.18	5.14	91.08
BoB Average similarity: 38.08					
Gavialiceps taeniola	0.72	17.49	0.93	45.92	45.92
Sauromuraenesox vorax	0.56	12.8	0.61	33.62	79.54
Bathyuroconger vicinus	0.36	2.88	0.37	7.57	87.11
Xenomystax trucidans	0.32	2.82	0.3	7.4	94.51
AN Average similarity: 27.73					
Gavialiceps sp. A	0.66	15.3	0.74	55.16	55.16
Coloconger raniceps	0.45	5.71	0.45	20.6	75.76
Ophichthus sp. A	0.17	1.6	0.16	5.77	81.53
Nemichthys scolopaceus	0.24	1.55	0.21	5.57	87.11
Bathyuroconger vicinus	0.24	1.27	0.23	4.59	91.7

The average dissimilarity between AS & BoB (Table 4.7) is 89%. The three major species contributing to the dissimilarity between AS & BoB were *G. taeniola, S. vorax,* and *B. vicinus* with a cumulative contribution of 45%. The average dissimilarity between AS & AN (Table 4.8) is 92%. The 4 major species contributing the dissimilarity between

AS & AN were *G. taeniola, B. vicinus, C. raniceps and N. scolopaceus* with a cumulative contribution of 47%. Similarly average dissimilarity between BoB & AN (Table 4.9) is 92%. The three major species contributing the dissimilarity between BoB & AN were *G. taeniola*, *Gavialiceps* sp. A and *S. vorax* with a cumulative contribution of 43%.

Table 4.7: Results of SIMPER showing species contributing dissimilarity between AS & BoB

AS & BoB Average dissimilarity =88.47				
Species	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Gavialiceps taeniola	14.39	1.19	16.27	16.27
Sauromuraenesox vorax	13.07	0.94	14.78	31.05
Bathyuroconger vicinus	12.76	0.96	14.43	45.48
Xenomystax trucidans	6.6	0.62	7.46	52.94
Coloconger raniceps	5.19	0.62	5.87	58.8
Nemichthys scolopaceus	4.95	0.55	5.6	64.4
Bathycongrus sp. B	4.85	0.54	5.48	69.88
Ariosoma sp. A	3.62	0.37	4.1	73.98
Avocettina infans	2.97	0.43	3.36	77.34
Synaphobranchus oregoni	1.86	0.31	2.1	79.43
Ariosoma gnanadossi	1.81	0.28	2.05	81.48
Rhynchoconger squaliceps	1.68	0.29	1.9	83.38
Bathymyrus echinorhynchus	1.42	0.19	1.6	84.98
Japonoconger sp. A	1.42	0.19	1.6	86.58
Serrivomer sp.	1.4	0.27	1.59	88.17
Dysomma muciparus	1.15	0.2	1.29	89.46
Bathycongrus sp. A	0.95	0.21	1.07	90.53

Table 4.8: Results of SIMPER showing species contributing dissimilarity between AS & AN

AS & AN Average dissimilarity = 92.10				
Species	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Gavialiceps sp. A	14.18	1.05	15.4	15.4
Bathyuroconger vicinus	13.32	1.01	14.47	29.86
Coloconger raniceps	8.93	0.77	9.69	39.55
Nemichthys scolopaceus	7.05	0.62	7.65	47.21
Ophichthus sp. A	5.06	0.41	5.5	52.7
Bathycongrus sp. B	4.88	0.53	5.3	58
Xenomystax trucidans	3.89	0.53	4.23	62.22
Ariosoma sp. A	3.66	0.37	3.97	66.19
Congrhynchus talabonoides	2.74	0.37	2.98	69.17
Macrocephenchelys sp. A	2.62	0.35	2.85	72.02
Synaphobranchus sp. A	2.54	0.45	2.75	74.77
Bathycongrus macrocercus	2.12	0.38	2.3	77.07
Synaphobranchus oregoni	1.87	0.31	2.03	79.1
Avocettina infans	1.75	0.32	1.9	81
Gavialiceps taeniola	1.6	0.32	1.74	82.74
Serrivomer sp.	1.41	0.27	1.53	84.27
Gnathophis sp. B	1.3	0.25	1.41	85.68
Dysomma muciparus	1.16	0.2	1.25	86.94
Bathycongrus sp. A	0.95	0.21	1.04	87.97
Rhynchoconger squaliceps	0.95	0.21	1.04	89.01
Bathycongrus trimaculatus	0.87	0.18	0.95	89.96
Facciolella sp. G	0.87	0.18	0.95	90.9

Table 4.9: Results of SIMPER showing species contributing dissimilarity between BoB & AN

BoB & AN Average dissimilarity = 91.56				
Species	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Gavialiceps taeniola	13.91	1.29	15.19	15.19
Gavialiceps sp. A	13.06	1.09	14.27	29.46
Sauromuraenesox vorax	12.08	0.95	13.2	42.65
Coloconger *ranicps*	8.96	0.84	9.79	52.44
Xenomystax trucidens	7.24	0.71	7.91	60.35
Bathyuroconger vicinus	7.2	0.82	7.86	68.22
Nemichthys scolopaceus	5.34	0.58	5.83	74.05
Ophichthus sp. B	4.57	0.42	4.99	79.04
Congrhynchus talabonoides	2.55	0.37	2.78	81.83
Macrocephenchelys sp. A	2.14	0.32	2.34	84.17
Bathycongrus macrocercus	2.01	0.38	2.19	86.36
Synaphobranchus sp. A	1.83	0.39	2	88.36
Ariosoma gnanadossi	1.69	0.28	1.84	90.2

Analysis of similarity (ANOSIM) (Figure 4.7) was carried out to test the differences in species composition between two depth zones Upper Bathyal Zone (UBZ) and Lower Bathyal zone (LBZ) using species distribution data. The result reveals that there is significant difference (R=0.87, P=1.7) in species composition between the two depth zones Upper bathyal zone (UBZ) and Lower bathyal zone (LBZ).

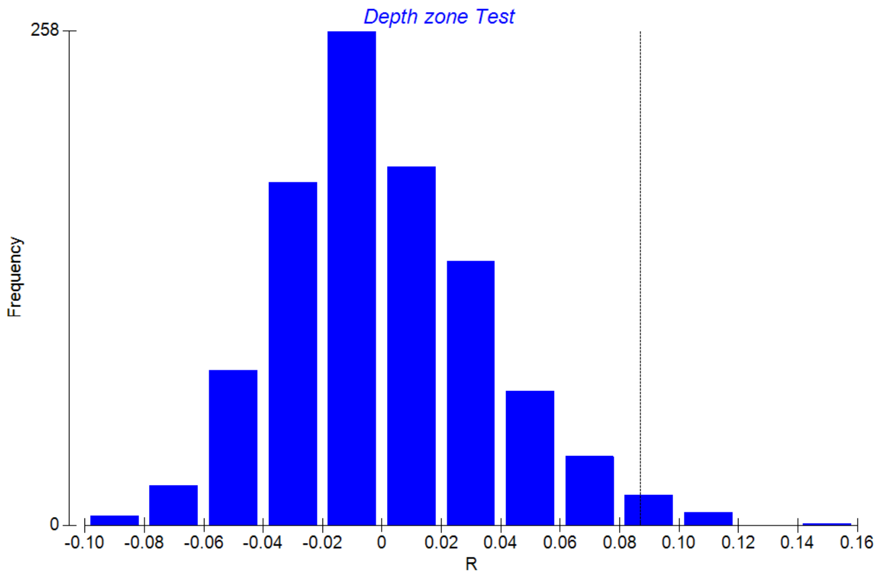

Figure 4.7: ANOSIM showing bathymetric distinction between two depth zones (UBZ & LBZ)

SIMPER analysis was carried out to find the species which were contributing to the similarity within the depth zones and dissimilarity between the depth groups. Seven species causes average group similarity of 15% within UBZ group (Table 4.10). The 3 major species contributing the similarity within UBZ group were *B. vicinus, C. raniceps* and *Gavialiceps* sp. A with a cumulative contribution of 50%. Three species cause average group similarity of 36% within LBZ group (Table 4.11). The three species causing the similarity within LBZ group were *B. vicinus, Bathycongrus* sp. B and *N. scolopaceus* with a cumulative contribution of 93%.

The average dissimilarity between UBZ and LBZ (Table 4.12) is 87%. The four species contributing the dissimilarity between UBZ and LBZ were *B. vicinus, Bathycongrus* sp. B, *N. scolopaceus, G. taeniola, C. raniceps* and *Gavialiceps* sp. A with a cumulative contribution of 55%.

Table 4.10: Results of SIMPER showing species contributing to similarity within the UBZ

UBZ Average similarity: 14.50					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib %**	**Cum. %**
Bathyuroconger vicinus	0.3	2.48	0.29	17.08	17.08
Coloconger raniceps	0.3	2.45	0.29	16.88	33.95
Gavialiceps sp. A	0.27	2.37	0.25	16.35	50.31
Gavialiceps taeniola	0.27	2.2	0.26	15.19	65.5
Sauromuraenesox vorax	0.24	2.11	0.22	14.58	80.08
Xenomystax trucidens	0.22	1.3	0.21	8.94	89.02
Nemichthys scolopaceus	0.15	0.54	0.13	3.72	92.75

Table 4.11: Results of SIMPER showing species contributing to similarity within the LBZ

LBZ Average similarity: 36.20					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Bathyuroconger vicinus	0.82	26.71	1.25	73.77	73.77
Bathycongrus sp. B	0.36	4.39	0.36	12.13	85.9
Nemichthys scolopaceus	0.29	2.62	0.27	7.23	93.13

Table 4.12: Results of SIMPER showing species contributing dissimilarity between UBZ & LBZ

UBZ & LBZ Average dissimilarity = 87.47	**Group UBZ**	**Group LBZ**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Bathyuroconger vicinus	0.3	0.82	14.83	1.1	16.96	16.96
Bathycongrus sp. B	0	0.36	7.31	0.7	8.35	25.31
Nemichthys scolopaceus	0.15	0.29	7.1	0.65	8.12	33.43
Gavialiceps taeniola	0.27	0.14	6.82	0.64	7.8	41.22
Coloconger raniceps	0.3	0.07	6.16	0.62	7.04	48.26
Gavialiceps sp. A	0.27	0.04	6.12	0.54	7	55.26
Sauromuraenesox vorax	0.24	0	5.21	0.5	5.95	61.21
Xenomystax trucidans	0.22	0.04	4.31	0.51	4.93	66.14
Avocettina infans	0.01	0.18	3.47	0.46	3.97	70.11
Synaphobranchus oregoni	0	0.14	2.79	0.39	3.2	73.31
Ariosoma sp. A	0.09	0	2.38	0.27	2.72	76.03
Synaphobranchus sp. A	0.04	0.11	2.18	0.4	2.5	78.53
Ophichthus sp. A	0.07	0	2.12	0.26	2.43	80.95
Serrivomer sp.	0	0.11	2.11	0.33	2.41	83.37
Macrocephenchelys sp. A	0.06	0	1.22	0.24	1.39	84.76
Congrhynchus talabonoides	0.06	0	1.16	0.23	1.32	86.08
Bathycongrus macrocercus	0.06	0	0.9	0.24	1.03	87.11
Rhynchoconger squaliceps	0.04	0	0.9	0.21	1.03	88.13
Dysomma muciparus	0.03	0	0.75	0.15	0.86	88.99
Promyllantor purpureus	0	0.04	0.68	0.19	0.78	89.78
Venefica sp.	0	0.04	0.68	0.19	0.78	90.56

4.3.2.1 Discussion

Diversity indices of deep-sea Anguilliformes were worked out on a regional and bathymetric basis Viz. Shannon-Wiener diversity index (H’), Margalef richness index (d), Pielou’s evenness index (J’) and Simpson dominance (λ’) index. The diversity indices calculated for three regions and two depth zones shows significant differences between them. Indices of species richness, evenness, and diversity of deep-sea Anguilliformes were high in AS. In BoB, species richness is less compared to AS and AN while evenness and diversity are higher than AN due to even distribution of the species in the region. Where as in AN species richness is higher but having less diversity than AS due to the dominance of single species (*Gavialiceps* sp. A). Hashim (2012) reported similar trend of diversity indices from AS. Among the two depth zones UBZ shows high species richness, evenness and diversity compared to LBZ. The UBZ of all the regions shows high species richness. UBZ of BoB & AS as well as LBZ of AN shows high diversity. Among the UBZ of all the three regions, UBZ of AS shows high species richness as well as diversity and very low richness was observed along LBZ of BoB. Similar trend was also reported by Hashim (2012) and Sudhakar et.al (2013).

The *K*-dominance plot of three regions reveals that AN have high dominance of single species (*Gavialiceps* sp. A) with poor evenness. BoB and AS have less dominance of species with high evenness, among them AS is observed with lesser dominance and increased evenness. Region wise *K*-dominance plot of Hashim (2012) indicate that high dominace of single species contribution is in BoB, followed by AN & AS. *K*-dominance curves of two depth zones depicts that LBZ have high dominance and less evenness and the situation in UBZ is vice versa. Similar trend was also reported in Hashim (2012). *K*-dominance plot of two depth zones within three regions indicate that UBZ of AN have higher dominance and lesser evenness than LBZ. LBZ of AS and BoB have higher dominance and lesser evenness than their UBZ.

Species assemblage pattern revealed 3 distinct regional groupings viz. Arabian Sea (AS), Bay of Bengal (BoB) and Andaman Sea (AN) as well as two bathymetric zones, Upper Bathyal Zone (UBZ) and Lower Bathyal Zone (LBZ). In AS 91% observed similarity is contributed by 3 species with 23.5% average similarity, in BoB 94.5% observed similarity is contributed by 4 species with 38.1% average similarity and in AN 92% of observed similarity is contributed by 5 species with 27.7% average similarity. The observed dissimilarity of 90.5% between the AS and BoB is contributed by 17 species with 88.5% average dissimilarity, similarly 90.9% of observed dissimilarity between AS and AN is contributed by 22 species with 92.1% average dissimilarity and observed dissimilarity of 90.2% between BoB and AN is contributed by 13 species with 91.6% average dissimilarity. The similarity/ dissimilarity within the bathymetric zones reveals that in UBZ 92.8 % observed similarity is contributed by 7 species with 14.5% average similarity, in LBZ 93.1 % observed similarity is contributed by 3 species with 36.2% average similarity. The observed dissimilarity of 90.6 % between UBZ and LBZ is contributed by 21 species with 87.5% average dissimilarity.

4.3.3 Abundance of deep-Sea Anguilliformes in the Indian EEZ

Regional wise abundance of deep-sea Anguilliformes (Figure 4.8) shows that BoB have higher abundance (avg. abundance of 1361.3 Ind./Km^2) ranging between (7–11321 Ind./Km^2) followed by AN (avg. abundance of 695.36 Ind./Km^2) ranging between (8–26182 Ind./Km^2) and AS (avg.

abundance of 512.78 Ind./Km^2) ranging between (8–7555 Ind./Km^2). While considering two depth zones, the UBZ of all regions have higher abundance ranging between 8 to 26182 Ind./Km^2.

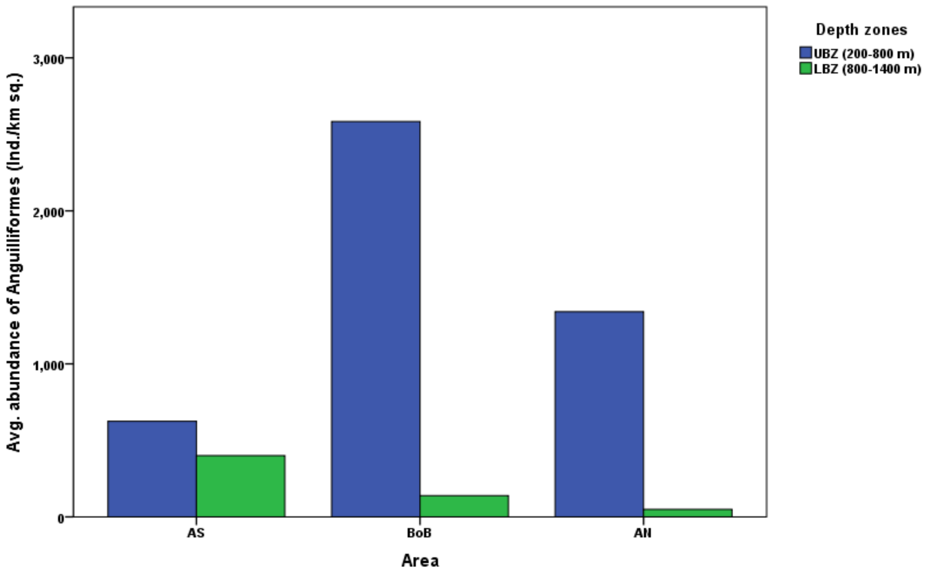

Figure 4.8: Regional wise average abundance of deep-sea Anguilliformes

Family wise contribution of deep-sea Anguilliformes (Figure 4.9) to the abundance were also analyzed which establishes that in all the regions irrespective of depth zones, deep-sea eels were dominated by the members of Congridae family. In AS, abundance is contributed by 10 families, Congridae (avg. abundance of 389.845 Ind./Km^2 [79%]) followed by Muraenidae (avg. abundance of 89.95 Ind./Km^2 [14.35%]), Muraenesocidae (avg. abundance of 12.69 Ind./Km^2 [2.05%]), Synaphobranchidae (avg. abundance of 9.845 Ind./Km^2 [2.05%]), Nemichthyidae (avg. abundance of 6.44 Ind./Km^2 [1.6%]), Serrivomeridae (avg. abundance1.75 Ind./Km^2 [0.45%]), Ophichthidae (avg. abundance of 1.095 Ind./Km^2 [0.2%]) and Derichthyidae (avg. abundance of 0.54 Ind./Km^2 [0.15%]) Colocongridae (avg. abundance of 64.5 Ind./Km^2 [0.15%]), and Nettastomatidae (avg. abundance of 35.5 Ind./Km^2 [0.1%]),.

