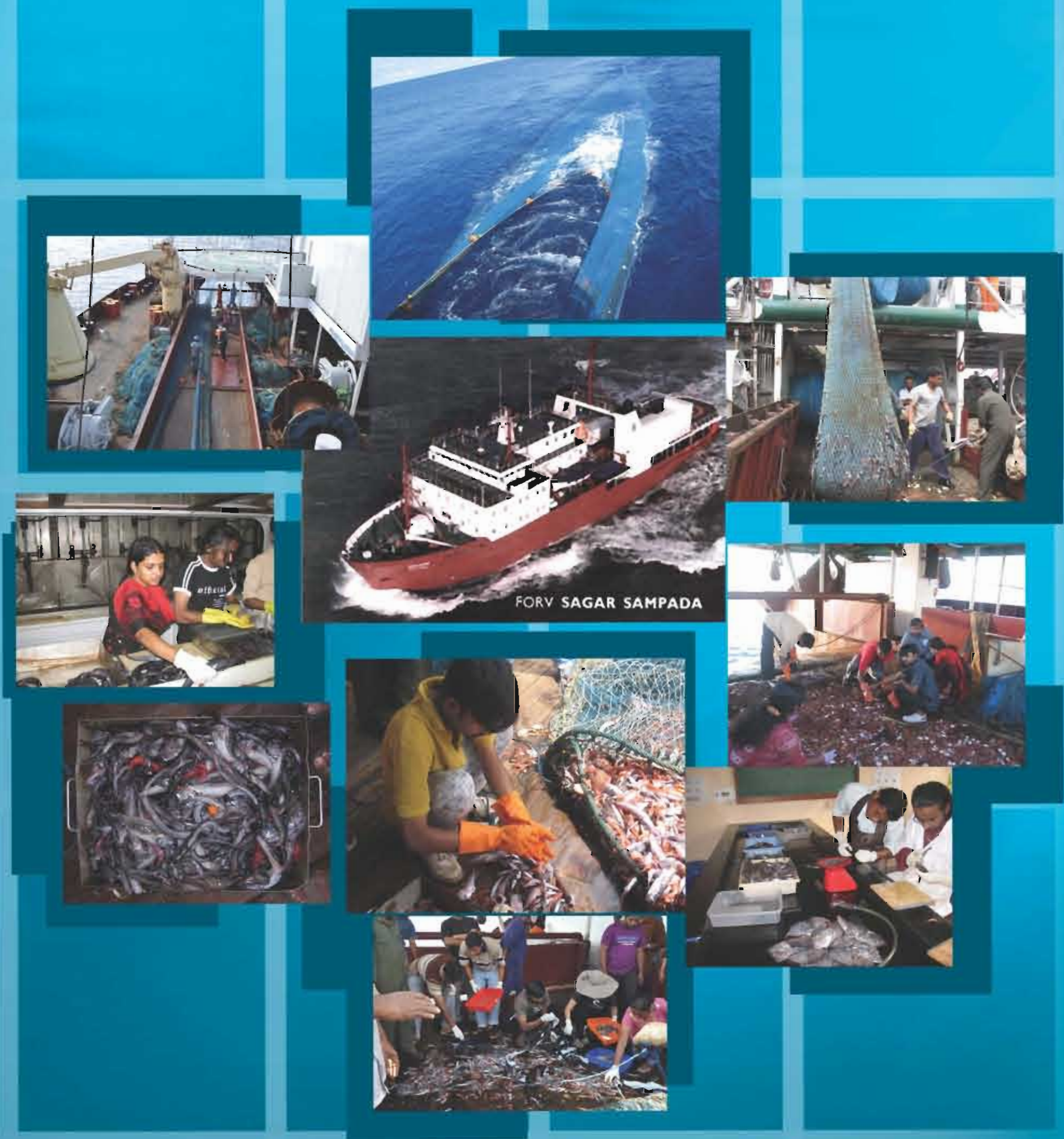

HASHIM. M

DISTRIBUTION, DIVERSITY AND BIOLOGY OF DEEP-SEA FISHES IN THE INDIAN EEZ

2012

DISTRIBUTION, DIVERSITY AND BIOLOGY OF DEEP-SEA FISHES IN THE INDIAN EEZ

Thesis submitted to the

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

in partial fulfilment of the requirement for

the degree of

DOCTOR OF PHILOSOPHY

Under

Faculty of Marine Sciences

HASHIM. M

(Reg. No. 3402)

केंद्रीय समुद्री मात्स्यिकी अनुसंधान संस्थान

Central Marine Fisheries Research Institute

(भारतीय कृषि अनुसंधान परिषद)

(Indian Council of Agricultural Research)

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Declaration

*I Hashim. M., hereby declare that the thesis entitled "**Distribution, diversity and biology of deep-sea fishes in the Indian EEZ**" is an authentic record of research work carried out by me under the supervision and guidance of Dr. N.G.K. Pillai, ICAR Emeritus Scientist,CMFRI, Kochi 682 018., in partial fulfilment of the requirements for the award of Ph.D. degree of Cochin University of Science and Technology in the Faculty of Marine Sciences and no part of this work has previously formed the award of any degree, associateship, fellowship or any other title or recognition.*

Kochi – 682 018 *Hashim M.*

Date:

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

Certificate

*This is to certify that the thesis entitled "**Distribution, diversity and biology of deep-sea fishes in the Indian EEZ**" is an authentic record of research work carried out by Mr. HASHIM M., Full-time Research Scholar of this Institute and registered student for Ph.D. degree in Faculty of Marine Sciences, CUSAT (Reg. No. 3402) under my guidance and supervision and no part thereof previously presented for the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.*

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

Kochi –682 018
Date:

Dedicated to my Parents...

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Hashim. M

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Chapter I

General Introduction

Ocean constitute the largest habitat on earth with continental shelves (0-200 m) covering approximately 5% of the entire surface, slopes (200-3000 m) covering 13%, abyssal depths 3000-6000 m covering 51% and hadal depth (>6000 m) covering 2%. However, the deep-sea is least productive part of the oceans, although in very limited places fish biomass supported is very high. This is caused normally by topographic features like sea mounts, mid-oceanic ridges and continental slopes which modify the physical and biological dynamics in ways that offer best food and feeding, breeding grounds etc. allowing fish biomass concentrations, and sometimes highly valuable fishery resources (Norse *et al.,* 2012).

While assessing marine fish biodiversity globally, two habitats identified where most new marine taxa will likely to be found are the deep-slopes and deep-reefs which are areas so far poorly sampled and studied (Eschmeyer *et al.,* 2010). All these facts make a study on deep-sea fishes valuable as it is likely to influence estimation of marine biodiversity as well as options for harvesting of valuable fishery resources by the concerned maritime nation.

Through several dedicated explorations in the Atlantic and Pacific oceans, the fishes inhabiting the deep-sea especially in the four zones such as mesopelagic (150-1000 m); bathypelagic (1000-3000 m); abyssopelagic (3000-6000 m); and hadal zone, below 6000 m depth, in the deep ocean trenches (FAO, 2005) have been mostly listed. However, the Indian Ocean is identified as a region where more work is needed. Some of the pioneering works on biodiversity and taxonomy of deep-sea fishes in this region has been done by Lt. Col. A. W. Alcock, Sir James Hornell and F. M. Gravely during the late 19th century and early 20th century.

Since the late 1970s deep-sea fishes like the Orange Roughy (*Hoplostethus atlanticus*), the oreos (*Pseudocyttus maculatus*, *Allocyttus niger* and *Neocyttus rhomboidalis*) and the alfonsino (*Beryx* spp.) were exploited from the Atlantic, Pacific and Indian Ocean. According to Bensch *et al.,* (2009), 285 vessels were active in high seas bottom fisheries worldwide in 2006 and the total catch was estimated as 2,50,000 tonnes valued at EUR 405 millions. In the Indian subcontinent, the status of deep-sea fisheries is different from that of other regions. Information on the deep-sea finfish resources, their biology and abundance which actually forms the baseline information on which a fishery can be developed is scanty.

Since 1984, the Fisheries and Oceanographic Research Vessel (FORV) *Sagar Sampada* owned by the Ministry of Earth Sciences (MoES), Govt. of India has been conducting exploratory fishery resource surveys in the Indian EEZ. From the results of these cruises, the occurrence of several deep-sea fishes has been listed but no comprehensive study on distribution and abundance has been yet made.

The exploratory fishing surveys by Fishery Survey of India (FSI), Central Marine Fisheries Research Institute (CMFRI) and Centre for Marine Living Resources & Ecology (CMLRE) have contributed significantly to the knowledge on availability of deep-sea fishes in India. Based on the exploratory surveys conducted during the last century, the harvestable potential of finfishes in Indian waters has been estimated as 7.0 tonnes km^{-2} in the inshore waters and only 0.7 tonne km^{-2} in the deep-sea and far sea (Vivekanandan, 2006).