In BoB, abundance is contributed by 5 families. Among them Congridae (avg. abundance of 813.07 Ind./Km^2 [76.9%]) show the highest abundance followed by Muraenidae (avg. abundance of 517.25 Ind./Km^2 [20%]), Nemichthyidae (avg. abundance of 10.115 Ind./Km^2 [2.3%]), Colocongridae (avg. abundance of 20.68 Ind./Km^2 [0.8%]), and Ophichthidae (avg. abundance of 0.25 Ind./Km^2 [0.005%]).

In AN sea abundance is contributed by 7 families. Among them, Congridae with an avg. abundance of 658.195 Ind./Km^2 [78.8%] lead the list, followed by Colocongridae (avg. abundance of 16.62 Ind./Km^2 [12.4%]), Synaphobranchidae (avg. abundance of 5.4 Ind./Km^2 [7.7%], Ophichthidae (avg. abundance of 8.815 Ind./Km^2 [0.65%]),), Nemichthyidae (avg. abundance of 5.075 Ind./Km^2 [0.4%]), Nettastomatidae (avg. abundance of 0.65 Ind./Km^2 [0.05%]) and Muraenesocidae (avg. abundance of 0.575 Ind./Km^2 [0.05%]).

Contribution of different families to the abundance of deep-sea Anguilliformes in the two depth zones of AS, BoB & AN sea reveals that in the UBZ of AN and LBZ of AS, the abundance is contributed by 7 families followed by UBZ of AS (6 families), UBZ of BoB (5 families), LBZ of AN (3 families) and LBZ of BoB (2 families). While comparing the contribution of families to the abundance within two depth zones of a region UBZ of AS have 6 families viz. Congridae (avg. abundance of

409.06 Ind./Km^2 [65.5%]), Muraenidae (avg. abundance of 179.19 Ind./Km^2 [28.7%]), Muraenesocidae (avg. abundance of 25.38 Ind./Km^2 [4.1%]), Synaphobranchidae (avg. abundance of 8.69 Ind./Km^2 [1.4%]), Ophichthidae (avg. abundance of 2.19 Ind./Km^2 [0.4%]) and Colocongridae (avg. abundance of 0.5 Ind./Km^2 [0.1%]) whereas LBZ of AS have 7 families viz. Congridae (avg. abundance of 370.63 Ind./Km^2 [92.5%]), Colocongridae (avg. abundance of 79 Ind./Km^2 [0.2%]), Nemichthyidae (avg. abundance of 12.88 Ind./Km^2 [3.2%]), Synaphobranchidae (avg. abundance of 11 Ind./Km^2 [2.7%]), Serrivomeridae (avg. abundance of 3.5 Ind./Km^2 [0.9%]), Derichthyidae (avg. abundance of 1.08 Ind./Km^2 [0.3%]) and Nettastomatidae (avg. abundance of 0.71 Ind./Km^2 [0.2%]).

UBZ of BoB have 5 families viz. Congridae (avg. abundance of 1492.64 Ind./Km^2 [57.8%]), Muraenidae (avg. abundance of 1034.5 Ind./Km^2 [40%]), Colocongridae (avg. abundance of 41.36 Ind./Km^2 [1.6%]), Nemichthyidae (avg. abundance of 14.73 Ind./Km^2 [0.6%]) and Ophichthidae (avg. abundance of 0.5 Ind./Km^2 [0.005%]) whereas LBZ of BoB have 2 families viz. Congridae (avg. abundance of 133.5 Ind./Km^2 [96%]) and Nemichthyidae (avg. abundance of 5.5 Ind./Km^2 [4%]).

UBZ of AN have 7 families viz. Congridae (avg. abundance of 1285.89 Ind./Km^2 [95.9%]), Colocongridae (avg. abundance of 21.74 Ind./Km^2 [1.6%]), Ophichthidae (avg. abundance of 17.63 Ind./Km^2 [1.3%]), Nemichthyidae (avg. abundance of 10.15 Ind./Km^2 [0.8%]), Synaphobranchidae (avg. abundance of 3.3 Ind./Km^2 [0.2%]), Nettastomatidae (avg. abundance of 1.3 Ind./Km^2 [0.1%]) and Muraenesocidae (avg. abundance of 1.15 Ind./Km^2 [0.1%]) whereas LBZ of AN have 3 families viz. Congridae (avg. abundance of 30.5 Ind./Km^2 [61.6%]), Colocongridae (avg. abundance of 11.5 Ind./Km^2 [23.2%]) and Synaphobranchidae (avg. abundance of 7.5 Ind./Km^2 [15.2%]).

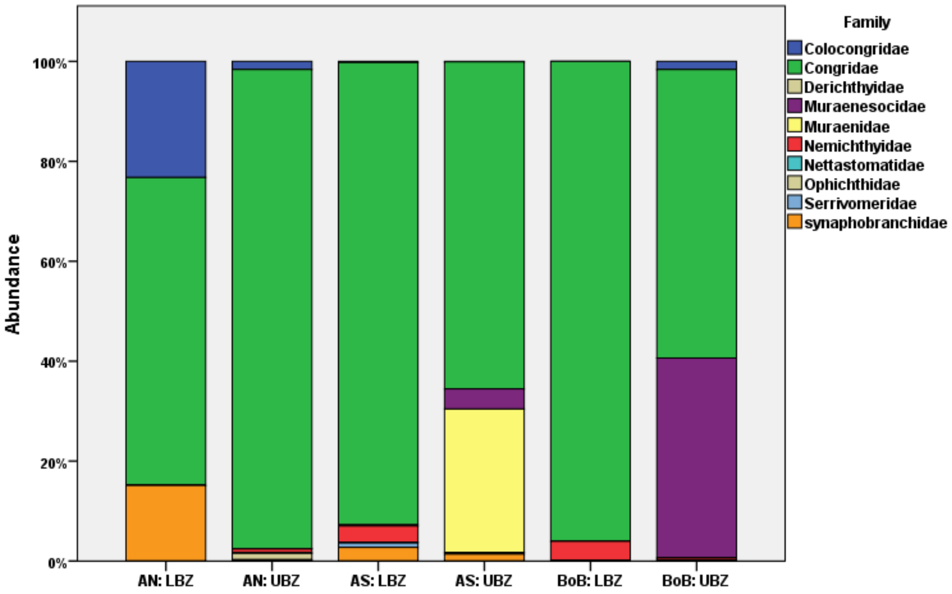

Figure 4.9: Family- wise average abundance of deep-sea Anguilliformes

4.3.3.1 Discussion

Present study is an attempt to explain the regional as well as bathymetric trend in abundance of deep sea Anguilliformes. The regional wise abundance shows that BoB has higher abundance followed by AN and AS. Bathymetric trend shows that in all regions UBZ has higher abundance compared to LBZ. This decrease in abundance with increasing depth clearly matches the global trend reported by various authors (Rex 1976; Thiel 1979; Haedrich 1996; Vinogradova 1997; Hashim 2012; Sudhakar et al. 2013).

Family wise contribution of deep-sea Anguilliformes was also analyzed. In AS abundance is contributed by 10 familes, BoB 5 families and AN 7 families. The major portion of abundance in AS is contributed by *B. vicinus* (8104.81 Ind./Km^2) followed by *Ariosoma* sp. A (4691.02 Ind./Km^2) and *G. reticularis* (2854.51 Ind./Km^2). In BoB, it is contributed by *G. taeniola* (29356.27 Ind./Km^2) followed by *S. vorax* (22757.70 Ind./Km^2) and *B. vicinus* (2742.69 Ind./Km^2). In AN, it is contributed by *Gavialiceps* sp. A (33044.65 Ind./Km^2) followed by *X. trucidans* (961.33 Ind./Km^2) and *C. raniceps* (587.29 Ind./Km^2).

Further, family wise contribution to the abundance in the two depth zones reveals that the number of families in these depth zones of AS, BoB & AN are distinct. That is; in AS: UBZ (6 families) and LBZ (7 families), in BoB: UBZ (5 families) and LBZ (2 families) and AN: UBZ (7 families) and LBZ (3 families). In UBZ of AS, abundance is contributed mostly by *Ariosoma* sp. A (4691.02) followed by *G. reticularis* (2854.51 Ind./Km^2) and *G. taeniola* (1069.09 Ind./Km^2) and in LBZ, by *B. vicinus* (8104.81) followed by *Bathycongrus* sp. B (743.50 Ind./Km^2) and *N. scolopaceus* (245.12 Ind./Km^2). In the UBZ of BoB, the major portion of abundance is contributed by *G. taeniola* (29356.27 Ind./Km^2) followed by *S. vorax* (22757.70 Ind./Km^2) and *B. vicinus* (2742.69 Ind./Km^2) and in the LBZ, *G. taeniola* (233.24 Ind./Km^2) followed by *B. vicinus* (33.93 Ind./Km^2) and *A. infans* (11.31 Ind./Km^2). In UBZ of AN, the major contributor to abundance is *Gavialiceps* sp. A (33044.65 Ind./Km^2) followed by *X. trucidans* (961.33 Ind./Km^2) and *C. raniceps* (587.29 Ind./Km^2) and in LBZ, *Gavialiceps* sp. A (38.40 Ind./Km^2) followed by *C. raniceps* (23.04 Ind./Km^2) and *B. vicinus* (15.36 Ind./Km^2). The present study also show that in all regions irrespective of depth zones, members of family Congridae contributed more towards the abundance. Hence we can assign family Congridae as the major contributior towards abundance of deep-sea Anguilliformes in Indian waters.

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Chapter 5

BIOLOGY OF DEEP-SEA ANGUILLIFORMES

Contents

5.1 Length–weight relationship (LWRs)

5.1.1 Introduction

LWRs are regularly used in fishery biology and is one of the standard method followed in fishery research and population dynamics (Erzini 1994; Froese et al. 2011). They are useful for converting growth-in-length into growth-in-weight in stock assessment models (Richter et al. 2000; Morato et al. 2001), estimation of biomass from length data (Petrakis & Stergiou, 1995), provide information on condition of fish and helps to determine whether somatic growth in a fish species is isometric or allometric (negative or positive) (Le Cren 1951; Ricker 1973), comparing relative conditions of the stock in different regions and also useful for performing morphometric comparisons of growth rate of different populations (Petrakis & Stergiou 1995). LWRs of juveniles and adults may differ due to ontogenetic change of body form with size, feeding habits and factors related to reproduction (Froese 2006).

LWRs are scarce for fishes inhabiting deep waters along the shelf edge and continental slope (Rosa et al. 2006; Ferreira et al. 2008; Orlov & Binohlan 2009; Pereira et al. 2012). India has a rich diversity of deep-sea fish. However, limited studies have been conducted on the biology including LWRs (Philip & Mathew 1996; Khan et al. 1996; Venu & Kurup 2002, 2006; Thomas et al. 2003; Kurup et al. 2005; Kurup & Venu 2006; Kurup et al. 2006; Jayaprakash et al. 2006; Thankappan et al. 2007; Karuppasamy et al. 2008; Vipin et al. 2011; Bineesh et al. 2012, 2018; Hashim 2012; Sreedhar et al. 2013; Manju et al. 2013; Manju 2014; Vipin 2015; Kumar et al. 2016c; Vinu 2017; Meera et al. 2018; Rajeeshkumar et al. 2018). Anguilliformes are one among the group having rich diversity among the deep-sea fishes and LWRs of the following species have been reported, *Bathyuroconger vicinus*, *Gavialiceps taenila*, *Xenomystax trucidans*, *Coloconger raniceps* (Jayaprakash et al. 2006; Thankappan et al. 2007; Hashim 2012; Sreedhar et al. 2013; Vinu et al. 2017). LWRs of 8 deep-sea eels belonging to 8 genera and 5 families are presented through this study. The objective of the study is to provide baseline information of growth patterns of deep-sea eels which can be used by other fishery researchers.

5.1.2 Materials & methodology

Samples were collected on board *FORV Sagar sampada* during the deep-sea exploratory fishery surveys conducted in the Indian EEZ by Centre for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Sciences, Government of India using demersal trawls. The samples were sorted onboard and preserved in 8% formaldehyde solution and taken to the onshore laboratory of CMLRE for further biological analysis. Specimens were identified using standard references (Alcock 1899; Talwar 1977; Karmovskaya 1994a; Smith & Böhlke 1997). The length (TL) and weight of the individual specimens were measured to the nearest 0.1 cm and nearest 0.1 gm respectively.

The relationship of length and weight of fish were calculated by the least square regression equation $W= aL^b$ (Le Cren 1951; Ricker 1973; Zar 1999; Froese 2006). This was logarithmically transformed into $\text{Log } 10 W= \text{Log } 10a +b \log 10 L$, where 'W' is the body weight, 'L' is total length, the parameter 'a' is the intercept of the regression curve and 'b' is the regression coefficient. Taking 95% confidence limit for the parameters a and b, the strength of the relationship was evaluated by coefficient of determination (r^2). Values were converted into logarithmic form and the outliers in the length and weight data were identified by checking the curvilinear plots for exclusion of such data from further analysis (Froese 2006). The *b* value for each species was evaluated by performing t test at 0.05 significance level to know whether the slope of regression line was significantly different from the isometric value 3 (Economou et al. 1991; Pauly 1993). Analysis of covariance (ANCOVA) was used to test whether there is significant difference in the length weight relationship between sexes. R software version 3.4.3 and Microsoft EXCEL 2013 were used for data analysis.

5.1.3 Results

Eight species (*Coloconger raniceps, Bathyuroconger vicinus, Xenomystax trucidans Ariosoma* sp. A, *Gavialiceps* sp. A, *Ophichthus* sp. A, *Gymnothorax reticularis,* and *Sauromuraenesox vorax*) of deep-sea eels belonging to 8 genera and 5 families were analyzed for their LWRs. Only species with n>25 numbers were selected for LWR analysis. LWRs were carried out separately for male, female and Sex combined. Sample size, minimum and maximum length (TL), minimum and maximum weight (gm), regression parameters a, b and coefficient of determination (r^2) for the 8 species selected are given in the table 5.1. The graphical representations of length-weight relationship of the species given in the figure 5.1.

Table 5.1: Length- weight relationships of deep-sea Anguilliformes.

Species	**Sex**	**N**	**Total length (cm)**		**Weight (gm)**		**Regression parameters**				
			Min	**Max**	**Min**	**Max**	**a**	**B**	**95% CL a**	**95 % CL b**	**r^2**
Bathyuroconger vicinus	M	31	46.5	79	155	775	0.0006	3.2078	0.0001-0.0040	2.72-3.69	0.86
	F	69	50.5	90	154	1100	0.0003	3.3570	0.0001-0.0012	2.95-3.76	0.80
	SC	100	46.5	90	15	1100	0.0004	3.3084	0.0001-0.0013	3.01-3.61	0.83
Coloconger raniceps	M	17	30.2	38.5	132	294	0.0059	2.9354	0.0006-0.0550	2.30-3.57	0.87
	F	23	29.4	42.6	130	345	0.0081	2.8615	0.0022-0.0282	2.51-3.21	0.93
	SC	40	29.4	42.6	130	345	0.0046	3.0161	0.0019-0.0112	2.76-3.27	0.94
Xenomystax trucidans	M	15	52	70.5	100	260	0.0006	3.0264	0.0001-0.0028	2.67-3.38	0.96
	F	25	50	72.5	80	270	0.0002	3.3050	0.00003-0.0016	2.81-3.80	0.89
	SC	40	50	72.5	80	270	0.0004	3.1607	0.0001-0.0013	2.86-3.46	0.92
Gavialiceps sp. A	M	15	57	88	70	225	0.0023	2.5753	0.0003-0.0151	2.14-3.01	0.93
	F	32	57.2	90.1	75	225	0.0007	2.8577	0.0001-0.0035	2.47-3.24	0.88
	SC	47	57	90.1	70	229	0.001	2.7559	0.0003-0.0035	2.47-3.04	0.89
Ariosoma sp. A	M	17	22.7	43	25	169	0.0027	2.9394	0.0010-0.0071	2.66-3.22	0.97
	F	29	21.2	40.8	20	158	0.0019	3.0767	0.0009-0.0041	2.84-3.30	0.96
	SC	46	21.2	43	20	169	0.0026	2.9664	0.0014-0.0049	2.78-3.15	0.96
Ophichthus sp. A	M	11	33	44.8	30	78	0.0025	2.7178	0.0006-0.0102	2.33-3.10	0.97
	F	25	30	45	22	79	0.0012	2.9255	0.0004-0.0089	2.60-3.25	0.94
	SC	36	30	45	22	79	0.0015	2.8489	0.0006-0.0036	2.60-3.09	0.95
Gymnothorax reticularis	M	10	31.2	41.5	52	111	0.0027	2.8459	0.0004-0.0209	2.28-3.41	0.94
	F	20	31.2	42	50	115	0.0009	3.1769	0.0001-0.0063	2.62-3.74	0.89
	SC	30	31.2	42	50	115	0.0013	3.0497	0.0003-0.0052	2.67-3.44	0.90
Sauromuraenesox vorax	M	21	33.3	49	58	222	0.0009	3.1487	0.00002-0.0014	3.03-4.22	0.87
	F	26	32.2	50.4	57	240	0.0019	2.9664	0.00006-0.0016	2.99-3.86	0.90
	SC	47	32.2	50.4	57	240	0.0015	3.0276	0.00005-0.0007	3.23-3.81	0.89

N: Number of observations; M: Male; F:Female; SC: Sexes combined; a and b:Parameters of Length-weight equation; r^2 : Coefficient of determination; CL: Confidence limit

Bathyuroconger vicinus**:** A total of 100 samples of *Bathyuroconger vicinus* were examined, which included 31 males and 69 females. The total length ranged from 46.5cm to 90cm with a mean length of 63.7 cm and the weight ranged from 154 gm to 1100 gm with a mean weight of 369 gm. LWRs of *B. vicinus* was estimated as: $W= 0.0006L^{3.20784}$ for males ($r^2= 0.86$); $W= 0.0003L^{3.357}$ for females ($r^2= 0.80$) and $W= 0.0004L^{3.3084}$ for sex combined ($r^2= 0.83$). Statistically (t-test) the exponent b deviates significantly ($P>0.05$) from the cube law and therefore the species shows positive allometric growth pattern. No significant difference was found in the LWRs between male and female fishes (ANCOVA, $P<0.05$).

Coloconger raniceps**:** A total of 40 samples of *C. raniceps* were examined, which included 17 males and 23 females. The total length ranged from 29.4 cm to 42.6 cm with a mean length of 35.3 cm and the weight ranged from 130 gm to 345 gm with a mean weight of 219 gm. LWRs of *C. raniceps* was estimated as: $W= 0.0059L^{2.9354}$ for males ($r^2= 0.87$); $W= 0.0081L^{2.8615}$ for females ($r^2= 0.93$) and $W= 0.0046L^{3.0161}$ for sex combined ($r^2= 0.94$). Statistically (t-test) the exponent *b* deviates significantly ($P>0.05$) from the cube law and therefore the species (male & female) shows negative allometric growth pattern and the sex combined data shows isometric allometric growth pattern. No significant difference was found in the LWR between male and female fishes (ANCOVA, $P<0.05$).

***Xenomystax trucidans*:** A total of 40 samples of *X. trucidans* were examined, which included 15 males and 25 females. The total length ranged from 50cm to 72.5 cm with a mean length of 61.4 cm and the weight ranged from 80 gm to 270 gm with a mean weight of 170 gm. LWRs of *X. trucidans* was estimated as: $W= 0.0006L^{3.0264}$ for males ($r^2= 0.96$); $W= 0.0002L^{3.3051}$ for females ($r^2= 0.89$) and $W= 0.0004L^{3.1607}$ for sex combined ($r^2= 0.92$). Statistically (t-test) the exponent b deviates significantly ($P>0.05$) from the cube law and therefore the species shows positive allometric growth pattern. No significant difference was found in the LWR between male and female fishes (ANCOVA, $P<0.05$).

***Gavialiceps* sp. A:** A total of 47 samples of *Gavialiceps* sp. A were examined, which included 15 males and 32 females. The total length ranged from 57cm to 90.1 cm with a mean length of 75.2 cm and the weight ranged from 70 gm to 229 gm with a mean weight of 160 gm. Graphical representations of length-weight relationship of the species are given in figure 5.3 (a) for male and female and (b) for pooled data. LWRs of *Gavialiceps* sp. A was estimated as: $W= 0.0023L^{2.5753}$ for males ($r^2= 0.93$); $W= 0.0007L^{2.8577}$ for females ($r^2= 0.88$) and $W= 0.001L^{2.7559}$ for males and females combined ($r^2= 0.89$). Statistically (t-test) the exponent b deviate significantly ($P>0.05$) from the cube law for females and do not deviate significantly ($P<0.05$) for males and sex combined data and shows negative allometric growth pattern. No significant difference was found in the LWR between male and female fishes (ANCOVA, $P<0.05$).

***Ariosoma* sp. A:** A total of 46 samples of *Ariosoma* sp. A were examined, which included 17 males and 29 females. The total length ranged from 21.2 cm to 43 cm with a mean length of 30.6 cm and the weight ranged from 20 gm to 169 gm with a mean weight of 73.8 gm. LWRs of *Ariosoma* sp. A was estimated as: $W= 0.0027L^{2.9393}$ for males ($r^2= 0.97$); $W= 0.0019L^{3.0767}$ for females ($r^2= 0.96$) and $W= 0.0026L^{2.9664}$ for males and females combined ($r^2= 0.96$). Statistically (t-test) the exponent b deviates significantly ($P> 0.05$) from the cube law and therefore the female species shows positive allometric growth pattern, male show negative allometric growth pattern and pooled data shows Isometric growth pattern. No significant difference was found in the LWR between male and female fishes (ANCOVA, $P<0.05$).

***Ophichthus* sp. A:** A total of 36 samples of *Ophichthus* sp. A were examined, which included 11 males and 25 females. The total length ranged from 30 to 45 cm with a mean length of 37.9 cm and the weight ranged from 22 to 79 gm with a mean weight of 50 gm. LWRs of *Ophichthus* sp. A was estimated as: $W= 0.0025L^{2.7178}$ for males ($r^2= 0.96$); $W= 0.0012L^{2.9255}$ for females ($r^2= 0.94$) and $W= 0.0015L^{2.8489}$ for sex combined ($r^2=0.95$). Statistically (t-test) the exponent b deviates significantly ($P>0.05$) from the cube law and therefore the species shows negative allometric growth pattern. No significant difference was found in the LWR between male and female fish (ANCOVA, $P<0.05$).

***Gymnothorax reticularis*:** A total of 30 samples of *G. reticularis* were examined, which included 10 males and 20 females. Total length ranged from 31.2 to 42 cm with a mean length of 35.8 cm and the weight ranged from 50 to 115 gm with a mean weight of 75.2 gm. LWRs of *G. reticularis* was estimated as: $W= 0.0027L^{2.8459}$ for males ($r^2= 0.94$); $W= 0.0009L^{3.1769}$ for females ($r^2= 0.89$) and $W= 0.0013L^{3.0497}$ for sex combined ($r^2= 0.9$). Statistically (t-test) the exponent b deviates significantly ($P>0.05$) from the cube law and therefore the male species shows negative allometric growth whereas female & sex combined data shows positive allometric growth pattern. No significant difference was found in the LWR between male and female fishes (ANCOVA, $P<0.05$).

***Sauromuraenesox vorax*:** A total of 47 samples of *S. vorax* were examined, comprising of 21 males and 26 females. The total length ranged from 32.2 to 50.4cm with a mean length of 40.9 cm and the weight ranged from 57 to 240 gm with a mean weight of 114.3 gm. LWRs of *S. vorax* were estimated as: $W= 0.0009L^{3.1487}$ for males ($r^2= 0.87$); $W= 0.0019L^{2.9664}$ for females ($r^2= 0.90$) and $W= 0.0015L^{3.0276}$ for sex combined ($r^2= 0.89$). Statistically (t-test) the exponent b deviates significantly ($P> 0.05$) from the cube law and therefore the male species shows positive allometric growth pattern and female & sex combined shows isometric growth pattern. No significant difference was found in the LWRs between male and female fishes (ANCOVA, $P<0.05$).

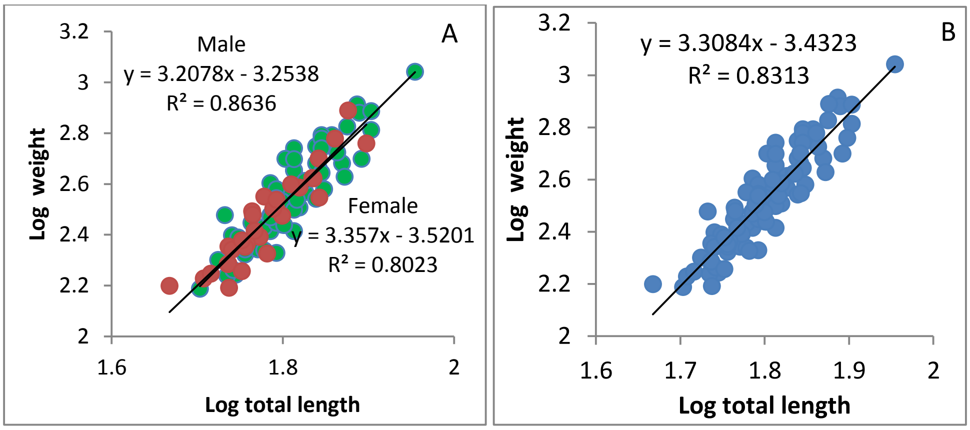

Figure 5.1: Length-weight relationship of *Bathyuroconger vicinus* .(A) Male & Female (B) Pooled data

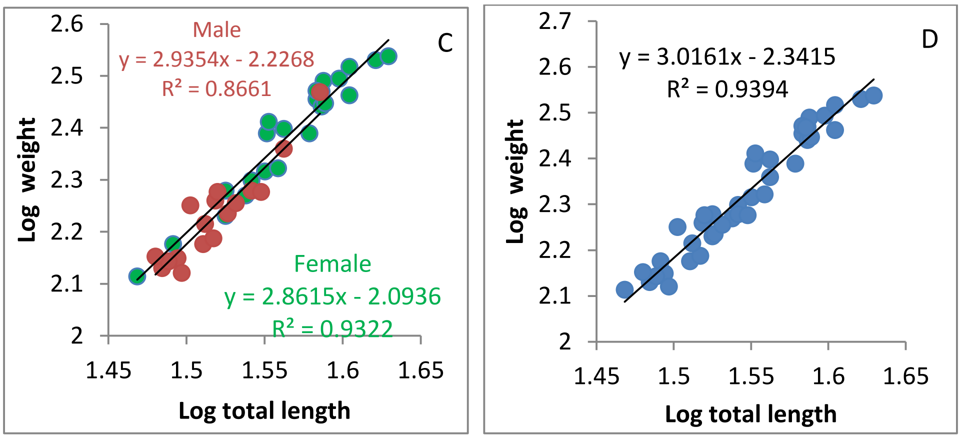

Figure 5.1: Length-weight relationship of *Coloconger raniceps*.(C) Male & Female (D) Pooled data

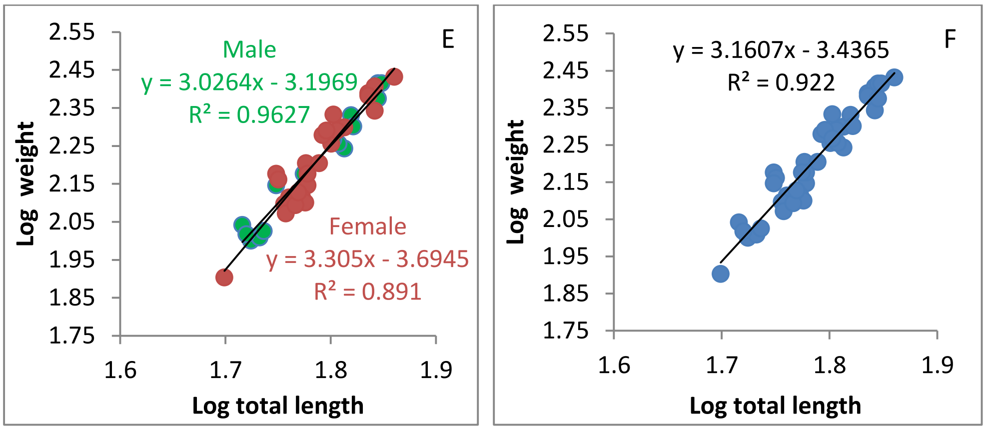

Figure 5.1: Length-weight relationship of *Xenomystax trucidans.* (E) Male & Female (F) Pooled data

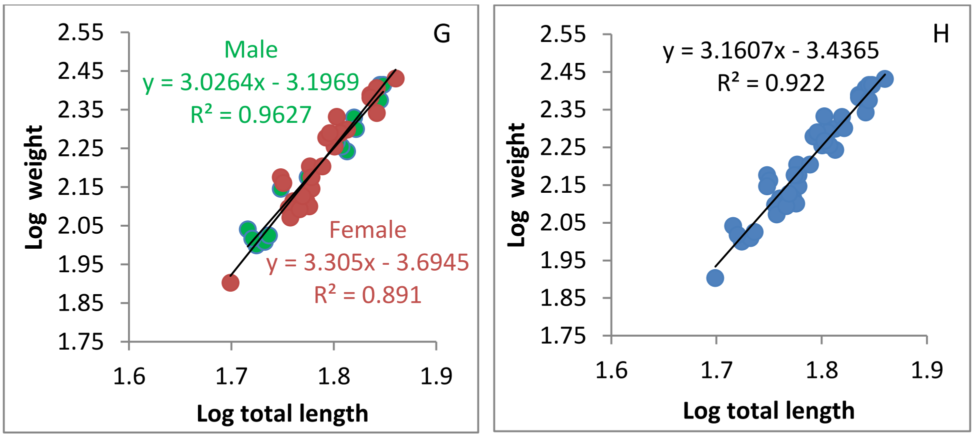

Figure 5.1: Length-weight relationship of *Gavialiceps* sp. A.(G) Male & Female (H) Pooled data

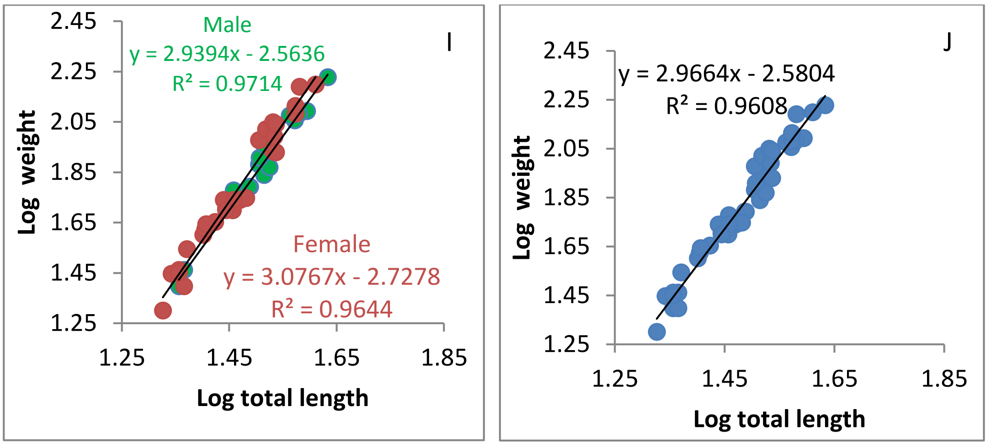

Figure 5.1: Length-weight relationship of *Ariosoma* sp. A.(I) Male & Female (J) Pooled data

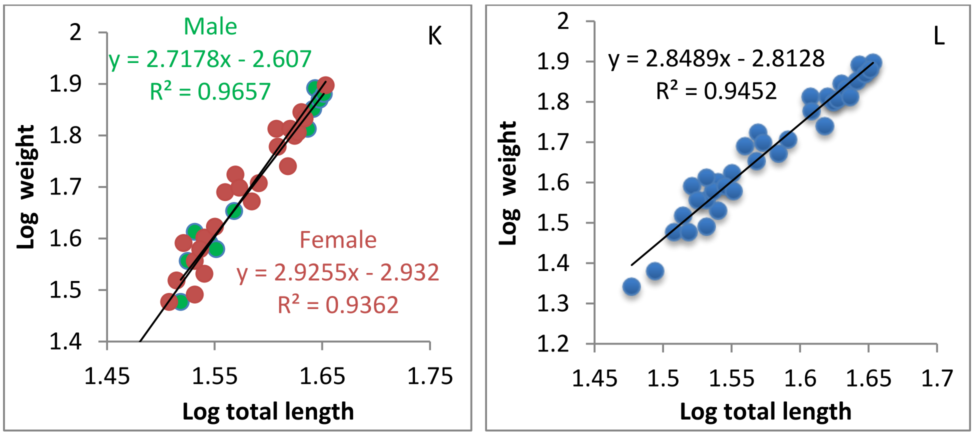

Figure 5.1: Length-weight relationship of *Ophichthus* sp. A.(K) Male & Female (L) Pooled data

5.1.4 Discussion

The LWRs of most of the deep-sea fishes are not known. Even in the largest database on fish (Fishbase), the LWRs of only 55 species among 3000 deep-sea fishes are available (Orlov & Binohlan 2009). From this it is clear that there is a dearth of knowledge on the LWRs of deep-sea fishes especially that of deep-sea eels. In the present study we analyzed the LWRs of 8 species of deep-sea eels. Among them the LWRs of 5 species (*Ariosoma* sp. A, *Gavialiceps* sp. A, *Ophichthus* sp. A, *G. reticularis* and *S. vorax*) are provided for first time globally. The parameter *a* in deep-sea eels ranges from 0.0002–0.0081. While analyzing the sex separately the *a* value in males ranged from 0.0006 to 0.0027 and in females it ranged from 0.0002 to 0.0081 and in pooled data the range was 0.0004 to 0.0046. The b value reveals the pattern of change in body form and condition with increase in size (Carlander 1969, Froese 2006). In the present study *b* value ranged from 2.6–3.4. The b values of all the species in the present study falls within the expected range of 2.5–3.5 (Froese 2006). In males the range of b value was 2.6–3.2, in females 2.9–3.4 and in sex combined data the range is 2.8–3.3.