Deep-sea fishes are generally considered to have high longevity, slow growth, late maturity, and low fecundity which means that these stocks can be rapidly depleted though fishing and recovery can be slow (Morato *et al.,* 2006). The deep-sea ecosystems have also been identified as Vulnerable Marine Ecosystems (VME) and the United Nations General Assembly resolutions in 2012 have been mostly related to VMEs. Considering the significance of deep-sea fishery resources, a targeted study was undertaken on deep-sea demersal fishes collected during the fishery oceanographic survey of FORV *Sagar Sampada* along the entire continental slope of Indian EEZ during the period 2006-2010. The objectives of the study were as given below:

Objectives

1. To study the distribution patterns of deep-sea fishes in the Indian EEZ comprising Arabian Sea, Bay of Bengal and Andaman Sea.
2. To study the distribution of deep-sea fishes in various depth ranges of the deep-sea realm of Indian EEZ.
3. To study the species composition in the different depth ranges and regions of Indian EEZ.
4. To assess the community structure of deep-sea fishes in the Indian EEZ.
5. To study the life history traits of selected deep-sea finfish species.
6. To make recommendations for the sustainable and economical exploitation of deep-sea fishery resources.

Chapter II

Review of Literature

Fishes constitute more than half of the living vertebrates recognised (Nelson, 2006). The number of valid fish species is nearly 31,000, and 500 new species being constantly added in every year. This increase in the number of fish species in the recent years has been attributed to the increasing resource surveys/expeditions in new areas and depths which were not accessible earlier, modern approaches to taxonomy and cataloguing of the resources (Eschmeyer *et al.,* 2010).

More studies have been conducted on deep-sea fishes in Atlantic and Pacific Oceans than Indian Ocean on aspects like diversity, taxonomy and biology. In the Indian Ocean most of these studies were restricted to the Arabian Gulf, Madagascar, Natal, Somalia, Mozambique in the western side and South and West of Australia (Atkinson, 1995; Clark, 1995, 1998; Haedrich *et al.*, 2001). Eschmeyer *et al.* (2010) assessed the existing knowledge database on marine fish biodiversity over the last 250 years and concluded that two habitat where most new marine taxa will likely to be found would be the deep-reef and deep-slopes, areas poorly sampled and studied so far.

One of the earliest deep water fisheries is in the north Atlantic developed in the late 1960's when former USSR trawlers began to fish round nose grenadier (*Coryphaenoides rupestris*) and Greenland halibut (*Reinhardtius hippoglossoides*) on the mid Atlantic ridge (Troyanovsky and Lisovsky, 1995). Extensive studies on the biology and ecology of deep water fishes were done by many researchers during eighties and nineties (Mauchline and Gordon, 1984, 1991;

Gordon and Duncan, 1985, 1987; Gordon, 1986; Gordon and Mauchline, 1990; Gordon and Bergstad, 1992; Merrett *et al.*, 1991; Merrett and Haedrich, 1997). The deep-sea megafaunal community, especially fish and crustaceans have been reported (Haedrich *et al.*, 1980; Haedrich and Merrett, 1988, 1990; Cartes, 1993; Koslow, 1993; Stefanescu *et al.*, 1993; Morales-Nin *et al.*, 2003). Troncoso *et al.,* 2006 studied the bathymetric distribution of deep-sea fish assemblages of the Flemish Cap while Rätz (1999) reported the structure and changes of demersal fish assemblages of Greenland.

Several recent studies such as Merrett and Haedrich (1997), Koslow *et al.,* (2000) and Norse *et al.,* (2012) discussed the issues related to deep-sea fisheries development and Moratto *et al.,* (2006) concluded that globally the increase in the mean depth of fishing has resulted in an increase in the landing of orange roughy. When the high seas fisheries began to increase their production, concern regarding the resilience capacity of the deep-sea fish stocks arose among several organizations such as International Union for Conservation of Nature. A typical example of the impact of overfishing among deep-sea fishes is reported declining size (1 kg in 1980s to 200g in 1990) of the Greenland halibut (*Reinhardtius hippoglosoides*) in the Atlantic (Cox, 2005).

Though fish catch increased exponentially during early decades of last century due to development in fishing technology, in the later decades the industry also suffered setbacks due to over exploitation. There has been a decline in global fish catches since late 1980s (Zeller and Pauly, 2005) at an approximate rate of 0.4 million tonnes per year. Prompted by the need to augment production, industrial fishing began to expand to the offshore region (Christensen *et al.,* 2003; Myers and Worm, 2003) and to the deeper region (Koslow *et al*., 2000).

Recent archeological studies have proved that even during the prehistoric period (early Holocene period) pelagic fishing in high seas involving complex maritime technology was prevalent (O'Connor, *et.al.,* 2011). They have clearly stated that the inhabitants of Jerimalai Shelter in East Timor had fished in the high seas about 42000 years ago, much before the modern fishing technology and fleets were developed.

History of Ichthyology -India

Among the Indian works on fishes, Kautilya's '*Arthashasthra*' (300 B.C); *Abhilashitarthachintamani*or *Manasollasa* by the Chalukya King Someshvardeva during 1126–1138 AD (Sadhale and Nene, 2005) were the earliest. Hamilton-Buchanan's (1822) account on the fishes of Ganges. Contributions made to the systematic ichthyology of Indian region by early taxonomists like McClelland (1839), Sykes (1839), Jerdon (1849) and Blyth (1858, 1860). Gunther (1864, 1868) '*Catalogue of the fishes*' are some of the important works. The monumental treatise *Fishes of India* by Day (1875-1878) included 1418 species found within the boundaries of India, Pakistan (including Afghanistan), Bangladesh, Myanmar and Sri Lanka. Jordan compiled *Genera of Fishes* (1917-1920) and Classification of fishes (1923) in order to bring the acceptance and application of generic names of fishes in accordance with the 'RULES' or 'CODE' laid down by the International Commission on Zoological Nomenclature, a judicial body set up by International Congress of Zoology.

The taxonomy of deep-sea fishes in India is indebted to the outstanding publication of *Lt. Col.* A. W. Alcock*, C.I.E., F.R.S.* on the samples collected during the voyage of Indian marine survey steamer, *HMS Investigator* and which were published between the years 1889-1905. The details of bathybial fishes of Arabian Sea and Laccadive Sea and Bay of Bengal were given by Alcock (1889a,b,c,d, 1890a,b,c, 1892a,b, 1894a,b,c, 1985a, 1987, 1898a, 1899a,b, 1900 and 1905). A detailed account of deep-sea collection and a catalogue of Indian deep-sea fishes made during 1892-93 were presented by Alcock (1896, 1899a). New species and genus of the family Ophidiidae were reported by Alcock (1895b and1898b). The results of fishes collected during deep-sea dredging were presented by Alcock (1891). Hornell (1916) compiled many fishing grounds for future exploitation during the exploratory cruises along the Indian and Ceylon coasts and in his account on the results of the systematic survey on deep-sea fishing grounds by *Lady Goschen,* Gravely (1929) gave detailed information on the various resources along the Indian coast during the period 1927-1928.

Throughout the history of ichthyology numerous classifications of fishes have been proposed. Recent one has been built on the studies of many previous taxonomists (Cuvier, Valenciennes, Gill, Boulenger, Gunther, Jordan and Regan). The major approaches to classification *viz.* cladistics, synthetic and numerical were by Nelson and Platnick (1981), and Wiley (1981). Misra (1947, 1952, 1953, 1962, 1969, 1976a&b) published a series of checklists and manuals for the identification of the fish fauna of Indian region and its adjacent countries.

The first authentic record of the deep-sea fishes from India was made with the help of fishes collected during the explorations made by

RIMS Investigator in the book *A Descriptive Catalogue of the Indian deep-sea fishes in the Indian museum* by Alcock in 1889a, *Investigator* had surveyed 711 stations in the Indian Ocean covering the range 5°-29°N; 46°-98° E during 1884-1914 and collected specimens up to a depth of 3652 m. *Valdivia* expedition (1898-1899) covered 12 stations in the Bay of Bengal in the geographical range 0°2'S - 6°N; 73°-93°E and sampled between the sounding depths of 296-2500 m. The John Murray expedition (1933 -1934) surveyed 212 stations in the Indian Ocean within the range 29° N-7°S; 32°-73°E in the Arabian Sea in the depth 27 - 4793m (Weitkamp and Sullivan, 1939). The *International Indian Ocean* Expedition (1959 to 1964) explored the Indian Ocean including adjacent seas the main objectives were the complete survey of the Indian Ocean, including descriptive physical, chemical, biological oceanography, marine geology, geophysics and meteorology. Tholasilingham *et al.* (1964) gave some insight to the bathypelagic fishes from the continental slope of southwest coast of India. Jones and Kumaran (1964, 1965) described many new records from the seas around India. Other major studies include those by Rao (1965), Silas and Prasad (1966), Kartha (1971), Silas and Rajagopalan (1974), Silas and Regunathan (1974), Silas and Selvaraj (1980), Philip *et al.,* 1984; Joseph, 1984; Oommen, 1985; John and Sudarsan, 1988; Sudarsan and Somavanshi, 1988; Sulochanan and John, 1988; Vijayakumaran and Naik, 1988 and Philip and Mathew, 1996. The bathypelagic fish, *Epinnula orientalis* was reported from the Konkan coast by Rao (1965). Jones (1965) reported *Dactyloptena* and *Lepidotrigla* from Madras coast. Prasad and Nair (1973) recorded high abundance of deep-sea fishes such as *Chlorophthalmus agassizi, Neoepinnula orientalis, Psenopsis cyanea, Cubiceps natalensis,* etc., in the upper continental slope (180 – 450 m depth zone) in the Indian EEZ. Silas and Rajagopalan (1974) reported the occurrence of *Trichiurus auriga* in demersal deep neritic waters and from the continental slope. Occurrence of *Ruvettus pretiosus* (Silas and Regunathan, 1974), *Lestidium blanci* (Kartha, 1971), *Neoharriotta pinnata* (Silas and Selvaraj, 1980) have also been reported. Joseph (1984) reported many important non-conventional and under-exploited marine fishery resources from Indian EEZ based on the results of fishery resource surveys during 1983-84.