In our analysis of sex combined LWRs, 3 species (*C. raniceps*, *Ariosoma* sp. A, *S. vorax*) exhibited isometric growth pattern. Three species (*B. vicinus*, *X. trucidans* and *G. reticularis*) exhibited positive allometric growth pattern and 2 species (*Gavialiceps* sp. A & *Ophichthus* sp. A) showed negative allometric growth pattern. Considering the sexes separately, in males 1 species *(X.trucidans*) exhibited isometric growth pattern, 2 species (*B. vicinus* & *S. vorax*) showed positive allometric growth pattern and 5 species (*C. raniceps*, *Ariosoma* sp. A, *Ophichthus* sp. A, *Gavialiceps* sp. A and *G. reticularis*) showed negative allometric growth. Similarly in females 1 species (*S. vorax*) showed isometric growth, 4 species (*B. vicinus, X. trucidans, Ariosoma* sp. A, *G. reticularis)* showed positive allometric growth pattern and 3 species (*C. raniceps*, *Gavialiceps* sp. A and Ophichthus sp. A) showed negative allometric growth.

The LWRs of 3 species (*B. vicinus*, *X. trucidans, C. raniceps*) were reported earlier from Indian waters (Jayaprakash et al. (2006), Sreedhar et al.2013, Vinu 2017). Present estimates of LWR for *X. trucidans* shows positive allometric growth (b: 3.3 & 3.2) for females & sexes combined and an isometric growth pattern (3.03) for males. These values are much higher than the previous estimates of negative allometric growth (b: 2.8) reported by Sreedhar et al. (2013). However our estimates agrees with positive allometric growth (b: 3.17) reported by Jayaprakash et al. (2006). Present LWRs of *C. raniceps* show isometric growth for sexes combined data (b: 3.02) whereas the sexes separate data show negative allometric growth (b: 2.7–2.9) for both male and female. Our b estimates are much higher than that reported by Sreedhar et al. 2013 (b =2.5) which indicate negative allometry. The negative allometric growth pattern (b:2.7–2.9) of *C. raniceps* for sexes separate data in present study agrees with Jayaprakash et al. (2006) (b: 2.9). Results of our study on *B. vicinus* show positive allometric growth (*b*>3) which agree with estimation of Vinu 2017 (b: 3.3) & Jayaprakash et al. (2006) (b: 3.3) but is slightly higher than the estimatie of Sreedhar et al. 2013 (*b*: 3.03). The possible reasons for these differences in b values with earlier estimations may be attributed to one or more factors such as the length ranges used, study seasons, habitat, sex, diet, health and annual differences in environmental conditions (Moutopoulos and Stergiou, 2002;Froese 2006; Ye et al., 2007). In the case of 5 species (*Gavialiceps* sp, A, *Ophichthus* sp. A, *Ariosoma* sp., *Gymnothorax reticularis*) previous estimates were not available even though the growth parameter can be compared with their congeners. *Gavialiceps* sp. A shows slightly higher b value (2.8) than its congener *G. taeniola,* (2.32) reported by Sreedhar et al. 2013, Hashim 2012 (2.69) and Thankappan et al. 2007 (2.29). However both the species agree in that they exhibit negative allometric growth pattern. Similarly, in the present study on LWR of *G. reticularis* our results indicate a positive allometric growth (b: 3.1) in sex combined, which agrees with the previous report of positive allometric growth pattern reported in 29 congers of *Gymnothorax* sp. by Loh et al. (2011). *Ariosoma* sp. A in the present study show an isometric growth pattern (b: 2.97) in sex combined which is an intermediate value with the *b* values of *Ariosoma baleracium* reported by Edelist (2014) (b:2.89) and Morey et al. (2003) (*b*: 3.07). *Ophichthus* sp. A in the present study, show negative allometric growth pattern (b: 2.8) and differs in growth pattern from the only available report (Miller et al. 2008) of its congener *Ophichthus zophochir* which is reported to exhibit positive allometric growth (b: 3.2). This difference may be due to less sample size or difference in growth between these two species. *Suromuraenesox vorax* is the only species in the genus and it exhibit isometric growth pattern for females and positevly allometric pattern for males. In sex combined data, majority of the eels exhibit isometric to positive allometric growth pattern which is consistent with the observations of Ilkyaz et al. (2008) and Loh et al (2011b). The present estimates of LWRs of deep-sea eels will be useful for the fishery biologist for various applications including the stock-assessment of deep-sea eels.

5.2 Sex ratio

5.2.1 Introduction

Sex ratio is the proportion of males to females in a population. Fisher (1930) in his sex ratio theory explained that, natural selection should maintain 1:1 sex ratios by continuously favoring the rare sex, thereby always returning skewed sex ratios to equality. However biased sex ratios are very common in species inhabiting deep sea environment (Shotton 2005) due to differences between the sexes in age at maturity, sex change behavior (in hermaphrodites), reproductive longevity and differential mortality (Lovich & Gibbons 1990, Arnold et al. 2003, Donald 2007, Arendt et al. 2014). Sex ratio of a population has a strong influence on reproductive behavior and may vary over time and space. The sex ratio provides basic information to assess the reproductive potential and estimate the stock size of fish populations (Stratoudakis et al. 2006). Information on sex ratio is important for understanding the relationship between individuals, the environment and the state of the population (Vicentini & Araujo 2003) and to ensure proportional fishing of two sexes (Vazzoler 1996). The information on sex ratio of Anguilliformes is scare and from the limited reports it is found that skewed sex ratios are common among them.

5.2.2 Materials & Methodology

Eight species of deep-sea eels belonging to 8 genera, 5 families were analyzed in the present study to establish the Sex ratio. The specimens were collected onboard *FORV Sagar Sampada* using demersal trawls, preserved in 8% formaldehyde solution and transported to the onshore laboratory of CMLRE for further analysis. Males and females of each species were separated by visual examination of gonads after dissection. The sex ratio (M:F) was calculated and the deviation in the sex ratio was assessed by Chi-square (χ^2) test in order to verify whether the population of males and females differed from the expected ratio of 1:1 (Rao & Yoon 1983).

5.2.3 Results

Sex ratio show a dominance of female over male in the population of all species studied (Table 5.2). The sex ratio (M: F) of *B. vicinus* is found to be 1:2.2 which is statistically significant ($P<0.05$) when chi-square test was performed. The sex ratio (M: F) of *Gavialiceps* sp. A is 1:2.1 and *Ophichthus* sp. A is 1:2.3, which are also statistically significant ($P<0.05$). No significant difference in sex ratio ($P>0.05$) was observed in the remaining 5 species viz. *C. raniceps*, *X. trucidans*, *Ariosoma* sp. A, *G. reticularis* and *S. vorax* . The sex ratios obtained were 1:1.4, 1:1.7, 1:1.7, 1:2 and 1:1.2 respectively. Dissected male and female of *Ariosoma* sp. A is shown in figure 5.2

Figure 5.2: Figure showing male and female of *Ariosoma sp.* A

Table 5.2: Sex ratio of deep-sea Anguilliformes

Species	Male	Female	Ratio	Chi-square value	df	P- value
Bathyuroconger vicinus	31	69	1:2.2	14.4	1	<0.05
Coloconger raniceps	17	23	1:1.4	0.9	1	>0.05
Xenomystax trucidans	15	25	1:1.7	2.5	1	>0.05
Gavialiceps sp. A	15	32	1:2.1	6.1	1	<0.05
Ariosoma sp. A	17	29	1:1.7	3.1	1	>0.05
Ophichthus sp. A	11	25	1:2.3	5.4	1	<0.05
Gymnothorax reticularis	10	20	1:2	3.3	1	>0.05
Sauromuraenesox vorax	21	26	1:1.2	0.5	1	>0.05

5.2.4 Discussion

For all the species of deep-sea eels analyzed in the present study females were predominant than males ie., the sex ratio was skewed towards female. The minimum skewness in sex ratio (M: F) was observed in *S. vorax* (1: 1.2) and maximum was observed in *Ophichthus* sp. A (1: 2.3). Such female biased sex ratios were reported in Anguilliform species by various reseachers. Casadevall et al. (2001) reported predominance of females over males in *Ophichthus rufus,* Similarly Shouji (2003) reported for *Conger japonicas*, Correia et al. 2009 & Casadevall 2017 reported in *Conger conger*, Thankappan et al. (2007) & Hashim (2012) in *Gavialiceps taeniola*; Porcu et al. (2013) in *Nettastoma melanurum*, Yokouchi et al. (2014) in *Anguilla japonica*, Kobayashi et al. (2015) in *Muraenesox cinereus* species. The reasons for this sex biased aggregation was explained by above authors as different depth preferences by males and females, different habitat use among sexes, spawning aggregation, more avoidance of sampling gears by males than females etc. The exact reason for skewed sex ratio towards females could not be established in the present study due to lack of frequent and seasonal surveys as well as restriction of depth to 1400 m depth in our surveys. Future frequent surveys covering all the seasons and further increase in the sampling depth can explain this female skewed sex ratio in deep-sea Anguilliformes with more authenticity.

5.3 Fecundity

5.3.1 Introduction

The term ‘fecundity’ denotes the egg laying capacity of a fish or the number of ripening eggs prior to spawning (Bagenal 1978). It is also described as seasonal spawning potential (Bagenal & Tesch, 1978). Information on fecundity is important for assessing the individual reproductive potential, studying the population dynamics through stock-recruitment relationships, evaluating the productivity of the population and characterizing specific populations, subpopulations and fish stocks (Kraus et al. 2002; DeMartini & Sikkel 2006; Lambert 2008; Armstrong & Witthames 2012). It is also an important aspect in stock size assessment, stock discrimination (Holden & Raitt 1974) and rational utilization of stock (Morales 1991). More over these studies also provide useful information for investigating population resilience in relation to climate change and fishing pressure (Sadovy 2001; Pankhurst & King 2010; Strüssmann et al. 2010). Hence the study on fecundity is a basic requirement for the effective fishery resources management and conservation (Marshall et al. 2003; Grandcourt et al. 2009). Studies on fecundity of marine fishes (especially deep-sea fishes) are scarce worldwide, and are mainly available for commercially important species inhabiting tropical and subtropical ecosystems (Tomkiewicz et al. 2003; Lowerre-Barbieri et al. 2011; Fitzhugh et al. 2012). Due to the decrease in coastal fishery resources, commercial fishing has extended to greater depths around the world. As a result some of the important fish stocks have collapsed or are beginning to show warning signs of population decline (Baum et al. 2003; Devine et al. 2006; Coll et al. 2008, Pontecorvo & Schrank, 2014). Hence it is necessary to have knowledge about the life history stages and fecundity of deep-sea fishes. Information on fecundity of deep sea eels are limited and majority of works are based on commercially important species viz. *Anguilla, Conger and Muraenesox*. Present study provides information on fecundity of few deep-sea eel species from Indian waters for the first time which will be useful for their effective management and conservation.

5.3.2 Materials & Methodology

Fecundity of 8 species of deep-sea Anguilliformes (*Bathyuroconger vicinus*, *Coloconger raniceps*, *Xenomystax trucidans*, *Sauromuarenesox vorax*, *Gymnothorax reticularis*, *Ariosoma* sp. A, *Ophichthus* sp. A & *Gavialiceps* sp. A) were examined. Samples were collected on board FORV *Sagar Sampada* and preserved in 8% formaldehyde solution. Further analysis was carried out in the CMLRE laboratory. Total length and body weight of the specimens were measured to the nearest 0.1 mm and 0.1 gm respectively. Samples were dissected and analyzed macroscopically and females in advanced maturity stages (Maturity stage 4) were sorted out to estimate the fecundity. Identification of spawning capable phase follows Porcu et al. (2013). In this stage ovaries are very large and big, clearly visible in the body cavity and could be expelled by slight pressure. Ovaries were separated out, washed and weighed using a digital weighing balance after drying on a blotting paper. Random samples were taken, then weighed and evenly spread on a counting slide with few drops of water. Numbers of ova were counted and ova diameter was measured and photographed using stereo zoom trinocular microscope (Leica S8APO Camera, Leica DFP-425). Total number of ova (Fecundity) was obtained from the equation F= n G/g (Venkataramanujam & Ramanathan 1994) as explained in chapter 2.

5.3.3 Results

Eight species of deep-sea eels were analyzed for estimating fecundity. Ovaries of all the species observed were paired with two lobes. Each lobe is oriented dorso-ventrally to the gut and originates much anteriorly near the branchial region and extends backwards to the entire length of body cavity slightly beyond the anal opening. Ovaries were covered by a thin membrane, the tunica albuginea. Eggs are spherical to oval in shape (Figure 5.3). As there are no oviducts, eggs were released directly into the body cavity. The total length, weight, fecundity and ova diameter of the species analyzed are given in table 5.3.

Fecundity in *B. vicinus* range from 46866 to 75000 eggs and ova diameter range from 0.9–1.4 mm. *B. vicinus* has the highest fecundity among the 8 species analyzed whereas *Ophichthus* sp. A has the lowest fecundity ranging from 8000 to 12405 eggs and ova diameter ranging from 0.8–1.0 mm. *Xenomystax trucidans* has fecundity ranging from 22020 to 48350 eggs and ova diameter ranging from 0.8–1.1mm. *Colonger raniceps* has fecundity ranging from 19110 to 28450 eggs and ova diameter ranging from 1.3–1.5 mm. *Gavialiceps* sp. A has a fecundity ranging from 14000 to 26300 eggs and ova diameter ranging from 0.8–1.1mm. In *G. reticularis* fecundity ranges between 23420 to 26600 eggs and ova diameter ranging from 0.9–1.4 mm. In *Sauromuraenesox vorax* fecundity ranges from 29780 to 36640 eggs and ova diameter range from 0.7–1.1 mm.