Biological as well as ecological aspects and stock characteristics of big eye snappers (Priacanthidae) in the Indian seas were studied (Joseph and John, 1986; Sivaprakasam, 1986; Vijayakumaran and Philip, 1988; Sulochanan and John, 1988; Vijayakumaran and Nayak, 1988; Gopalakrishnan *et al.*, 1988). Most of the studies were mainly concentrated on the stock assessment and the pattern of abundance of these fishes from the Indian EEZ (John and Sudarsan, 1988). Bande *et al.* (1990) studied the distribution and abundance of Bull's eye (*Priacanthus* spp.) in the EEZ of India. Birader, (1988) estimates the stock density, biomass and maximum sustainable yield of *P. hamrur* off North west coast of India.

Till 1980, the trawling operations and exploration of the Indian EEZ were conducted by smaller vessels which can operate only in the coastal waters up to a depth of 50m. The few larger vessels of the Fishery Survey of India, Integrated Fisheries Project, Central Institute of Fisheries Nautical and Engineering Training and UNDP/FAO Pelagic Fisheries Project were also conducted exploratory surveys in the EEZ (James and Pillai, 1989). The Department of Ocean Development, (Government of India) acquired a 71.5m OAL modern sophisticated *FORV Sagar Sampada* in December 1984. The vessel which has the capacity to explore the fishery resources by trawling operations in the sea floor up to 1100 m depth was put to use since then by various organizations. Since then, the vessel is continuously exploring the Indian EEZ for newer resources as part of the Marine Living Resources Assessment (MLR) Programme. These studies have brought to light many little known deep-sea fishes from the Indian EEZ beyond 200 m depth. James and Pillai (1990) gave a detailed account on the fishes and crustaceans in the offshore and deep-sea areas of the Indian Exclusive Economic Zone based on observations made onboard *FORV Sagar Sampada* during the period 1985 to 1988.

The results have shown the availability of fishable concentrations of exploited resources such as threadfin bream, ribbon fish, lizard fish, barracuda, cat fish, Indian mackerel and deep-sea lobster beyond the presently exploited zone and also under-exploited deep water resources such as bull's eye, drift fish, scads and deep-sea prawns within the Indian EEZ. A check list of fishes of the Indian EEZ based on the pelagic and bottom trawl collections of *FORV Sagar Sampada* was compiled by Balachandran and Nizar (1990), included 87 families and 242 species. Nair and Reghu (1990) reported the distribution of *Saurida* spp. in the continental shelf and the upper continental slope from the EEZ of India. Menon (1990) recorded myctophids, gonostomatids, Bregmaceros, eel larvae and juveniles of many fishes from the deep scattering layer (DSL) of Indian EEZ. Sivakami (1990) reported the occurrence of unconventional forms like *Psenopsis* sp., *Trichiurus auriga, Chlorophthalmus agassizi, Neoepinnula orientalis* and *Cubiceps* spp. Panicker *et al.,* (1993) reported C*entrolophus* sp. and *Chlorophthalmus* spp. as dominant species in the depth zone 200 – 500 m in the 7°-17° N latitude, off west coast of India.

Philip (1994) studied the fishes of the family Priacanthidae from the Indian waters and reported five species. Length weight relationship of *Priacanthus hamrur* was studied by Kurup and Venu (2006). Menon *et al.,* (1996) reported the abundance of Priacanthids, Nemipterids and *Psenes indicus* from the depth beyond 200 m from the northeast region of Indian EEZ. While Khan *et al.* (1996) observed grounds with potentially rich unexploited deep-sea finfish resources from the southeastern Arabian Sea. The dominant groups included *Chlorophthalmus* sp.*, Cubiceps natalensis, Neoepinnula orientalis, Psenopsis cyanea, Chascanopsetta lugubris, Priacanthus hamrur* and *Chlorophthalmus bicornis*. Similar results were also reported by Sivakami *et al.* (1996,1998). According to Venu and Kurup (2002a) the major species constituting the deep-sea fishes were *Chlorophthalmus punctatus*, *Chlorophthalmus bicornis, Psenopsis cyanea, Neoepinnula orientalis, Hoplostethus mediterraneus, Psenes squamiceps, Nettastoma parviceps* and *Priacanthus hamrur* and observed that the most productive depth ranges reported to be 200-400 m. *Psenopsis cyanea* was found to dominant component of the deep-sea demersal catches during exploratory surveys of *FORV Sagar Sampada* (Jayaprakash *et al.*, 2006). Information on the distribution and life history traits of deep-sea fishes from the southwest coast of India are on *Psenopsis cyanea* (Venu and Kurup, 2002b)*, Chlorophthalmus bicornis* (Kurup *et al.*, 2005), *Hoplostethus mediterraneus* (Venu and Kurup, 2006a), *Neoepinnula orientalis* and *Psenes squamiceps* (Venu and Kurup, 2006b). A detailed depth wise study on the length weight relationships of deep-sea fishes collected from the southwest coast of Indian EEZ revealed that there exists a definite difference in the growth between the fishes inhabit in higher depths and those living in relatively shallow depths and those at greater depths (Thomas *et al.*, 2003; Kurup *et al.*, 2006). Sreedhar *et al.* (2007) reported domination of eels

(21.3%) followed by the shark, *Echinorhinus brucus* (13.3%) in the deep-sea fish catches along the southeast coast of India. Deepu *et al.* (2007) studied the catch and biology of *Alepocephalus bicolor* from the southwest coast of India. The distribution and biology of the deep-sea eel, *Gavialiceps taeniola* along the continental slope off Indian EEZ was studied by Divya *et al.* (2007). Hashim *et al.* (2007) reported 63 species from North Andaman waters and Hashim *et al.* (2009) reported 126 species belonging to 29 families from the Indian EEZ are based on the exploratory surveys conducted by *FORV SagarSampada.* Karuppasamy *et al.,* (2008) gave an account on the food of some deep-sea fishes collected from the eastern Arabian Sea.

The recent studies on deep-sea fish taxonomy from Indian EEZ include the documentation and redescription of *Glyptophidium oceanium* from the west coast (Kurup *et al.,* 2008), deep-sea eel *Bassozetus robustus* (Cubelio *et al.,* 2009a), *Dicrolene nigricaudis* (Cubelio *et al.,* 2009b), deep-sea sharks like *Hexanchus griseus, Deania profundorum, Etmopterus pusilllus* by Akhilesh *et al.* (2010). Description of a new shark *Mutstelus manglorensis* by Cubelio *et al.* (2011) and *Symphysanodon xanthopterygion* by Anderson and Bineesh (2011).

3.1. Study Area

The study area included continental slope of Arabian Sea, Bay of Bengal and Andaman waters of Indian EEZ. The samples were collected during the deep-sea trawling surveys onboard *FORV Sagar Sampada* during the Cruise No. 241, 250, 281 (Arabian Sea), Cruise No. 247 (Bay of Bengal) and Cruise No. 252 (Andaman waters). The survey period was during 2006 to 2010 along the continental slope (200-1070 m) of Indian EEZ. A total of 68 trawling stations were surveyed which include 51 stations along the Arabian Sea, 8 in Bay of Bengal and 9 in the Andaman waters (Table-3.1, Fig.3.1).

Fig. 3.1. Map showing total trawling stations surveyed along the Arabian Sea, Bay of Bengal and Andaman waters.

3.2. Trawling Operations

High Speed Demersal Trawl II (HSDT, 38m) and Expo- model Demersal Trawls (45.6m) were used for fishing in the above cruises in the depth from 200 to 1100 m. The ground was scanned using SIMRAD EK 60 echo-sounder to determine the suitability of the bottom for trawling. The scanning stations were fixed using navigational Admiralty charts. The latitude, longitude, speed, time, depth and the nature of the bottom were noted down. The speed of the vessel was kept normally around 3 to 5 knots. Bottom trawling operations were conducted during day time on even grounds ascertained with the help of scanning carried out during the previous night. The details of the fishing stations is given in Table- 3.1.

3.3. Distribution

The catch composition, species wise catch in kilogram and number at each fishing station were recorded and the specimens were taken to the laboratory for detailed identification. The fishes were identified up to species level with the help of keys (Goode and Bean, 1895; Alcock, 1899a; Fischer and Bianchi, 1984; Smith and Heemsta, 1986; www.*fishbase.org* and FAO species catalogues and field guides). The scheme of classification followed in this study was Nelson (2006) as given in the Catalogue of Fishes.

The entire study area was divided into three geographical sectors; Arabian Sea, Bay of Bengal and Andaman Sea and six depth zones *ie.,* <150-200 m, 201-400 m, 401-600 m, 601-800 m, 801-1000 m, >1000 m were made (Hashim *et al.,* 2009). The geographical distribution surfaces (Maps) were created through IDW (Inverse Distance Weighted) interpolation of the field stations point feature class with the fish count (Order wise) in the feature attribute table using *ArcGIS 9.3* Software.

3.4. Community structure:

PRIMER v6 software for windows was used for the analysis of community structure.

3.4.1. Diversity Indices:

(i) Shannon - Wiener index (H′)

Shannon - Wiener diversity index (H′) is defined as:

$$H' = -\sum_{i} P_i \log_e P_i$$

Which can be rewritten as,

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.

(ii) Margalef richness index (d)

Margalef richness index (d) were calculated using formula.

$$d = (S-1) / \log N$$

Where, S = total number of species and N = total number of individuals in the collection.

(iii) Pielou's evenness index (J′):

Pielou's evenness index (J′) were calculated using the formula

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\ln S}$$

Where, J' = evenness, H' = species diversity in bits of information per individual and S = total number of species

(iv) Simpson dominance index (λ):

Simpson dominance index (λ) can be explained using the equation

$$\lambda = \sum p_i^2$$

$$p_i = \frac{n_i}{N}$$

n_i = number of individuals of *i1*, *i2* etc. and N = total number of individuals.

(v) Taxonomic diversity index / Taxonomic distinctness index

Warwick and Clarke (1995) proposed two new biodiversity indices, capturing the structure not only of the distribution of abundances amongst species but also the taxonomic relatedness of the species in each sample. The first index is taxonomic diversity (Δ) and the second one is taxonomic distinctness (Δ*). The taxonomic distinctness can be divided based on presence/absence data into two types namely (i) average taxonomic distinctness (Δ+) and (ii) variation in taxonomic distinctness (Λ+). The Δ and Δ* were calculated using the following two equations:

$$\Delta = \frac{\sum\sum_{i<j} \omega_{ij}\, x_i x_j}{[N(N-1)/2]}$$

$$\Delta^* = \frac{\sum\sum_{i<j} \omega_{ij}\, x_i x_j}{\sum\sum_{i<i} x_i x_j}$$

(a) Average taxonomic distinctness index (Δ +)

Average taxonomic distinctness (delta+) was calculated using the following formula:

$$\Delta+ = \frac{[\sum\sum_{i<j} \omega_{ij}]}{[S\,(S-1)/2]}$$

Where, S is the number of species present, the double summation is over all parts *i and j* of these species such that $i< j$ and ω_{ij} is the 'distinctness weight' between species *i* and *j*.

(b) Variation in taxonomic distinctness index (λ +)

Variation in taxonomic distinctness (λ+) was calculated using the following formula:

$$\lambda+ = \frac{[\sum\sum_{I<j} (\omega\omega_{ij} - \Delta^{+})^2]}{[S\,(S-1)]}$$

(c) 95% histogram, 95% confidence funnel and 2 – dimensional plot

Average taxonomic distinctness index (Δ^+) and variation in taxonomic distinctness (λ^+) were studied graphically by the funnel method. Combined λ+ and Δ^+ were represented by ellipse plot.

(vi) *k*-Dominance plot

The species were ranked in terms of abundance. The ranked abundances calculated as percentages of the total abundances of all species were plotted against the relevant species rank.

3.4.2. Similarity Indices:

(i) Cluster analysis

Cluster analysis was done to find out the similarities between groups. The most commonly used clustering technique is the hierarchical agglomerative method. The results of this are represented by a tree diagram or dendrogram with the x- axis representing the full set of samples and the y-axis defining the similarity level at which the samples or groups are fused. Bray - Curtis coefficient (Bray and Curtis 1957) was used to produce the dendrogram. The coefficient was calculated by the following formula:

$$S_{jk} = 100 \left\{ 1 - \frac{\sum_{i=1}^{p} \left| y_{ij} - y_{ik} \right|}{\sum_{i=1}^{p} (y_{ij} + y_{ik})} \right\}$$

where, y_{ij} 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;

y_{ik} 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.

(ii) MDS (Non - metric Multi Dimensional Scaling)

This method was proposed by Shepard (1962) and Kruskal (1964) and this was used to find out the similarities (or dissimilarities) between each pair of entities to produce a 'map', which would ideally show the interrelationships of all.

The relative abundances or biomasses of different species were plotted as a curve, which retains more information about the distribution than a single index. True to this, the data collected were considered for dominance plot, geometric abundance class plot and species area plot.

3.5. Biology

3.5.1. Length-weight: Specimens were sorted by sex, length measured to the nearest 1 mm (total length, TL) and weighed to the nearest 0.1 g (weight, W). The relationship between the length and weight of a fish is expressed by the equation $W = aL^b$ ((Le Cren, 1951, Ricker 1973) where W is body weight (g), L is total length (cm), *a* and *b* are constants (Beverton and Holt 1957). A graph of log W against log L forms a straight line as per the following formula: $\log W = \log a + b \log L$. The parameters *a* and *b* of the length-weight relationships are estimated by the least-square method. (Sokal and Rohlf, 1981; Zar,1984), using log W as the dependent variable and log L as the independent variable. The degree of adjustment of the model studied was assessed by the correlation coefficient (r). Analysis of covariance was employed as followed by Snedecor & Cochran (1967) with a view to bring out the differences between regression coefficients of males and females.

3.5.2. Sex ratio: In each species male and females were separated based on the sexual dimorphism and the ratio was calculated as Male:Female (M:F). The deviation of the sex ratio from the hypothetical value was assessed using chi-square test (Birader, 1989)

3.5.3. Food and feeding: The feeding intensity was studied by analyzing the stomach fullness through visual examination and they were classified as Full, 3/4 Full, 1/2 Full, 1/4 Full and Trace. Relative measures of food item quantity were estimated the Index of Relative Importance (IRI) (Pinkas *et al.*, 1971) IRI = (N + W) O where N is percentage of a particular food in the Gut contents W is percentage of food weight and O is percentage of frequency of occurrence. Percentage composition of various food items were calculated for each species.

3.6. Strength Weakness Opportunity and Limitations (SWOL) Analysis

SWOL analysis is an informative tool for assessing the potential and status of any industry or any sector of production. It provides a complete picture of its Strengths (S), Weaknesses (W), Opportunities (O) and Limitations (L). However, the analysis of its strengths and weaknesses, which is essential, is possible only when the threats are taken into consideration while also identifying the opportunities available too. The analysis of the strengths, weaknesses, opportunities and limitations are very important to upgrade the sector and to flourish it, since it helps in problem identification, planning, decision making, appropriate technology implementation, precautionary measures for accelerating fish production at sustainable level.

The SWOL analysis was done to analyze the present status and help in prediction of the future potentials of fisheries sector of the region, which will ultimately help in enhancement of the production and give better suggestion on management regime. The analysis of the strengths, weaknesses, opportunities and limitations are very important to help in problem identification, planning, decision making, appropriate technology implementation, precautionary measures for the development of the deep-sea fisheries sector in the country.

The survey was conducted among different stakeholders in the Cochin, Munambam, Sakthikulangara and Tuticorin (single day only) fishing harbours (Table-3.2). The different stakeholders include multiday trawl fishermen, boat owners, traders, consumers and producers (value added products). The stakeholder’s answers on the commercial exploitation and utilization of deep-sea fishery resources were used for the SWOL analysis based on the primary data collected using a structured survey schedule (Annexure- I).

Table.3.1. Details of trawling stations in the Indian EEZ.