Table 5.3: Fecundity and ova diameter of deep-sea eels

No.	Species	TL (mm)	Weight (gm)	Maturity stage	Total fecundity (eggs/females)			Ova diameter (mm)
					N	Range	Mean ± SD	
1	*B.vicinus*	610-770	350-820	IV	12	46866-75000	62400 ±8965	0.9-1.4
2	*C. raniceps*	356-402	245-290	IV	8	19110-28450	24800± 3110	1.3-1.5
3	*X. trucidans*	576-725	130-270	IV	9	22020-48350	28600± 6328	0.8-1.1
4	*Gavialiceps* sp. A	790-900	186-229	IV	10	14000-26300	18680± 3087	0.8-1.1
5	*Ariosoma* sp. A	330-408	105-158	IV	9	14240-26500	19468± 4320	0.6-0.8
6	*Ophichthus* sp. A	355-405	42-65	IV	7	8000-12405	9972± 880	0.8-1.0
7	*G. reticularis*	360-410	86-109	IV	6	23420-26600	24750± 1590	0.9-1.4
8	*S.vorax*	457-503	144-240	IV	10	29780-36640	33994± 3103	0.7-1.1

TL: Total length; N: Number of observations; SD: Standard deviation

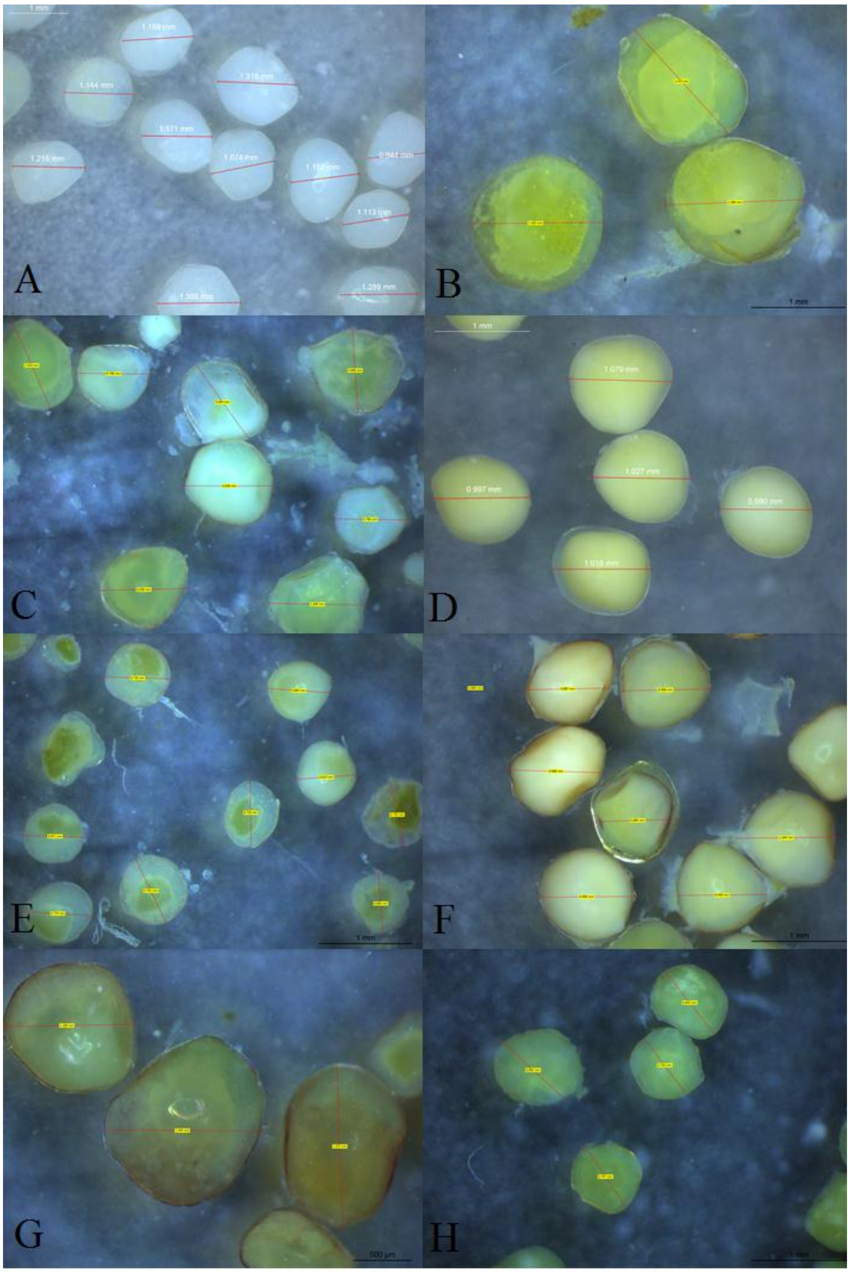

Figure 5.3: Ovadiameter of deep-sea eels A) *Bsthyuroconger vicinus*, B) *Coloconger raniceps*, C) *Xenomystax trucidans*, D) *Gavialiceps* sp. A, E) *Ariosoma* sp. A, F) *Ophichthus* sp. A, G) *Gymnothorax reticularis*, H) *Sauromuraenesox vorax*

5.3.4 Discussion

Our understanding on the fecundity of deep-sea fishes especially that of deep-sea eels is very limited. In the present study we provide a baseline information on the fecundity of deep-sea eels for the first time in India and perhaps globally. We could not find any information regarding the fecundity of these fishes elsewhere. Fecundity of deep-sea eels examined in the present study range between 8000–75000 eggs. *B. vicinus* has highest fecundity with egg numbers ranging from 46866–75000 whereas the lowest fecundity was found to be for *Ophichthus* sp. A ranging from 8000–12000 eggs. The ova diameter in deep-sea eels ranges between 0.6–1.54 mm. Ova diameter was large for *C. raniceps* followed by *B. vicinus* and *G. reticularis*. Ova diameter is smaller in the case of *Ariosoma* sp. A. There is a general hypothesis that the deep-sea fishes have less fecundity and larger egg size than shallow water species (Allain 2001). Shallow water species of eels such as *Muraenesox talabonoides*, fecundity is estimated to range between 306,573–922,033 eggs (Kagwade 1969). Similarly fecundity in various other shallow water species of *Anguilla* are; *A. bicolor* (550,000–4,960,000 eggs) *A. bengalensis* (330,000–1,720,000 eggs) and *A. marmorata* (9,90,000 eggs) (Kadir et al. 2017). The fecundity of the above said shallow water eels are very high when compared to the fecundity in deep-sea eels from the present study (8000–75000 eggs) as well as documented by various researchers ie in *Nettastoma melanuram* (2025–53132), *Gnathophis mystax* (2951–26522) (Porcu et al. 2013; Fernandez-Arcaya et al. 2016).Hence our study also supports the hypothesis of decreasing fecundity with increase in depth but it should be also noted that we could not find any difference in egg sizes over depth in case of Anguilliform species. Shallow water species of *Muraenesox talabonoides* has an egg size of 1.6–2.2 mm which is larger than the egg size (0.6–1.5 mm) of deep-water species reported in our study as well as by other researchers (Porcu et al. 2013; Fernandez-Arcaya et al. 2016).

5.4 Food and feeding

5.4.1 Introduction

Food is a basic need of a species which governs its growth, fecundity, migration and abundance. Examining the food and feeding habits of a species is important for evaluating the ecological role and position of the species in the food web structure of ecosystems (Allan & Castillo 2007). Diets of fishes represent an integration of many ecological components that include behavior, condition, habitat use, energy intake and inter and intraspecific interactions (Chipps & Garvey 2007). The links within the food web will change over time. Small fishes eat food different from the adults; hence their position in the food web may change accordingly with growth (Pauly et al. 2001, 2002). Fishes undertake vertical and horizontal migrations in search of favorable and abundant food materials. Fishes are critical components of marine food webs as they occupy intermediate trophic levels and also act as top predators (Drazen & Sutton 2016). Apex predators play an important role in many communities by controlling prey populations, exerting selective pressure, and influencing general community dynamics (Drazen et al. 2001). Trophic relationships, in terms of predator-prey interactions, significantly influence community structure and population dynamics (Abollo et al.

1998). Even though 92% of world Oceans occur below 200 m, we have little understanding on deep-sea food webs and exchange of biomass in deep-sea ecosystems (Feagans-Bartow & Sutton 2014). In deep-sea, food is limited due to the absence of photosynthesis. Food webs associated with deep-sea habitat are assumed to be dependent on a slow organic matter flux from the surface or occasional fall of large carcass (Rowe et al. 2008). Deep-sea fauna are maintained mostly by predators with broadly overlapping food resources (Dayton & Hessler 1972; Grebmeier et al. 1989). Most studies on food and feeding habits in fishes are based on stomach content analysis which provides important insights into the fish diet, feeding patterns and feeding intensity. Quantitative assessment of food habits is an important aspect of fisheries management. Several studies on food and feeding of deep-sea fishes have been carried out globally (McLellan 1977; Goldschmidt et al. 1996; Bulman & Koslow 1992; Modica et al. 2014; Gerringer 2017) and few studies are also reported from India (Philip 1994; Venu & Kurup 2002, 2006; Thankappan et al. 2007; Deepu et al. 2007; Karuppasamy 2008; Venu 2009; Hashim 2012; Viji et al. 2017; Vinu 2017; Meera et al. 2018). Works regarding food and feeding of deep-sea Anguilliformes is limited (Mead & Earle 1970; Martin 1984; Merrett & Domanski 1985; Anderson 2005; Feagans 2008; Geidner 2008; Feagans-Bartow & Sutton, 2014). Information on food and feeding of deep-sea Anguilliformes from Indian waters are limited to two species (*Gavialiceps taeniola* and *Bathyuroconger vicinus*) (Thankappan et al. 2007; Hashim 2012; Viji et al. 2017; Vinu 2017). Present study provides baseline information on food and feeding habits of few selected species of deep-sea Anguilliformes from Indian waters which may provide insights to their ecological role and position in the food web dynamics of deep-sea ecosystems.

5.4.2 Materials & Methodology

Samples for the present study were collected using demersal trawls (HSDT, EXPO & HOT) except for one species (*Nemichthys scolopaceus*) which was collected in Isaacs-Kid Midwater Trawl (IKMT) during the exploratory deep-sea fishery surveys of FORV *Sagar Sampada* of Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, Government of India along the Indian waters. Gut content analysis were done for 10 species (*B. vicinus, C. raniceps, X. trucidans, N. scolopaceus*, *Ariosoma sp. A, Ophichthus sp. A, G. reticularis, Gavialiceps sp. A, S. vorax* & *S. oregoni*) of deep-sea eels collected from depths ranging from 200 to 1400 m. Gut content analysis was performed by Index of Relative Importance (IRI) following Pinkas et al. (1971). Fullness of the stomach was also checked to study the feeding intensity by visual examination. (Details of IRI and feeding intensity were given in chapter 2).

5.4.3 Results

Prey items observed from the gut of deep-sea eels composed of fishes, shrimps, crabs, cephalopods, euphausiids, polychaetes, stomatopods and semidigested matter. The presence of particular food materials and their proportions varies among the species **(**Table 5.4, Figure 5.4 & 5.5). The percentage of stomach fullness (Table 5.5, Figure 5.6) also varies among the species and within the species. Feeding intensity revealed that higher proportion of fullness was observed in *Ariosoma* sp. A & *S. vorax* (13%) and least in *B. vicinus* (5%).Three quarter fullness is high in

Ariosoma sp. A (43%) and least in *Gavialiceps* sp. A (10%). Higher proportion of half fullness was observed in *Gavialiceps* sp. A (30%) and least in *B. vicinus* & *X. trucidans* (10%). One quareter fullness is high in *N. scolopaceus* (20%) and least in *Gavialiceps* sp. A (2%).

Bathyuroconger vicinus: Among the 100 specimens analyzed, gut of 70 individuals was empty. The diet mainly included crabs (37%) [*Charybdis* sp.] fishes (21%) [Tuna flesh, *Alepocephalus* sp., *Diaphus* sp., *Benthosema* sp. and unidentified fishes] shrimps (17%) [*Aristaeopsis* sp., *Heterocarpus* sp., unidentified shrimps], cephalopods (15%) [squid, octopus] and semidigested matter (10%) in % of IRI. The percentage of fullness of the stomach obtained was fully filled (5%) half filled (10%), one quarter filled (15%) and empty (70%).

Coloconger raniceps: The diet of 40 specimens was analyzed. Among them, stomachs of 26 individuals was empty. Prey mainly constituted semidigested matter (90%), shrimps (8%) [*Plesionika* sp.] and fishes (2%) [unidentified fishes] .Fullness of stomach obtained was half filled (20%), one quarter filled (15%) and empty (65%).

Xenomystax trucidans**:** The diet of 40 specimens was analyzed. Among them, gut of 24 individuals was empty. Prey mainly included fishes (40%) [*Diaphus* sp., *Nemichthys* sp., unidentified fishes, mesopelagic fishes] shrimps (35%) [*Plesionika* sp., *Metapenaeopsis* sp., unidentified shrimps] and semi digested matter (25%). Fullness of stomach obtained was half filled (10%) one quarter filled (30%) and empty (60%).

Gavialiceps sp. A: Among the 100 specimens analyzed, gut of 50 individuals was empty. Prey items mainly consisted of fishes (31%) [*Diaphus* sp., leptocephalus larvae, mesopelagic fishes, *Nemichthys* sp.,], shrimps (27%) [*Metanephropsis* sp., *Pleseonika* sp., unidentified shrimps], semidigested matter (22%) and cephalopods (20%) [squid] in % of IRI. Percentage of fullness of stomach obtained was fully filled (8%), three quarter filled (10%) half filled (30%), one quarter filled (2%) and empty (50%).

***Ariosom*a sp. A**: The diet of 46 specimens was analyzed. Among them, gut of 20 individuals (44%) was empty. Prey consisted of shrimps (65%) [*Plesionika* sp.] and fishes (35%) [*Chloropthalmus* sp., unidentified fishes] in % of IRI. Fullness of stomach obtained was fully filled (13%), three quarter filled (43%) and empty (44%).

Nemichthys scolopaceus: The diet of 12 specimens was analyzed. Among them gut of 8 individuals was empty. Prey consisted of shrimps (50%) [*Acetes* sp., unidentified shrimp], euphausiids (40%) and semidigested matter (10%) in % of IRI. Percentage of fullness of stomach obtained was half filled (13%), one quarter filled (20%) and empty (67%).

***Ophichthus* sp. A:** The diet of 36 specimens was analyzed. Among them, gut of 20 individuals was empty. Prey consisted of shrimps (46%) [caridians, unidentified coral shrimps], crabs (21%) [*Munida sp.*, unidentified coral crabs], stomatopods (6%) fishes (13%) [flat fishes, unidentified fishes], semidigested matter (10%) and polychaetes (4%) in % of IRI. Fullness of stomach obtained was fully filled (8%), half filled (19%), one quarter filled (17%) and empty (56%).

Gymnothorax reticularis: The diet of 30 specimens was analyzed. Among them, gut of 15 individuals was empty. Prey mainly included fishes (45%) [*Chloropthalmus* sp., *Platycephalus* sp., *Saurida* sp., unidentified species], crab (35%) [*Portunus* sp.], semidigested matter (5%) and cephalopods (15%) [octopus, squid] in % of IRI. Fullness of stomach obtained was; fully filled (7%), three quarter filled (30%), half filled (13%) and empty (50%).

Sauromuraenesox vorax: The diet of 47 specimens was analyzed. Among them, gut of 21 individuals was empty. Prey mainly comprised of fish (64%) [*Diaphus* sp., *Benthosema* sp., Stomiforms] shrimp (20%) [*Plesionika* sp.], cephalopods (10%) [squid] and semidigested matter (6%) in % IRI. Fullness of stomach obtained was fully filled (13%), three quarter filled (20%), half filled (12%), one quarter (10%) and empty (45%).

Synaphobranchus oregoni: The diet of 7 specimens was analyzed. Among them, gut of 4 individuals was empty. Prey mainly comprised of fishes (50%) [*Bathypterois* sp., unidentified fish fleshes], shrimp (30%) [*Aristeopsis* sp., unidentified shrimp.], cephalopods (2%) squid, semidigested matter (18%) in % IRI. Fullness of stomach obtained was three quarter filled (28%), half filled (15%) and empty (57%).