Cruise No.	Station	Area	Latitude °N	Longitude °E	Depth (m)
241	A1	AS	11°18′	74°09′	691
241	A2	AS	11°27′	74°87′	600
241	A3	AS	11°87′	74°04′	631
241	A4	AS	12°37′	74°17′	565
241	A5	AS	14°28′	73°15′	692
241	A6	AS	14°57′	73°08′	565
241	A7	AS	14°72′	73°00′	546
241	A8	AS	15°05′	72°67′	752
241	A9	AS	15°48′	72°08′	269
241	A10	AS	15°23′	72°73′	844
241	A11	AS	15°18′	72°82′	374
241	A12	AS	14°65′	73°02′	603
241	A13	AS	13°68′	73°27′	905
241	A14	AS	12°43′	74°12′	723
241	A15	AS	12°15′	74°18′	918
241	A16	AS	12°15′	74°15′	1071
241	A17	AS	10°78′	75°15′	810
241	A18	AS	10°63′	75°27′	687
241	A19	AS	10°27′	75°55′	778
241	A20	AS	09°37′	75°78′	287
241	A21	AS	09°42′	75°72′	333
241	A22	AS	09°04′	75°06′	597
241	A23	AS	10°53′	75°35′	438
241	A24	AS	10°06′	75°28′	706
241	A25	AS	11°37′	74°82′	168
241	A26	AS	11°77′	74°48′	238
241	A27	AS	12°65′	74°13′	229
241	A28	AS	12°82′	74°02′	260
241	A29	AS	13°78′	73°35′	239
241	A30	AS	13°08′	73°04′	177
241	A31	AS	14°88′	72°98′	269
241	A32	AS	12°07′	74°00′	862
241	A33	AS	09°97′	75°57′	301
250	A34	AS	09°35′	75°08′	282
250	A35	AS	09°28′	75°63′	524

250	A36	AS	10°55′	75°37′	265
250	A37	AS	10°57′	75°03′	649
250	A38	AS	11°07′	74°98′	670
250	A39	AS	11°23′	74°87′	666
250	A40	AS	11°33′	74°82′	256
250	A41	AS	12°08′	74°32′	328
250	A42	AS	12°07′	74°27′	735
250	A43	AS	12°05′	74°28′	729
250	A44	AS	12°01′	74°03′	331
250	A45	AS	12°47′	74°15′	415
250	A46	AS	12°42′	74°12′	740
281	A47	AS	08°21′	76°01′	995
281	A48	AS	10°06′	75°37′	400
281	A49	AS	14°15′	73°15′	214
281	A50	AS	20°28′	69°19′	275
281	A51	AS	20°25′	69°19′	310
247	B1	BoB	17°01′	83°42′	770
247	B2	BoB	11°01	80°33′	760
247	B3	BoB	10°95′	80°35′	637
247	B4	BoB	20°53′	88°47′	155
247	B5	BoB	20°38′	87°33′	50
247	B6	BoB	20°01′	87°17′	150
247	B7	BoB	19°38′	85°33′	58
247	B8	BoB	18°43′	84°77′	215
252	C1	AN	13°18′	93°25′	538
252	C2	AN	13°27′	93°28′	695
252	C3	AN	13°18′	93°13′	320
252	C4	AN	13°01′	93°18′	402
252	C5	AN	12°95′	93°12′	330
252	C6	AN	12°82′	93°07′	321
252	C7	AN	12°75′	93°15′	369
252	C8	AN	11°12′	92°35′	512
252	C9	AN	11°43′	92°15′	353

***AS- Arabian Sea, BoB-Bay of Bengal, AN- Andaman waters**

Table.3.2. Sampling distribution of the stakeholders in different fishing harbours.

Stakeholders	Cochin	Munambam	Sakthikulangara	Tuticorin*	Total
Fishermen	35	22	33	12	**102**
Boat owners	5	6	5	4	**20**
Traders	6	5	5	3	**19**
Consumers	30	26	25	18	**99**
Producers (VAP)	3	---	3	---	**6**
Total	**79**	**59**	**71**	**37**	**246**

***Single day trawl operations**

Chapter IV

Deep-sea fishes: Distribution and Community Structure

4.1. Introduction

Conservation and sustainable exploitation of the natural resources of the aquatic ecosystem is very important. Aquatic ecosystem covers 71% of the globe and fishes, one of the most exploited natural resources need special attention for the conservation of their biological diversity. Baseline information on the distribution and community structure of the fishes is a primary requisite for the formulation of any management strategy and implementation of the conservation policies. Deep-sea, due to its unapproachable nature impart a barrier for the recurrent investigations on faunal distribution pattern and community structure especially that of deep-sea fishes.

Deep-sea fishes are considered as one of the promising resources for the future, as coastal fishery alone cannot ensure the nutritional requirement of the population. Exploitation of deep sea resources has not yet acquired the necessary momentum in India due to the heavy investment the sector entails, lack of consumer acceptance and market channels and unknown fishing grounds. In terms of habitat diversity fishes live in almost every conceivable aquatic habitat. Biodiversity of deep-sea fishes of the world has always remained a challenge to eminent ichthyologists and taxonomists. Exploration and exploitation of deep-sea fishes beyond 200m in the Indian EEZ is a difficult task due to the technical limitations of creating a suitable fishing fleet. The remarkable diversity of deep-sea resources is not yet fully understood, only a few surveys conducted in Indian waters (Venu and Kurup, 2002a; Thomas *et al.,* 2003;

Jayaprakash *et al.* 2006; Sreedhar *et al.,* 2007; Sajeevan *et al.,* 2007 and Hashim *et al.,* 2007, 2009). The present study is the first authentic work on the community structure of deep-sea fishes in the Indian EEZ.

The study specifically aimed to assess the distribution pattern and community structure of deep-sea fishes around Indian continent. This chapter is discussing about the geographical and bathymetric distribution and community structure of the deep sea fishes along the Indian EEZ.

4.2. Results

4.2.1. Distribution

(i) Geographical Distribution

The geographical distribution was explained for 25 orders, with support of maps generated using the Arc GIS software. The maps are given as Fig. 4.1-4.25 for order. Distribution of species is listed in the Table.1.

Order: Myxiniformes

Distribution of the order Myxiniformes is plotted in figure 4.1 and listed in Table-1. Fish belonging to this order were found only in Bay of Bengal at 10°58′ N; 80°19′ E in a depth of 600 m and represented by a single family with a single species *Eptatretus hexatrema* (Plate- 1a)

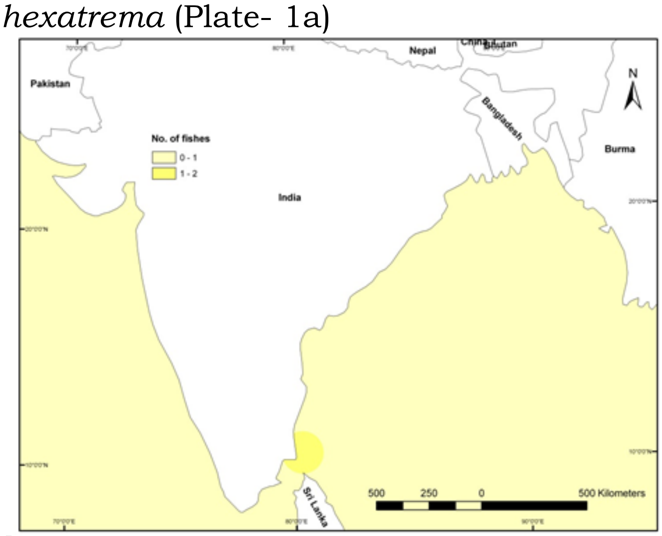


Fig.4.1. Map showing geographical distribution of the order Myxiniformes

Order: Chimaeriformes

Distribution of the order Chimaeriformes is plotted in figure 4.2 and listed in Table-1. Two species belonging to two different families were encountered in this order, *Hydrolagus africanus* (Chimaeridae) (Plate-1c) and *Neoharriotta pinnata* (Rhinochimaeridae) (Plate-1b). *N. pinnata* was found in Arabian Sea (9°28′-15°3′ N; 72 4′-75°63′ E at 328-751m depth range) and Andaman Waters (11°12′ N; 92°35′ E at 512 m Depth) whereas *H. africanus* was collected from Arabian Sea 08° 18′N; 76° 13′ E at 995 m depth and Bay of Bengal 17°07′ N; 83°25′ E at 770 m depth.

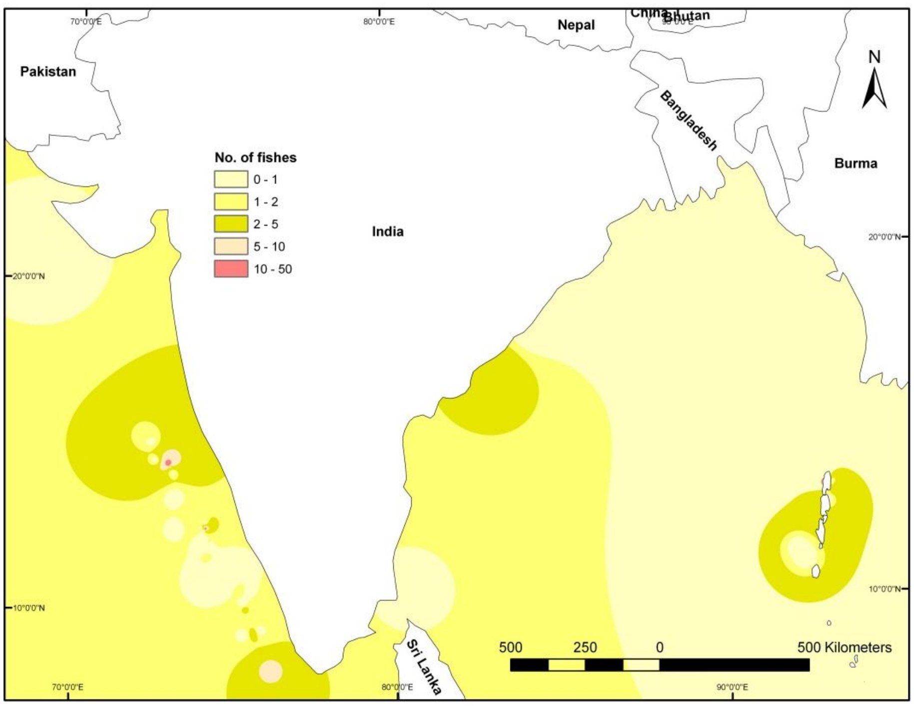


Fig.4.2. Map showing geographical distribution of the order Chimaeriformes

Order: Carcharhiniformes

Distribution of the order Carcharhiniformes is plotted in figure 4.3 and listed in Table-1. This order represented by two families, five genera and nine species; *Apristurus indicus* (Plate-1d), *A. investigatoris* (Plate-1e), *A. microps*, *Bythaelurus hispidus* (Plate-1f), *B. lutarius*, *Cephaloscyllium silasi* and *Halaelurus* sp. belonging to family Scyliorhinidae and *Eridacnis sinuans* and *E. radcliffei* (Plate-1g) from Proscyllidae. *A. investigatoris* and *A. indicus* were found at 9°28′-12°42′ N; 74°07′-75°63′ E at depth range of 524-740 m in Arabian Sea, whereas in Bay of Bengal (10°58′ N; 80°19′ E) the depth of occurrence was at 637-770 m. *A. microps* was found in Bay of Bengal (10°58′ N; 80°09′ E) and Andaman waters 11°12′ N; 92°35′ E at 637 m and 512 m depths respectively. *B. hispidus*, *B. lutarius, Cephaloscyllium sufflans* and *Halaelurus* sp was found only in Arabian Sea at 12°08′-14°39′ N; 73°01′-74°32′ E (328-602 m), 10°57′-12°47′ N; 74°32′-75°13′ E (328-649 m), 10°55′ N; 75°37′ E (265 m) and 10°57′N; 75°37′ E (328-649 m) respectively. *Eridacnis sinuans* found in Andaman waters at depth range 282-735 m (09°35′-14°39′ N; 73°01′-75°08′ E), and in Bay of Bengal at depth 637 m (10°58′ N; 80°19′ E) and *E. radcliffei* at all the three areas; 09°24′-15°03′ N; 72°4′-75°08′ E at 177-751m, 10°58′ N; 80°19′ E at 637m and 11°12′-13°18′ N; 92°35′-93°13′ E at 320-512 m depth respectively.

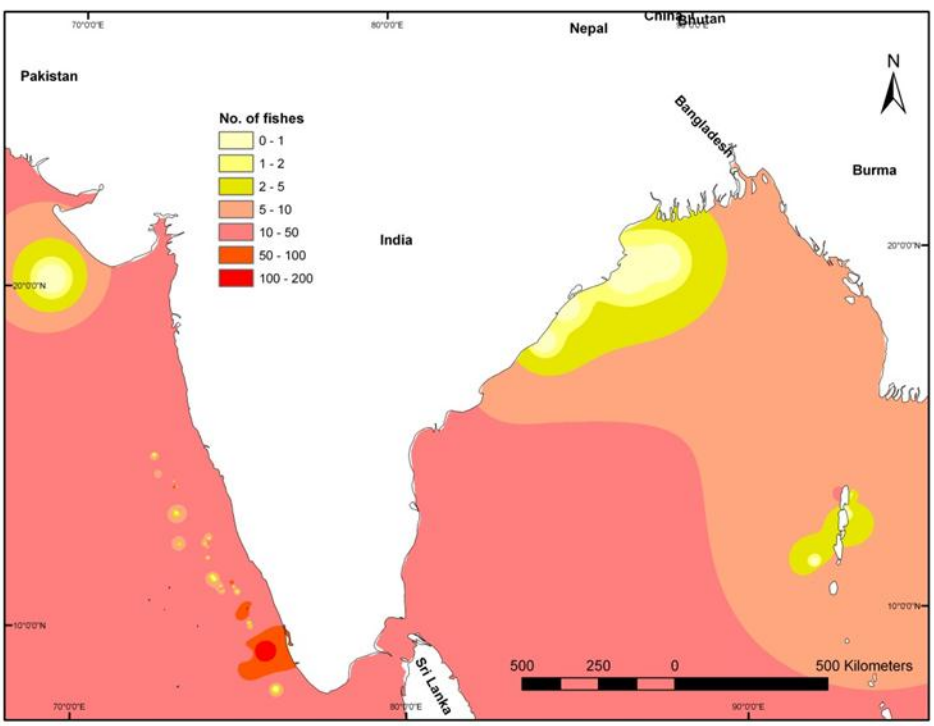


Fig.4.3. Map showing geographical distribution of the order Carcharhiniformes

Order: Echinorhiniformes

Distribution of the order Echinorhiniformes is plotted in figure 4.4 and listed in Table-1. This order represented by single family and species. *Echinorhinus brucus* (Plate-1h) of Echinorhinidae was encountered only in the Arabian Sea at 14°17′-14°44′ N; 73°08′ E of depth range 546-692m.

Order: Squaliformes

Distribution of the order Squaliformes is plotted in figure 4.5 and listed in Table-1. The order represented by three families, four genera and eight species. *Centrophorus* cf *granulosus* (Plate-1i), *C.* cf *lusitanicus*, *C. moluccensis* (Plate-1j), *C. squamosus* (Plate-1k) from the family Centrophoridae; *Centroscyllium fabricii, Etmopterus granulosus* and *E. pusillus* from Etmopteridae and *Centroscymnus crepidater* from Somniosidae. *C.* cf *granulosus* was found in Arabian Sea at 11°11′-11°52′ N; 74°24′-74°53′ E from 630-691 m depth range. *C.* cf *lusitanicus* was also found in Arabian Sea at 10°57′-11°52′ N; 74°24′-75°03′ E at depth range 599-691 m. *C. moluccensis* was recorded in Arabian Sea and Andaman waters at 11°07′ N; 74°98′E at depth of 670 m and 11°12′ N; 92°35′ E at depth of 512 m respectively. *C. squamosus* and *Centroscyllium fabricii* was found only in Arabian Sea at 12°09′-12°26′ N; 74°07′-74°12′ E depth range of 722-918 m, 12°05′ N; 74°28′ E depth of 728 m respectively. *E. granulosus* found in Arabian Sea and Bay of Bengal at 10°58′-15°03′ N; 72°04′-80°19′ E depth range of 637-1070 m and 10°58′ N; 80°19′ E depth of 637 m and *E. pusillus* is at Bay of Bengal only at 10°58′ N; 80°19′ E depth of 637 m. *Centroscymnus crepidater* was observed in Arabian Sea only at 12°42′ N; 74°12′ E from a depth of 740 m (Fig. 4.5).