Table 5.4: Percentage IRI of prey groups of deep-sea Anguilliform species

Species	No. of observations	Total length (mm)	Dietary contents observed	% of IRI
Bathyuroconger vicinus	30	465-900	**Crabs**	**37**
			Charybdis sp.	37
			Fishes	**21**
			Tuna flesh	3
			Alepocephalus sp.	3
			Diaphus sp.	3
			Benthosema sp.	4
			Unidentified fishes	8
			Shrimps	**17**
			Aristaeopsis sp.	4
			Heterocarpus sp.	7
			Unidentified shrimps	6
			Cephalopods	**15**
			Squid	9
			Octopus	6
			Semidigested matter	**10**
Coloconger raniceps	14	294-426	**Fishes**	**2**
			Unidentified fishes	2
			Shrimps	**8**
			Plesionika sp.	8
			Semidigested matter	**90**
Xenomystax trucidans	16	500-725	**Fishes**	**40**
			Diaphus sp.	2
			Nemichthys sp.	5
			Unidentified fishes	25
			Mesopelagic fishes	8
			Shrimps	**35**
			Plesionika sp.	6
			Metapenaeopsis sp.	9
			Unidentified shrimps	20
			Semidigested matter	**25**

Gavialiceps sp. A	50	572-880	**Fishes**	**31**
			Diaphus sp.	15
			Nemichthys sp.	4
			Leptocephalus larvae	4
			Mesopelagic fishes	8
			Shrimps	**27**
			Metapenaeopsis sp.	10
			Plesionika sp	12
			Unidentified shrimps	5
			Semidigested matter	**22**
			Cephalopods	**20**
			Squid	20
Ariosoma sp. A	26	212-430	**Shrimps**	**65**
			Pleseonika sp.	65
			Fishes	**35**
			Chloropthalmus sp.	22
			Unidentified fishes	13
Nemichthys scolopaceus	4	350-374	**Shrimps**	**50**
			Acetes sp.	35
			Unidentified shrimps	15
			Euphausiids	**40**
			semidigested matter	**10**
Ophichthus sp. A	16	300-450	**Shrimps**	**46**
			Carideans	26
			Unidentified coral shrimps	20
			Crabs	**21**
			Munida sp.	9
			Unidentified coral crabs	12
			Stomatopods	**6**
			Fishes	**13**
			Flat fishes	7
			Unidentified fishes	6
			Semidigested matter	**10**
			Polychaetes	**4**

Gymnothorax reticularis	15	312-420	**Fishes**	**45**
			Chloropthalmus sp.	13
			Platycephalus sp.	11
			Saurida sp.	12
			Unidentified fishes	9
			Crabs	**35**
			Portunus sp.	35
			Semidigested matter	**5**
			Cephalopods	**15**
			Octopus	6
			Squid	9
Sauromuraenesox vorax	26	322-504	**Fishes**	**64**
			Diaphus sp.	24
			Benthosema sp.	21
			Bregmaceros sp.	4
			Other mesopelagic fishes	15
			Shrimps	**20**
			Plesionika sp.	20
			Cephalopods	**10**
			Squid	10
			Semidigested matter	**6**
Synaphobranchus oregoni	4	542-628	**Fishes**	**50**
			Bathypterois sp.	10
			Unidentified fish fleshes	40
			Shrimps	**30**
			Aristeopsis sp.	19
			Unidentified shrimps	11
			Cephalopods	**20**
			Squid	2
			Semidigested matter	**18**

Figure 5.4: Gut contents of deep-sea eels

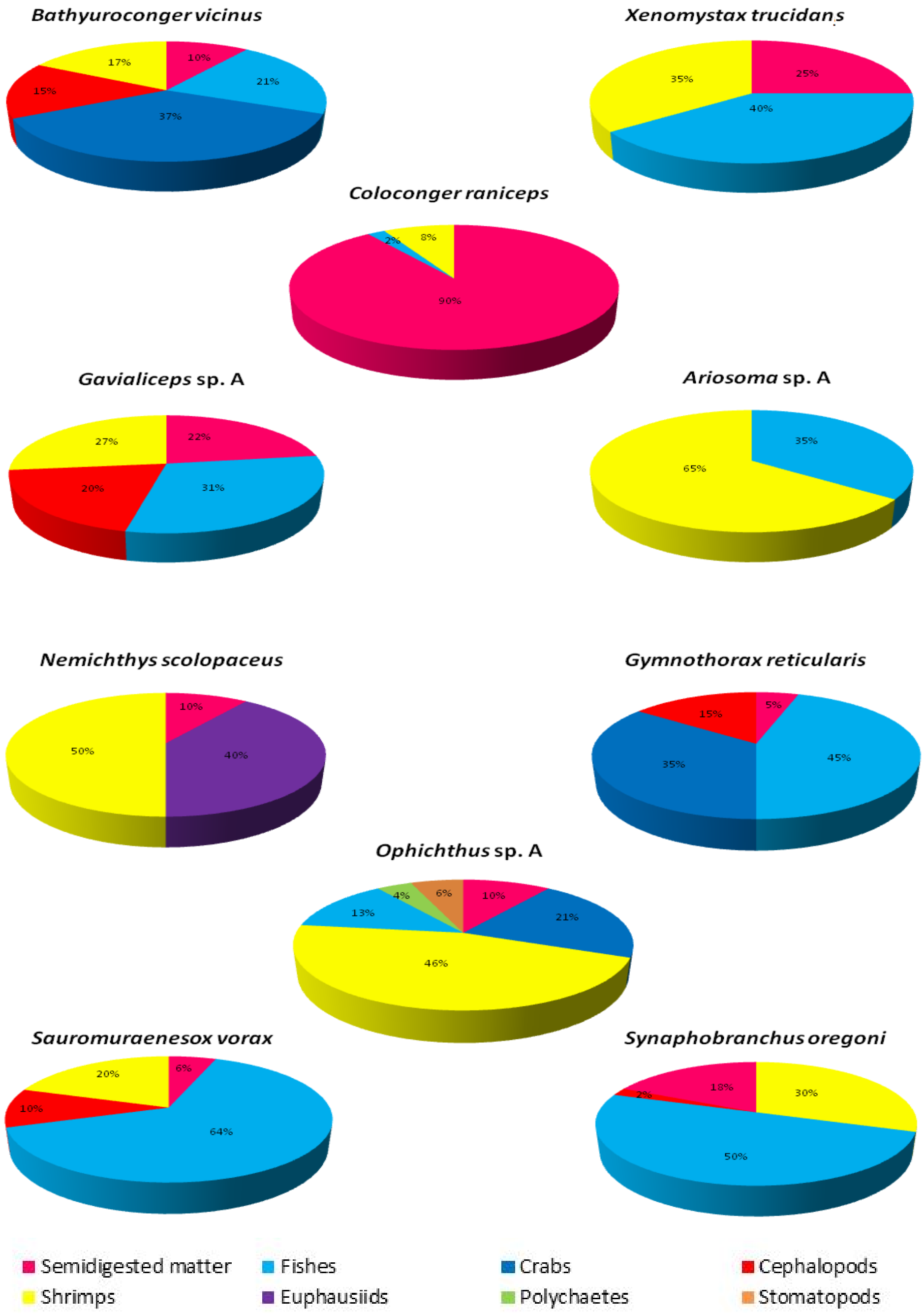

Figure 5.5: Percentage of IRI of prey groups of deep-sea Anguilliform species (fishes with empty stomach excluded).

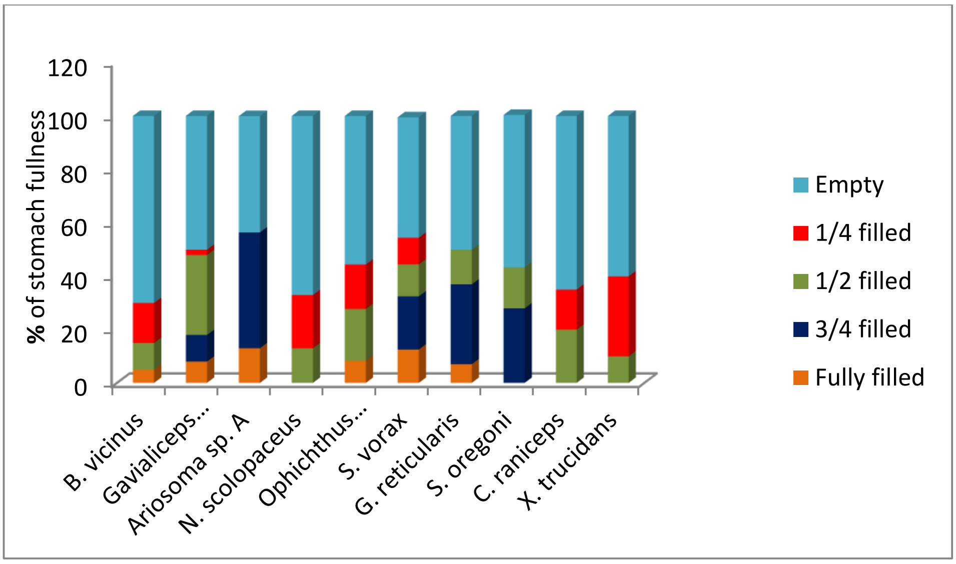

Figure 5.6: Percentage of stomach fullness of deep-sea Anguilliformes

Table 5.5: Percentage of stomach fullness of deep-sea Anguilliformes

Species	**Fully filled**	**3/4 filled**	**1/2 filled**	**1/4 filled**	**Empty**
Bathyuroconger vicinus	5		10	15	70
Gavialiceps sp. A	8	10	30	2	50
Ariosoma sp. A	13	44			43
Nemichthys scolopaceus			13	20	67
Ophichthus sp. A	8		19	17	56
Sauromuraenesox vorax	13	20	12	10	45
Gymnothorax reticularis	7	30	13		50
Synaphobranchus oregoni		28	15		57
Coloconger raniceps			20	15	65
Xenomystax trucidans			10	30	60

5.4.4 Discussion

Diet of 10 species of deep-sea Anguilliformes belonging to 10 genera and 7 families were analyzed. The study revealed that all species of deep sea eels are predatory and carnivorous and that the diet comprised of fishes, shrimps, stomatopods, crabs, cephalopods, euphausiids, polychaetes and semidigested matter. Among them fishes and shrimps form the major food items. Majority of the eels analyzed were having empty stomach. Higher proportion of empty stomach was observed in *B. vicinus* and *S. oregoni* ranging from (62–70%) and least was observed in *Ariosoma* sp. A and *S. vorax* (44–45%). The frequent occurrence of empty stomach may be attributed to faster digestion due to the presence of strong gastric enzymes in carnivorous fishes (Qasim 1972). Earlier studies also reported the frequent occurrence of empty stomachs in deep-sea eels (Thankappan et al. 2007; Hashim 2012; Vinu 2017; Viji et al. 2017).

Feeding intensity shows that higher proportion of fullness was observed in *Ariosoma* sp. A & *S. vorax* and least in *B. vicinus*. Three quarter fullness is high and low in *Ariosoma* sp. A and *Gavialiceps* sp. A respectively. Higher and lower proportion of half fullness was observed in *Gavialiceps* sp. A and *B. vicinus* & *X. trucidance* respectively. One quareter fullness is high in *N. scolopaceus* and least in *Gavialiceps* sp. A. The diet and other morphological characters (sharp fang like teeth and well developed sensory pores) of *B. vicinus* indicates their predatory and carnivorous behavior. The observation of large Tuna flesh in their diet indicates that in part they adopt scavenging mode of feeding. Similar mode of feeding was observed in *S. oregoni* during present study. Their diet (observation of large fish flesh in gut) and elongated vomerine teeth are indicative of their predatory and scavenging behavior. The present report of *S. oregoni* diet and feeding behavior is consistent with previous reports on diet of *Synaphobranchus* sp. involving fishes, cephalopods, crustaceans. Frequent carrions reveals their demersal piscivorus and scavenging life style (Merrett & Domanski 1985; Ruxton & Houston 2004; Bailey et al. 2005, 2007; Trenkel et al. 2004; Anderson 2005; King et al. 2006; Jones & Breen 2014; Drazen & Sutton 2016). Scavenging fishes play an important role in recycling the food that falls to deep-sea ecosystems. The diet of *Gavialiceps* sp. A and *S. vorax* shows that both are active feeders on mesopelagic fishes. Their elongated and numerous sharp vomerine teeth and diets show their predaceous and carnivorous nature. Thankappan et al. (2007) & Hashim (2012) have reported leptocephalus larvae, shrimps and *Nemichthys* sp. from diet of another *congener Gavialiceps taeniola* with the absence of myctophids. In *Gavialiceps* sp. A diet involves mesopelagic fishes such as *Diaphus* sp. and *Stomiformes*. which shows their affinity towards mesopelagic fishes. *Nemichthys scolopaceus* is a mesopelagic eel with extremely elongate and slender body, their diet clearly indicating their preference for shrimps and euphausiids. The slender and nonocclusive shape of jaws in *N. scolopaceus* are specialized to catch decapod prey by means of antennal entrapment (Mead & Earle 1970). The occurrence of pelagic decapods and large euphausiids in their diet have been reported by various authors (Mead & Earle 1970; Nielsen & Smith 1978; Gartner 1981; Appelbaum 1982; Karmovskaya 1982; Hopkins et al. 1996; Bowman et al. 2000; Feagans 2008; Feagans-Bartow & Sutton 2014). The importance of

Nemichthys species in cycling significant portion of macrocrustacean biomass to higher trophic levels was reported by Feagans-Bartow & Sutton (2014).The diet of *Gymnothorax reticularis* revealed that they are predatory and carnivorous and prefer mainly fishes and crustaceans. The presence of fang like teeth, pharyngeal jaws and high olfactory sense of *Gymnothorax* species reported by various authors (Bardach et al. 1959; Randall 1969; Cheve & Randall 1971; Carr & Hixon 1995; Mehta & Wainwright 2007) supports their predatory and carnivorous mode of life. Diet of *Ophichthus* sp. A shows that they exclusively feed on benthic organisms such as coral shrimps, coral crabs, stomatopods and polychaetes. They have evolved many adaptations such as rigid body, membranes on eye, flaps on nostrils, pointed snout & tail and reduced or absence of fins for this benthic mode of life. The preference of benthic preys is consistent with previous study of its congeneric species *Ophichthus rufus* by Casadevall et al. (1994) who reports benthic species such as *Callionymus maculatus*, *Alpheus glaber*, *Glossanodon leioglossus* and *Processa mediterannia* from the diet. From the overall diet analysis of 10 species of deep-sea eels it can be concluded that all of them are predatory and carnivorous in nature having their own ecological roles in food-web of the deep-sea ecosystem.

5.5 Biomass

5.5.1 Introduction

Biomass is defined as the total weight of a group of living organisms or of some defined fraction of it in an area at a particular time. Global seafloor harbors a living biomass of about 110 Mt C of which half is in deep-sea above 3000 m depth (Wei et al. 2010). The biomass and abundance of deep-sea fauna declines with depth (Rowe et al. 1982; Levin et al. 2001; Rex & Etter 2010). This is a widely accepted pattern attributed due to the decreasing quality and quantity of sinking organic matters with increasing depth and distance from the productive coastal waters (Wei et al. 2010). Deep-sea is the largest but least productive part of the oceans although in very limited places fish biomass can be very high (Norse et al. 2012). Compared to other taxa there is no data available on the biomass and abundance of deep-sea eels especially from Indian waters. Information on abundance, biomass and trophic level of a species can reveal their role in a particular ecosystem. Present study on biomass of deep-sea eels will provide baseline information on standing stock which will help future research in deep-sea trophic level studies and ecosystem modeling.

5.5.2 Materials & Methodology

In the course of the present study a total of 93 random stations in the Indian EEZ at depths ranging from 200–1400 m were surveyed for deep-sea Anguilliformes. Biomass from each station was recorded and standardized to 1Km^2 area, using swept area method (detailed in chapter 2). Biomass of deep-sea Anguilliformes was compared with total fish biomass for various regions (AS, BoB & AN) and depth zones (UBZ & LBZ). Family wise biomass of deep-sea Anguilliformes was also estimated for various regions and depth zones.

5.5.3 Result

Regional wise biomass of total fish (Figure 5.7) shows that AS has higher biomass ranging between 20–21156 Kg/Km^2 with an avg. biomass of 3492.3 Kg/Km^2 followed by BoB ranging between 14–7874 Kg/Km^2 with an avg. biomass of 1135.93 Kg/Km^2 and AN ranging between 11–4521 Kg/Km^2 with an avg. biomass of 771.92 Kg/Km^2. However, the biomass in deep-sea Anguilliformes in BoB was higher (biomass ranging between 0–1341 Kg/Km^2 with an avg. biomass of 160.98 Kg/Km$^{2)}$ followed by AS (ranging between 0–570 Kg/Km^2 with an avg. biomass of 93.85 Kg/ Km^2) and AN ranging between 0–2375 Kg/Km^2 with an avg. biomass of 69.6 Kg/Km^2.

While considering the two depth zones, in the case of total fish biomass, the UBZ of AS has higher biomass ranging between 45–21156 Kg/Km^2 with an avg. biomass of 3661.13 Kg/Km^2 followed by LBZ of AS ranging between 20–19647 Kg/Km^2 with an avg. biomass of 3323. 46 Kg/Km^2, UBZ of BoB ranging between 14–7874 Kg/Km^2 with an avg. biomass of 2006.35 Kg/Km^2, UBZ of AN ranging between 11–4521 Kg/Km^2 with an avg. biomass of 1397 Kg/Km^2, LBZ of BoB ranging between 23–508 Kg/Km^2 with an avg. biomass of 265.5 Kg/Km^2 and LBZ of AN ranging between 47–246 Kg/Km^2 with an avg. biomass of 146.5 Kg/Km^2. As far as Anguilliformes biomass is concerned, the UBZ of BoB has higher biomass ranging between 0–1341 Kg/Km^2 with an avg. biomass of 299.45 Kg/Km^2 followed by LBZ of AS ranging between 0–570 Kg/Km^2 with an avg. biomass of 135.63 Kg/Km^2, UBZ of AN ranging between 0–2375 Kg/Km^2 with an avg. biomass of 133.70 Kg/Km^2, UBZ of AS ranging between 1–521 Kg/Km^2 with an avg. biomass of 52.06 Kg/Km^2, LBZ of BoB ranging between 1–44 Kg/Km^2 with an avg. biomass of 22.5 Kg/Km^2 and LBZ of AN ranging between 3–8 Kg/Km^2 with an avg. biomass of 5.50 Kg/Km^2.