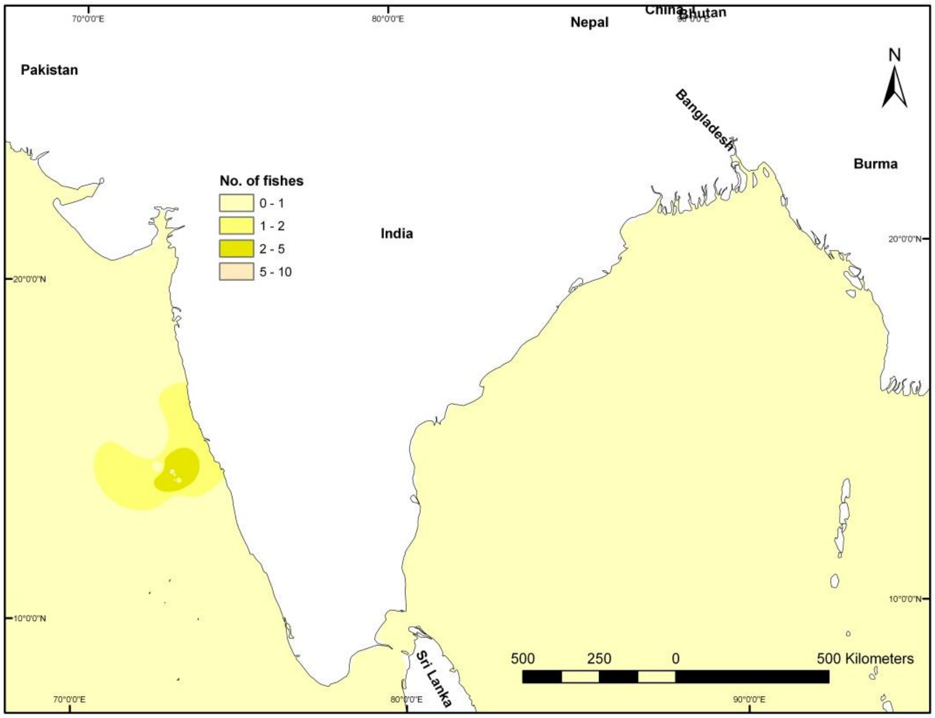


Fig.4.4. Map showing geographical distribution of the order Echinorhiniformes

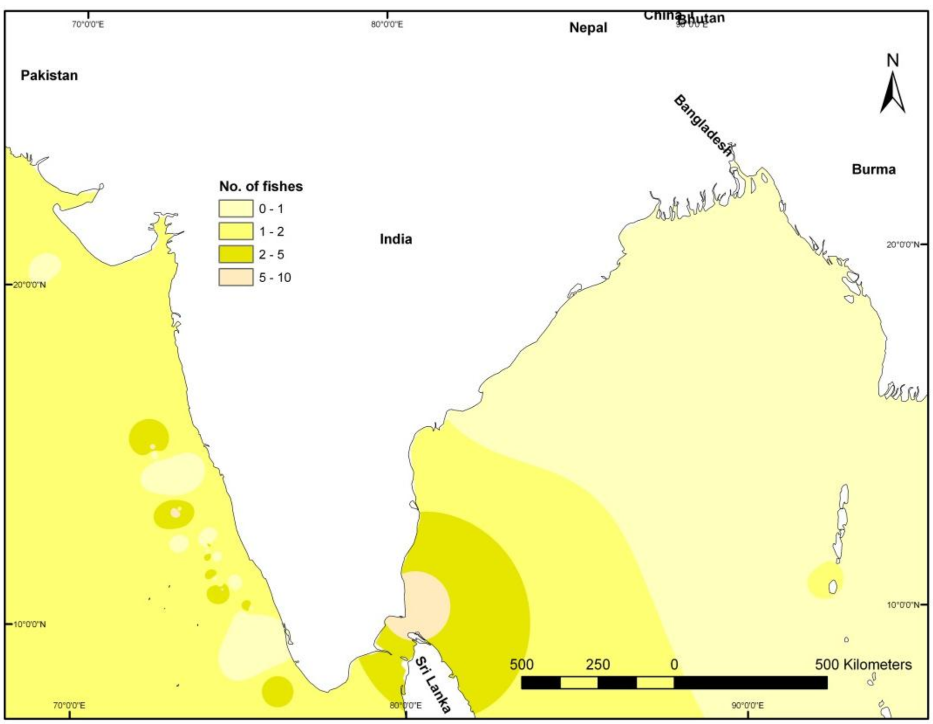


Fig.4.5. Map showing geographical distribution of the order Squaliformes

Order: Torpediniformes

Distribution of the order Torpediniformes is plotted in figure 4.6 and listed in Table-1. The order represented by a single species *Benthobatis moresbyi* (Plate-1l) of family Narcinidae. The species showed distribution in Arabian Sea, Bay of Bengal and Andaman waters at 09°28′-12°42′ N; 74°12′-75°63′ E of depth range 265-512 m, 10°58′ N; 80°19′ E at depth of 637 m and 11°12′ N; 92°35′ E at depth of 512 m respectively.

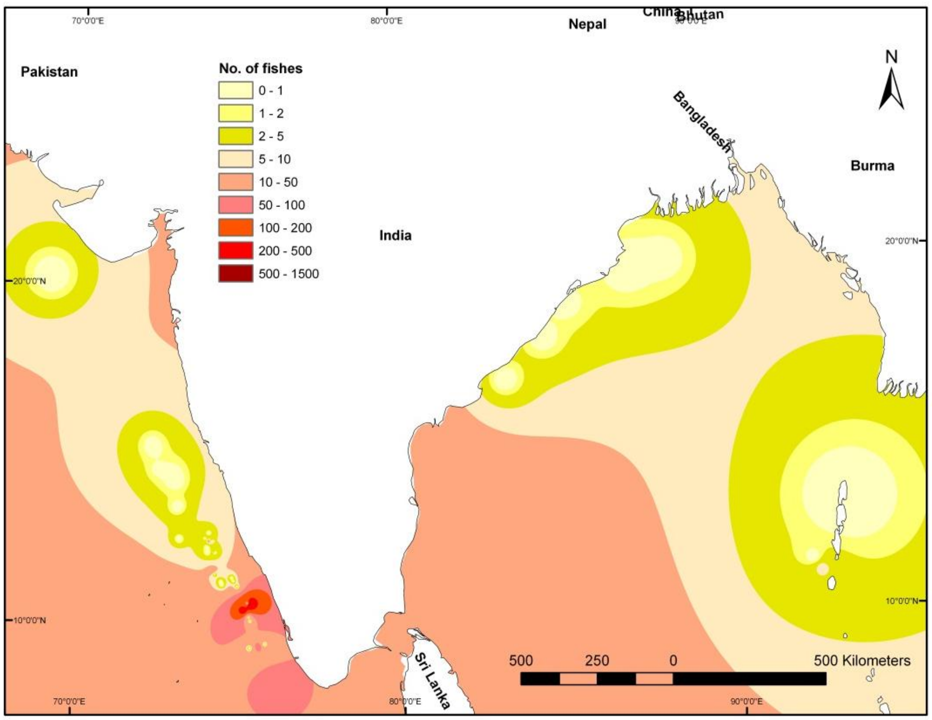


Fig.4.6. Map showing geographical distribution of the order Torpediniformes

Order: Rajiformes

Distribution of the order Rajiformes is plotted in figure 4.7 and listed in Table-1. This order represented a single family Rajidae of four genera and four species. *Cruriraja andamanica* (Plate-1m) was found only in Andaman waters at 13°18′ N; 93°13′ E (depth of 320 m), *Dipturus johannisdavisi* occurred only in Bay of Bengal at 10°58′ N;80°19′ E (depth of 637 m), *Leucoraja circularis* and *Raja miraletus* was only in Arabian Sea at 10°36′-12°08′ N; 74°27′-75°03′ E at a depth range of 328-735 m and 10°55′-12°42′ N; 74°12′-75°37′ E at a depth range of 265-740 m respectively.

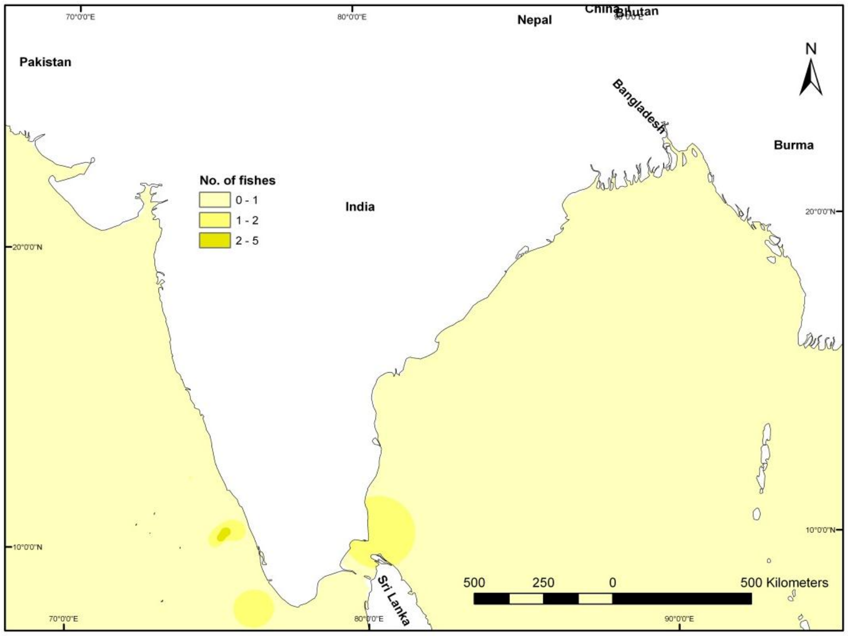


Fig.4.7. Map showing geographical distribution of the order Rajiformes

Order: Myliobatiformes

Distribution of the order Myliobatiformes is plotted in figure 4.8 and listed in Table-1. This order was represented by two families and two species, *Plesiobatis daviesi* (Plate-1n) of Plesiobatidae occurred only in Andaman waters at 12°75′ N; 93°15′ E of depth 369 m and *Pteroplatytrygon violacea* (Plate-2a)of Dasyatidae was found only in Arabian Sea at 10°36′ N; 75°17′ E at depth of 706 m.

Order: Albuliformes

Distribution of the order Albuliformes is plotted in figure 4.9 and listed in Table-1. This order was represented by a single family and species *Notacanthus sexspinis* (Plate-2b) from Notacanthidae was found only in Arabian Sea at 10°57′-13°41′ N; 73°15′-80°19′ E depth range of 637-905 m.