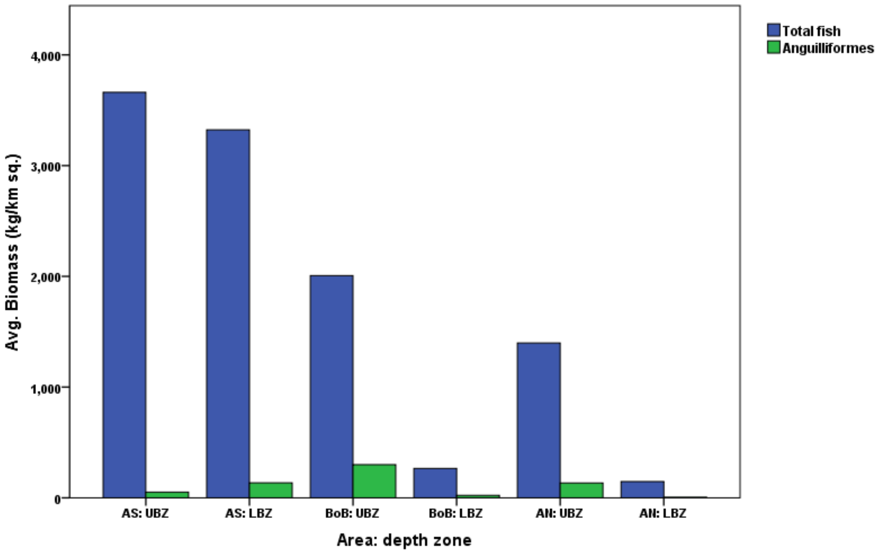

Figure 5.7: Depth wise average biomass of deep-sea Anguilliformes

Family wise contribution of deep-sea Anguilliformes (Figure 5.8) to the biomass were also analyzed which gives the information that in AS biomass is contributed by 10 families. Among them family Congridae has higher biomass (avg. biomass of 78.58 Kg/Km^2 [73.55%]) followed by Muraenesocidae (avg. biomass of 9.73 Kg/Km^2 [18.7%]), Muraenidae (avg. biomass of 2.63 Kg/Km^2 [5.05%]), Synaphobranchidae (avg. biomass of 2.42 Kg/Km^2 [1.85%]), Ophichthidae ((avg. biomass of 0.34 Kg/Km^2 [0.65%]), Nemichthyidae (avg. biomass of 0.13 Kg/Km^2 [0.1%]), Colocongridae, Derichthyidae, Serrivomeridae and Nettastomatidae has an avg. biomass of 0.02 Kg/Km^2 [0.01% each].

In the BoB, Anguuilliformes biomass is contributed by 4 families. Among them family Congridae (avg. biomass of 86.8 Kg/Km^2 [75.1%]) has higher biomass followed by Muraenesocidae (avg. biomass of 70.14 Kg/Km^2 [23.45%]), Colocongridae (avg. biomass of 3.84 Kg/Km^2 [1.3%]) and Nemichthyidae (avg. biomass of 0.24 Kg/Km^2 [0.15%]).

In AN, biomass is contributed by 7 families. Among them family Congridae (avg. biomass of 66.96 Kg/Km^2 [84.5%]) have higher biomass followed by Colocongridae (avg. biomass of 1.72 Kg/Km^2 [10.35%]), Synaphobranchidae (avg. biomass of 0.38 Kg/Km^2 [4.8%]), Ophichthidae (avg. biomass of 0.24 Kg/Km^2 [0.2%]), Nemichthyidae (avg. biomass of 0.14 Kg/Km^2 [0.1%]), Muraenesocidae (avg. biomass of 0.03 Kg/Km^2 [0.02%]) and Nettastomatidae (avg. biomass of 0.02 Kg/Km^2 [0.01%]).

Contribution of different families to the biomass of deep-sea Anguilliformes in two depth zones of various regions reveals that UBZ of AN and LBZ of AS the biomass is contributed by 7 families followed by UBZ of AS (5 families), UBZ of BoB (4 families), LBZ of AN (3 families) and LBZ of BoB (2 families). While comparing the contribution of families to the biomass within two depth zones of a region UBZ of AS have 5 families viz. Congridae (avg. biomass of 26.47 Kg/Km^2 [50.9%]), Muraenesocidae (avg. biomass of 19.45 Kg/Km^2 [37.4%]), Muraenidae (avg. biomass of 5.27 Kg/Km^2 [10.1%]), Ophichthidae (avg. biomass of 0.69 Kg/Km^2 [1.3%]) and Synaphobranchidae (avg. biomass of 0.13 Kg/Km^2 [0.2%]), whereas LBZ of AS have 7 families viz. Congridae ((avg. biomass of 130.69 Kg/Km^2 [96.2%]), Synaphobranchidae (avg. biomass of 4.70 Kg/Km^2 [3.5%]), Nemichthyidae (avg. biomass of

0.26 Kg/Km^2 [0.2%]), Colocongridae (avg. biomass of 0.04 Kg/Km^2 [0.05%]), Derichthyidae (avg. biomass of 0.04 Kg/Km^2 [0.04%]), Serrivomeridae (avg. biomass of 0.04 Kg/Km^2 [0.03%]) and Nettastomatidae (avg. biomass of 0.03 Kg/Km^2 [0.02%]).

UBZ of BoB have 4 families viz. Congridae (avg. biomass of 151 Kg/Km^2 [50.4%]), Muraenesocidae (avg. biomass of 140.28 Kg/Km^2 [46.9%]), Colocongridae (avg. biomass of 7.68 Kg/Km^2 [2.6%]) and Nemichthyidae (avg. biomass of 0.42 Kg/Km^2 [0.1%]). Whereas LBZ of BoB have 2 families viz. Congridae (avg. biomass of 22.6 Kg/Km^2 [99.8%]) and Nemichthyidae (avg. biomass of 0.05 Kg/Km^2 [0.2%]).

UBZ of AN have 7 families viz. Congridae (avg. biomass of 130.13 Kg/Km^2 [97.3%]), Colocongridae (avg. biomass of 2.44 Kg/Km^2 [1.8%]), Ophichthidae (avg. biomass of 0.48 Kg/Km^2 [0.4%]), Nemichthyidae (avg. biomass of 0.29 Kg/Km^2 [0.2%]), Synaphobranchidae (avg. biomass of 0.26 Kg/Km^2 [0.2%]), Muraenesocidae (avg. biomass of 0.07 Kg/Km^2 [0.06%]) and Nettastomatidae (avg. biomass of 0.04 Kg/Km^2 [0.04%]). Whereas LBZ of AN have 3 families viz. Congridae (avg. biomass of 3.8 Kg/Km^2 [71.7%]), Colocongridae (avg. biomass of 1 Kg/Km^2 [18.9%]) and Synaphobranchidae (avg. biomass of 0.5 Kg/Km^2 [9.4%]).

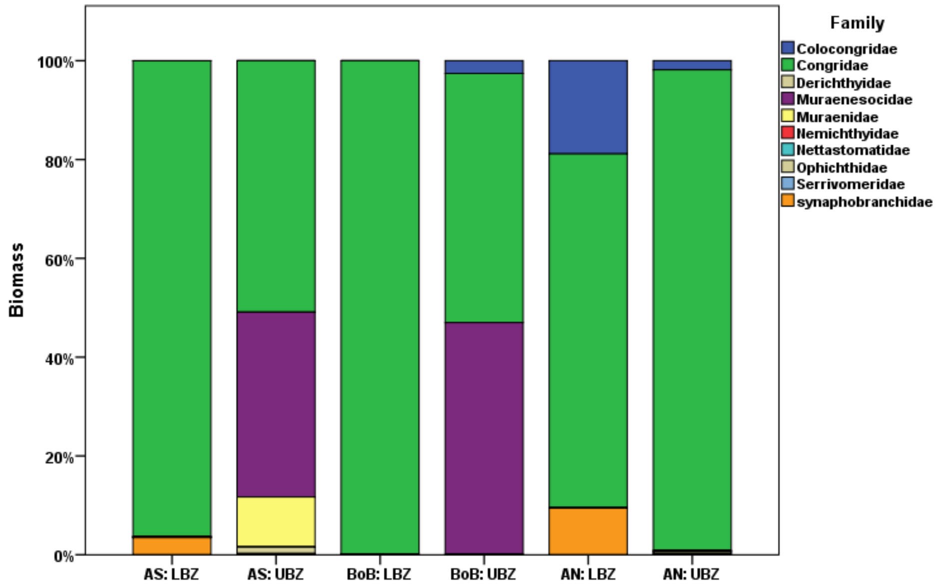

Figure 5.8: Family wise average biomass of deep-sea Anguilliformes

5.5.4 Discussion

Present study provides baseline information on regional as well as bathymetric trend in biomass of total fish and deep sea Anguilliformes along the Indian EEZ. The regional wise biomass of total fish shows that AS has higher biomass followed by BoB and AN where as the regional wise biomass of Anguilliformes reveals that BoB has higher biomass followed by AS and AN. The high biomass of total fish in AS is well supported by data of fish landings, ie landings along the west coast is 2.5 times more than east coast (Monolisha et al. 2017) as well as high productivity pattern reported in AS compared to BoB (Presanna kumar et al. 2002; Madhupratap et al. 2003).

Bathymetric trend in biomass of total fish shows that in AS, BoB & AN, UBZ has higher biomass compared to LBZ which agrees with the general global trend (Rowe et al. 1982; Levin et al. 2001; Rex & Etter 2010). However bathymetric trend in biomass of Anguilliformes shows that in AN & BoB, UBZ has higher biomass compared to LBZ and in AS, UBZ has low biomass compared to LBZ.

Family wise contribution of deep-sea Anguilliformes was also analyzed. In AS biomass is contributed by 10 familes, BoB 4 families and AN 7 families. The major species contributing to the biomass in AS were *B. vicinus* (2950.29 Kg/Km^2) followed by *M.bagio* (296.03 Kg/Km^2) and *Bathycongrus* sp. B (176.49 Ind./Km^2). In BoB, it is contributed by *S. vorax* (3086.42 Kg/Km^2) followed by *G. taeniola* (2674.71 Kg/Km^2) and *B. vicinus* (8104.81 Kg/Km^2). In AN, it is contributed by *Gavialiceps* sp. A (3337.37 Kg/Km^2) followed by *X. trucidans* (123.49 Kg/Km^2) and *C. raniceps* (66.41 Kg/Km^2).

Further family wise contribution to the biomass in two depth zones reveals that in AS: UBZ (5 families) and LBZ (7 families), similarly in BoB: UBZ (4 families) and LBZ (2 families) and AN: UBZ (7 families) and LBZ (3 families). In UBZ of AS, the major portion of biomass is contributed by *M.bagio* (4691.02) followed by *Ariosoma* sp. A (2854.51 Ind./Km^2) and *B. vicinus* (1069.09 Ind./Km^2) and in LBZ, *B. vicinus* (8104.81) followed by *Bathycongrus* sp. B (743.50 Ind./Km^2) and *S. oregoni* (245.12 Ind./Km^2). In UBZ of BoB, the major portion of biomass is contributed by *S. vorax* (29356.27 Ind./Km^2) followed by *G. taeniola* (22757.70 Ind./Km^2) and *B. vicinus* (2742.69 Ind./Km^2) and in LBZ, *G. taeniola* (233.24 Ind./Km^2) followed by *B. vicinus* (33.93 Ind./Km^2) and *A. infans* (11.31 Ind./Km^2). In UBZ of AN, the major portion of biomass is contributed by *Gavialiceps* sp. A (33044.65 Ind./Km^2) followed by *X. trucidans* (961.33 Ind./Km^2) and *C. raniceps* (587.29 Ind./Km^2) and in LBZ, *B. vicinus* (38.40 Ind./Km^2) followed by *Gavialiceps* sp. A (23.04 Ind./Km^2) and *C. raniceps* (15.36 Ind./Km^2). It was observed that in all regions irrespective of their depth zones, members of family Congridae provide major contribution to the biomass. The high abundance of leptocehali belonging to family Congridae reported in earlier studies of James & Prabhadevi (1990) wells supports our present observation.

⁂

SUMMARY AND CONCLUSIONS

- The results and interpretations reported through the present study are based on strong and reliable data generated over a period of 8 years (2010 to 2017) by participation in 21 deep-sea fishery cruises (each cruise of 25 days on an average) of *FORV. Sagar Sampada* and covering 93 sampling stations in the Indian EEZ encompassing the Arabian Sea (40 stations), the Bay of Bengal (25 stations) and the Andaman Sea (28 stations). The present coverage includes two depth strata's namely the Upper Bathyal Zone (200m to 800m depths) and the Lower Bathyal Zone (800 to 1500 m depths). As the deep-sea environment is near uniform throughout the year, we have not attempted seasonal coverage's in the course of present study.
- Sampling sufficiency for taxonomic purpose were ascertained separately for AS, BoB and AN through species accumulation plots, Chao-1, Jacknife-1 and Bootstrap of PRIMER software. These estimators indicate that our studies have gathered more than 72% of the maximum likely species that could probably be encountered in these seas through more intensified surveys.
- Order Anguilliformes comprise of 3 suborders; Anguilloidei, Congroidei and Muraenoidei. Suborder Anguilloidei has not been reported from deep-waters of Indian EEZ. Sub order Congroidei includes 9 families and all of them are reported from the deep-waters of Indian EEZ. Suborder Muraenoidei includes 3 families

and among them only the family Muraenidae has been reported from deep-waters of Indian EEZ.

- Present study has updated the taxonomic strength of Order Anguilliformes (true eels) in Indian EEZ to 10 Families, 31 Genera and 43 Species as against the previous records of 7 Families, 16 Genera and 19 Species. The updated list of deep-sea Anguilliformes in the Indian EEZ, however represent only 63% of the families, 20% of the genus and 4.4% of the Species of deep-sea Anguilliformes reported globally (16 Families, 156 Genera and 967 Species).
- Three families Derichthyidae, Ophichthidae and Muraenidae are reported for the first time from the deep-waters of Indian EEZ. However later two families have been reported earlier from the shallow waters of India.
- Seven genera reported through the present study (*Congrhynchus*, *Gnathophis*, *Japonoconger*, *Macrocephenchelys*, *Nessorhamphus*, *Facciolella* and *Nettastoma*) are all, new records of genera from Indian EEZ.
- Six genera (*Gymnothorax*, *Muraenesox*, *Neenchyles*, *Ophichthus*, *Pisodonophis* and *Uroconger*) reported earlier only from shallow waters of Indian EEZ, are reported for the first time from deep-waters of Indian EEZ, thereby extending their bathymetric range.
- The highlight of the present work is the discovery of 14 new Anguilliformes species. These 14 species, though not ascribed with

species name as yet, are definitely Species new to science, for reasons explained in Chapter -3. These include;

a) *Ariosoma* sp. A (Suborder-Congroidei, Family-Congridae, Subfamily- Bathymyrinae) recorded from the 200 – 214m depth strata of AS.

b) *Bathycongrus* sp. A (Suborder-Congroidei, Family-Congridae, Subfamily-Congrinae) recordrd from the 200-214 m depth strata of AS.

c) *Bathycongrus* sp. B (Suborder-Congroidei, Family-Congridae, Subfamily-Congrinae) recordrd from the 975-1338 m depth strata of AS.

d) *Gavialiceps* sp. A (Suborder-Congroidei, Family-Congridae, Subfamily-Congrinae) recordrd from the 323-812 m depth strata of AN.

e) *Gnathophis* sp. A (Suborder-Congroidei, Family-Congridae, Subfamily-Congrinae) recordrd from the 200 m depth strata of AS.

f) *Gnathophis* sp. B (Suborder-Congroidei, Family-Congridae, Subfamily-Congrinae) recordrd from the 363-441 m depth strata of AN.

g) *Japonoconger* sp. A (Suborder-Congroidei, Family-Congridae, Subfamily-Congrinae) recordrd from the 430 m depth strata of BoB.

h) *Macrocephenchelys* sp. A (Suborder-Congroidei, Family-Congridae, Subfamily-Congrinae) recordrd from the 323-392 m depth strata from AS & AN.

i) *Facciolella* sp. G (Suborder-Congroidei, Family-Nettastomatidae, Subfamily-Congrinae) recordrd from the 392 m depth strata from AN.

j) *Neenchelys* sp. A (Suborder-Congroidei, Family-Ophichthidae, Subfamily-Myrophinae) recordrd from the 544 m depth strata of AS.

k) *Ophichthus* sp. A (Suborder-Congroidei, Family-Ophichthidae, Subfamily-Ophichthinae) recordrd from the 314-363 m depth strata of AN.

l) *Ophichthus* sp. B (Suborder-Congroidei, Family-Ophichthidae, Subfamily-Ophichthinae) recordrd from the 644 m depth strata of BoB.

m) *Synaphobranchus* sp. A (Suborder-Congroidei, Family-Synaphobranchidae, Subfamily-Synaphobranchinae) recordrd from 635-1000 m depth strata of AS & BoB.

n) *Gymnothorax* sp. A (Suborder-Muraenoidei, Family-Muraenidae, Subfamily-Muraeninae) recordrd from 200 m depth strata of AS

- We also report 6 new records of species for the Indian EEZ. These new species records include; *Bathycongrus trimaculatus*, *Congrhynchus talabonoides*, *Nessorhamphus danae*, *Nettastoma solitarium*, *Ophichthus urolophus* and *Synaphobranchus oregoni*. There are

15 new records on Area wise distribution, that include 6 new records from AS, 2 new records from BoB and 7 new records of species from AN.

- Two species *Congromuraena mustuliceps* (Alcock, 1895) and *Nettenchelys taylyori* (Alcock, 1898) reported earlier from Indian waters, were not encountered in the present study. However, the former species have been reported recently from Oman waters (Smith et al. 2017) after a long gap of more than a century and the later species has not been collected after its original discovery.
- Otolith morphology of five species are described in this study, of which otoliths of 4 species are described for the first time in the World which can provide additional support to the taxonomic identification, especially for sorting out taxonomic ambiguities.
- Barcoding of 11 deep-sea eels under 11 genera and 5 families were carried out as a part of the present study. All the sequences developed through the present study are generated for the first time in the world. Present phylogenetic tree establishes the close relationship of *Gavialiceps* genus to the *Xenomystax* genus (of family Congridae) and provides molecular support to the recent placement of *Gavialiceps* from family Muraenesocidae to family Congridae. Our study also indicate that five species (*Gavialiceps* sp. A, *Japonoconger* sp. A, *Ophichthus* sp. A, *Neenchelys* sp. A and *Synaphobranchus* sp. A) are putative new species and that the two species (*Bathyuroconger vicinus* and *Nemichthys scolopaceus*) having circumglobal distribution though morphologically similar, are genetically different (cryptic species).

- Analysis of Species assemblage patterns reveals 3 distinct groupings representing the Arabian Sea, Bay of Bengal and Andaman Sea as well as two bathymetric assemblages representing the Upper bathyal zone (UBZ: 200–800 m) and Lower bathyal zone (800–1400 m).

- Cluster analysis on the Species collected, indicate to the occurrence of 3 distinct assemblages representing the Arabian Sea, Bay of Bengal and Andaman Sea as well as two bathymetric assemblages representing the Upper bathyal zone (UBZ: 200–800 m) and Lower bathyal zone (800–1400 m).

- 91% of the observed similarity in AS is explained by 3 species (*B. vicinus*, *Bathycongrus* sp. B, *N. scolopaceus*) with 23.5% average similarity. In BoB, 94.5% observed similarity is contributed by 4 species (*G. taeniola*, *S. vorax*, *B. vicinus*, *X. trucidans*) with 38.1% average similarity. In the case of AN, 92% of observed similarity is contributed by 5 species (*C. raniceps*, *Gavialiceps* sp. A, *Ophichthus* sp. A, *N. scolopaceus*, *B. vicinus*) with 27.7% average similarity.

- The observed dissimilarity between AS and BoB of 90.5% is explained by 17 species with 88.5% average dissimilarity. Similarly 90.9% of observed dissimilarity between AS and AN is contributed by 22 species with 92.1% average dissimilarity. The observed dissimilarity of 90.2% between BoB and AN is contributed by 13 species with 91.6% average dissimilarity.

- The similarity within the bathymetric zones and dissimilarity between the bathymetric zones reveals that in UBZ 92.8 % observed similarity is contributed by 7 species (*C. raniceps*, *Gavialiceps* sp. A, *N. scolopaceus*, *G. taeniola*, *S. vorax*, *B. vicinus*, *X. trucidans*) with 14.5 average similarities. In the LBZ 93.1 % observed similarity is contributed by 3 species (*N. scolopaceus*, *B. vicinus*, *Bathycongrus* sp. B) with 36.2% average similarity. The observed dissimilarity of 90.6 % between UBZ and LBZ is contributed by 21 species with 87.5% average dissimilarity.
- Region wise (AS, BoB & AN) distribution of Anguilliform families shows that all the 10 families reported from Indian EEZ are represented in the Arabian Sea, whereas Bay of Bengal represents only 5 families and the Andaman Sea represent only 7 families. Five families show wide distribution within Indian EEZ.
- Among the 29 genera reported under the present study from Indian waters, Arabian Sea represents 24 genera, Bay of Bengal 12 genera and Andaman Sea 14 genera. Seven genera are common for all the regions. Ten genera are common to Arabian Sea and Bay of Bengal, 11 genera are common between Arabian Sea and Andaman Sea and 7 genera are common to Bay of Bengal and Andaman Sea. Nine genera are restricted only to Arabian Sea, 2 genera are exclusive to Bay of Bengal and 2 genera exclusive to Andaman Sea.
- Of the 41 deep-sea eels reported under the present study, 28 species are found in the Arabian Sea, 16 species in the Andaman Sea and 12 species in the Bay of Bengal. Five species are widely distributed

and found in all the 3 regions. 8 species are common to both Arabian Sea and Bay of Bengal, 7 species are common to Arabian Sea and Andaman Sea and 5 species are common in Andaman Sea and Bay of Bengal. Fourteen species were restricted to Arabian Sea, 9 species to Andaman Sea and 4 species to Bay of Bengal.

- Analysis of the geographical distribution of Anguilliform species within the 3 regions reveals that in the Arabian Sea 7 species (*Arisoma* sp. A, *Bathycongrus* sp. A, *B. vicinus*, *A. infians*, *G. taeniola*, *N. scolopaceus, C. raniceps*) are widely distributed from 8°N to 12°N, 2 species (*Bathycongrus* sp.A, *S. oregoni*) distributed between 8°N to 10°N, 1 species (*Synaphobranchus* sp. A) between 8°N to 9°N, 2 species (*X. trucidans, D. bucephalus*) between 9°N to 12°N, I species (*G. reticularis*) was only found at 10°N and rest of the 15 species are represented from single collection and therefore their distributional range could not be ascertained. In Bay of Bengal 3 species (*C. raniceps, B. vicinus, S. vorax*) have wide distribution between 11° N to 19°N, 1 species (*G. taeniola*) distributed between 11°N to 17°N, 2 species (*X. trucidans, N. scolopaceus*) between 11°N to 12°N, 1 species (*Ariosoma gnanadossi*) between 12°N to 13°N and rest of the 5 species (*C. raniceps, B. vicinus, Gavialiceps* sp. A, *N. scolopaceus, Synaohobranchus* sp. A) were represented in single collection. In Andaman Sea 5 species are widely distributed between 7° N to 13°N, 1 species (*Ophichthus* sp. A) distributed between 7°N to 12°N, 2 species (*B. macrocercus, X. trucidans*) between 8°N to 13°N, 2 species (*Gnathophis* sp. B, *Macrocephenchelys sp*. A) between

11°N to 13°N, 1 species (C. talabanoids) between 12°N to 13°N and rest of the 5 species are represented by single collection.

- Species assemblage pattern in the two bathymetric zones (Upper bathyal Zone and Lower Bathyal Zone) are distinct. Among the 28 species reported from Arabian Sea, 16 species are restricted to the Upper Bathyal Zone, 8 species are exclusively found in the Lower Bathyal Zone and 4 species are common to both zones showing bathymetric extension towards deep-waters from shallow waters
- In the Bay of Bengal all 12 species reported are distributed in the Upper Bathyal Zone, with no species exclusive to Lower Bathyal Zone. However, 3 species are distributed both in the Upper & Lower Bathyal Zones.
- Among the 16 species reported from Andaman Sea, 11 species are distributed only in Upper Bathyal Zone, no species is distributed exclusively in the Lower Bathyal Zone, whereas 5 species are distributed both in the Upper and Lower Bathyal Zones. In all the regions upper bathyal Zone has more species abundance than the Lower Bathyal Zone.
- Analysis of Region-wise numerical abundance of Anguilliformes reveal that Bay of Bengal has higher abundance (avg. abundance 1361.3 Ind./Km^2) followed by Andaman Sea (avg. abundance 695.36 Ind./Km^2) and Arabian Sea (avg. abundance 510.78 Ind./Km^2).
- While considering the two depth zones; Upper Bathyal zone of all regions have higher abundance ranging between 8–26182 Ind./Km^2.

A decreasing trend in abundance with increasing depth is noticed which clearly agree with the global trend.

- In Arabian Sea the observed numerical abundance is contributed by 10 families; in Bay of Bengal by 5 families and in Andaman Sea by 7 families. The three major species contributing to the abundance in Arabian Sea were *Bathyuroconger vicinus*, *Ariosoma* sp. A and *Gymnothorax reticularis.* In Bay of Bengal abundance is contributed by *Gavialiceps taeniola*, *Sauromuraenesox vorax* and *B. vicinus.* and in Andaman Sea the 3 major species contributing to abundance were *Gavialiceps* sp. A, *Xenomystax trucidans* and *Coloconger raniceps*.
- Family wise contribution to the abundance in the bathyal zones revealed that in the Upper bathyal zone of Arabian Sea it is contributed by 6 families and in the Lower Bathyal Zone by 7 families. In the Bay of Bengal, numerical abundance of Upper Bathyal Zone is contributed by 5 families and in the Lower Bathyal Zone by 2 families. Similarly, the numerical abundance in Upper bathyal zone of Andamans is contributed by 7 families, and in the Lower Bathyal zone by 3 families.
- Numerical abundance in the Upper Bathyal Zone of Arabian Sea is contributed mainly by *Ariosoma* sp. A, followed by *G. reticularis* and *G. taeniola* whereas in the Lower Bathyal zone, it is by *B. vicinus,* followed by *Bathycongrus sp. B* and *Nemichthys scolopaceus*. In the Upper Bathyal Zone of Bay of Bengal major portion of abundance is contributed by *G. taeniola* followed by *S. vorax* and *B. vicinus* and

in Lower Bathyal zone, it is by *G. taeniola* followed by *B. vicinus* and *Avocettina infans*. Contributors to the numerical abundance in the Upper Bathyal Zone of Andaman Sea is mainly by *Gavialiceps* sp. A, followed by *X. trucidans* and *C. raniceps* and in Lower Bathyal zone, it is by *Gavialiceps* sp. A followed by *C. raniceps* and *B. vicinus*. It was observed that irrespective of depth zones, in all regions members of family Congridae contributes more to the abundance.

- The diversity indices (Shannon-Wiener diversity index (H'), Margalef richness index (d), Pielous evenness index (J') and Simpson dominance index (λ') were estimated for the 3 regions and for the two depth zones. Results show significant differences between regions and depth zones. Indices of species richness, evenness and diversity are high in Arabian Sea. In Bay of Bengal species richness is less compared to Arabian Sea and Andaman Sea while evenness and diversity are higher than Andaman Sea. In Andaman Sea species richness is higher but species diversity is less than Arabian Sea. Upper bathyal Zone of all regions show high species richness. Upper Bathyal Zone of Bay of Bengal and Arabian Sea as well as Lower Bathyal Zone of Andaman Sea shows high diversity. Among the Upper Bathyal Zones of all the 3 regions, Arabian Sea show highest species richness and diversity. Lowest species richness was observed in the Lower Bathyal Zone of Bay of Bengal.

- K dominance plot for the 3 regions reveals that Andaman sea has high species dominance whereas Bay of Bengal and Arabian Sea have less dominance but show high evenness. Among the 3 regions, Arabian Sea is observed to have low dominance. For the two depth zones, Lower Bathyal zone has high dominance and less evenness whereas Upper Bathyal zone show high evenness, but has low species dominance. A comparison of the two depth zones within the three regions indicate that Upper Bathyal Zone of Andaman Sea has higher dominance than Lower Bathyal Zone, while in Bay of Bengal and Andaman Sea Lower Bathyal Zone shows higher dominance.
- The region-wise biomass of total deep sea fish compared with biomass of deep-sea Anguilliformes shows that Arabian Sea has higher total fish biomass followed by Bay of Bengal and Andaman Sea. However, the biomass of deep–sea Anguilliformes in Bay of Bengal is higher followed by Arabian Sea and Andamans.
- Bathymetric trend in biomass of total fish compared with biomass of deep-sea Anguilliformes shows that Upper Bathyal Zones of all the three regions have higher total fish biomass compared to Lower Bathyal Zone. Whereas in deep-sea Anguilliformes the trend in biomass shows that in Andaman Sea and Bay of Bengal, Upper Bathyal Zone has higher biomass compared to Lower Bathyal Zone and in Arabian Sea it is vice versa.
- Family-wise contribution of deep-sea eels shows that the Arabian Sea biomass is contributed by 10 families, Bay of Bengal by 4

families and Andaman Sea by 7 families. Major species contributing to the biomass in Arabian Sea are *B. vicinus* followed by *M. bagio* and *Bathycongrus* sp. B, in Bay of Bengal it was *S. vorax* followed by *G. taeniola* and *B. vicinus* and in Andaman Sea it was *Gavialiceps* sp. A followed by *X. trucidans* and *C. raniceps.*

- Family-wise contribution to biomass in the 2 depth zones reveals that Upper Bathyal Zone of Arabian Sea biomass was contributed by 5 families and Lower bathyal zone by 7 families. Major contributors to biomass in Upper Bathyal Zone was *M. bagio* followed by *Ariosoma* sp. A and *B. vicinus* whereas in the Lower Bathyal zone it was *B. vicinus* followed by *Bathycongrus* sp. B and *S. oregoni.*
- Biomass in the Upper Bathyal Zone of Bay of Bengal was contributed by 4 families and in the Lower bathyal zone by 2 families. Species-wise, major portion of biomass in Upper bathyal zone was contributed by *S. vorax* followed by *G. taeniola* and *B. vicinus* whereas in Lower Bathyal Zone it was by *G. taeniola* followed by *B. vicinus* and *A. infans.*
- Upper Bathyal Zone biomass of Andaman Sea was contributed by 7 families and Lower Bathyal Zone by 3 families. Major portion of biomass in Upper bathyal zone was contributed by *Gavialiceps* sp. A followed by *X. trucidans* and *C. raniceps* whereas in Lower Bathyal Zone it was *B. vicinus* followed by *Gavialiceps sp.* A and *C. raniceps.*

- Length-weight relationships of 8 species of deep-sea eels were carried out. Among them LWRs of 5 species (*Ariosoma sp*. A, *Gavialiceps sp*. A, *Ophichthus sp*. A, *G. reticularis* and *S. vorax* are estimated for the first time globally. Considering the sexes combined, 3 species (*C.raniceps*, *Ariosoma* sp. A and *S. vorax*) show isometric growth pattern and 3 species (*B. vicinus*, *X. trucidans* and *G. reticularis*) show positive allometric growth whereas 2 species (*Gavialiceps* sp. A & *Ophichthus* sp. A) show negative allometric growth pattern. Considering the sexes separately, in males 1 species (*X. trucidans*) show isometric growth pattern, 2 species (*B. vicinus* & *S. vorax*) show positive allometric growth pattern and 5 species (*C. raniceps*, *Ariosoma sp. A*, *Ophichthus sp. A*, *Gavialiceps sp. A* and *G. reticularis*) show negative allometric growth pattern. In females 1 species (*S. vorax*) show isometric growth pattern, 4 species *(B. vicinus*, *X. trucidans*, *Ariosoma* sp. A, and *G. reticularis*) show positive allometric growth and 3 species (*C. raniceps*, *Gavialiceps* sp. A and *Ophichthus* sp. A) show negative allometric growth.
- Sex ratio of 8 species of deep-sea eels reveal that all species deviates from the general sex ratio theory (1:1) and that the ratio is skewed towards female. Minimum skewness in sex ratio was observed in *S. vorax* (1: 1.2) and maximum in *Ophichthus* sp. A (1: 2.3).
- Fecundity of 8 species of deep-sea eels is estimated for the first time globally, through the present study. Fecundity ranges from 8000–75000 eggs. Our results indicate that *Bathyuroconger vicinus* has

the highest fecundity (46866–75000 eggs) whereas the lowest fecundity is in *Ophichthus sp.* A (8000-12000 eggs). Ova diameter range from 0.6–1.5 mm with *C. raniceps* having larger ova and *Ariosoma* sp. A having the smallest ova among the species studied. Present study supports the hypothesis of decreasing fecundity over depth but could not find any difference in egg sizes with depth in Anguilliform species.

- Gut content of 10 species were analyzed which reveals that all species are predatory and carnivorous in nature and that their diet includes fishes, shrimps, stomatopods, crabs, cephalopods, euphausiids, polychaetes and semidigested matter. All Anguilliformes species studied have their own adaptations for feeding which *inter alia* help them to successfully occupy specific niches in the deep-sea ecosystem.

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