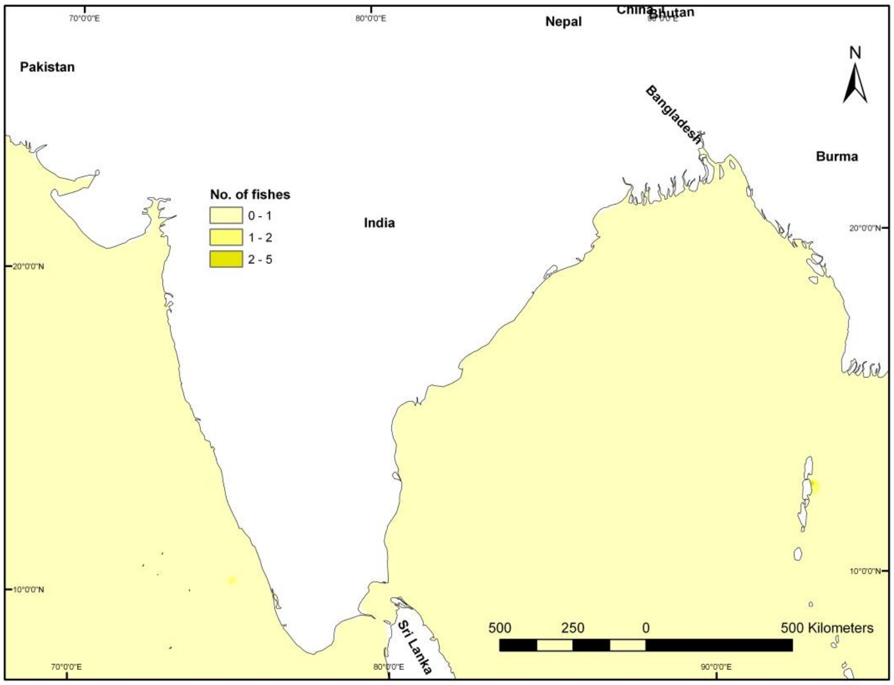


Fig.4.8. Map showing geographical distribution of the order Myliobatiformes

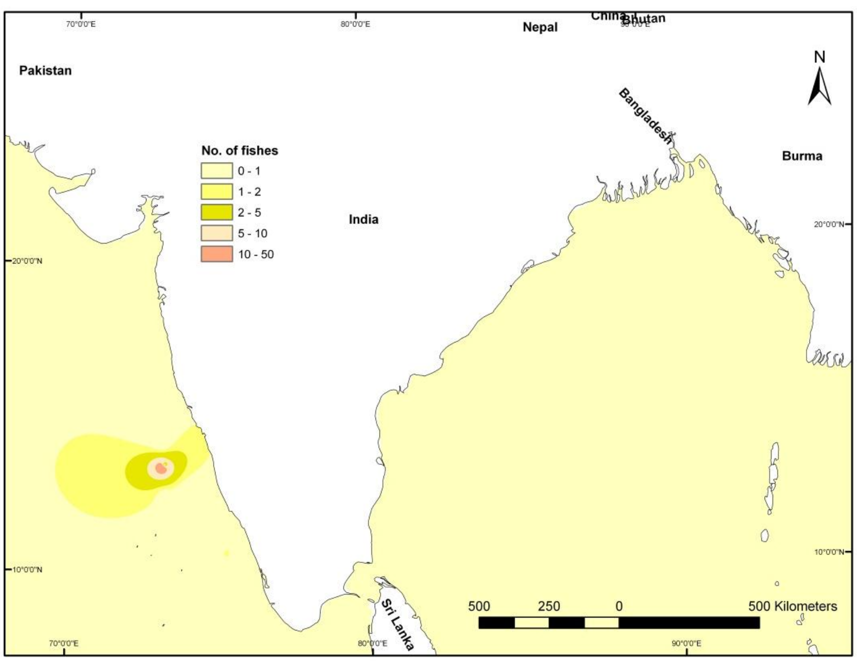


Fig.4.9. Map showing geographical distribution of the order Albuliformes

Order: Anguilliformes

Distribution of the order Anguilliformes is plotted in figure 4.10 and listed in Table-1. Six families, nine genera and ten species were documented in this order. Synaphobranchidae represented by two species, *Ilyophis brunneus* was found only in Arabian Sea at 12°49′ N; 74°02′ E depth of 259 m and *Synaphobranchus affinis* was found in Arabian Sea and Bay of Bengal at 09°24′ N; 75°36′ E depth of 333 m, 18°26′-20°32′ N; 84°46′-88°28′ E depth range of 125-214 m from, Colocongridae represented by *Coloconger raniceps* (Plate-2c) and *C. scholesi* from was found in Arabian Sea and Bay of Bengal at 09°28′-12°07′ N; 74°27′-75°63′ E depth range of 265-734 m, 10°58′ N; 80°19′ E depth of 637 m 10°57′ N; 75°03′ E depth of 649 m, 10°58′ N; 80°19′ E depth of 637 m respectively. Nemichthyidae *Avocettina paucipora* (Plate-2d) was only in Arabian Sea at 10°16′-12°26′ N; 74°07′-75°33′ E depth range of 599-777 m and *Nemichthys scolopaceus* (Plate- 2e) found in Arabian Sea, Bay of Bengal and Andaman waters at 10°16′-12°42′ N; 74-75° 33′ E depth range of 670-862 m, 10° 58′-17°07′ N; 80° 19′-83° 25′E depth range of 637-770 m, 13° 18′-13° 27′ N;93° 25′-93° ′28E depth range of 538-695 m from, *Bathyuroconger vicinus* (Plate-2f) and *Gavialiceps taeniola* (Plate-2g) was found in Arabian Sea and Bay of Bengal at 9° 28′-15° 13′ N;72° 44′ -75° 63′E depth range of 524-1070 m, 10° 58′ N; 80° 19′E depth of 637, 9° 24′ -15°03′ N; 72°04′-75°63′ E depth range of 268-918 m 10°58′ -17°07′ N; 80°19′-83°25′ E depth range of 637-770 m respectively and *Xenomystax trucidans* (Plate-2h) found only at Arabian Sea at 10°36′-12°42′ N; 74°09′-75°03′ E depth range of 565-740 m from Congridae and *Serrivomer beanii* from Serrivomeridae was found in Andaman waters only at 11°12′ N; 92°35′ E depth of 512 m (Fig. 4.10).

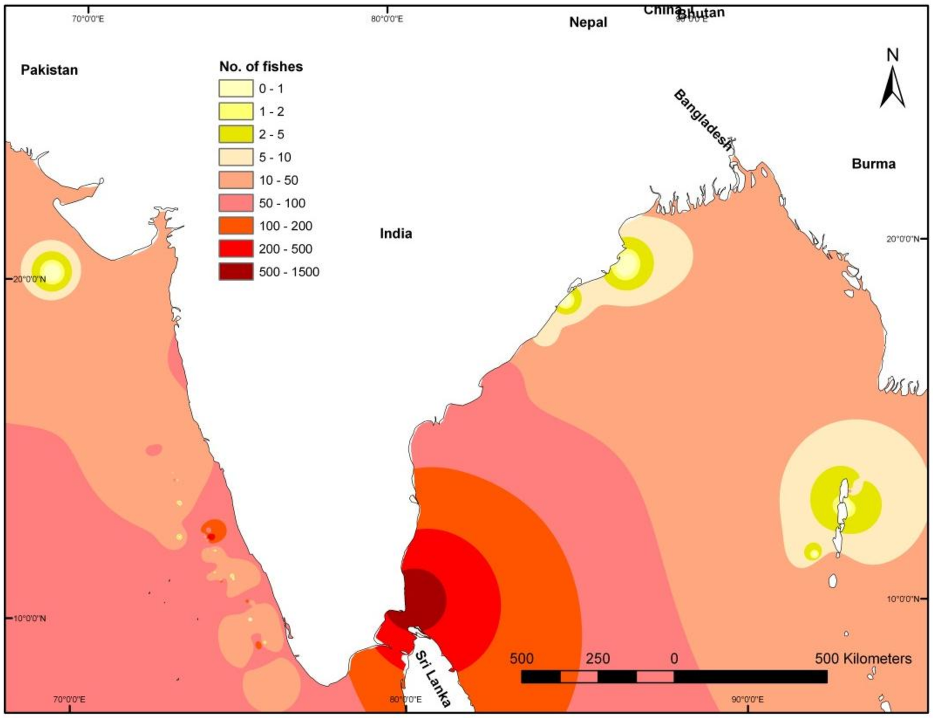


Fig.4.10. Map showing geographical distribution of the order Anguilliformes

Order: Argentiniformes

Distribution of the order Argentiniformes is plotted in figure 4.11 and is listed in Table-1. Two families and seven genera and eight species were reported from this order. *Maulisia mauli* and *Normichthys yahganorum* (Plate-2i) occurred only in Arabian Sea (11°07′-12°42′ N; 74°07′-74°98′ E and 09°24′-12°39′ N; 74°08′-75°36′ E) at depth range of 666-918 m and 229-333 m respectively from Platytroctidae. *Alepocephalus bicolor* (Plate-2j)was noticed in Arabian Sea (09°28′-14°54′ N; 72°59′-75°63′ E), Bay of Bengal (10°58′-17°07′ N; 80°19′-83°25′ E) and Andaman waters (11°12′-13°27′ N; 92°35′-93°28′ E) at a depth range of 268-1070 m, 637-770 m and 512-695 m respectively. *A. blanfordii* (Plate-2k), *Bathytroctes squamosus* and *Rouleina attrita* (Plate-2l) were found only in Arabian Sea (10°36′-12°42′ N; 74°12′-74°28′ E, 12°09′-13°41′ N; 73°15′-74°12′E and 11°11′-12 42′ N;74°12′-74°53′ E) at 630-740 m, 722-1070 m and 599-918 m depths respectively. *Talismania longifilis* (Plate-2m) was observed in Arabian Sea (10°16′-11°07′ N; 74°98′-75°33′ E) and Andaman waters (13°27′N; 93°8′ E) at depth range of 670-777 m and 695 m respectively. *Narcetes lloydi* (Plate-2n) of family Alepocephalidae was observed only in Arabian Sea (11° 04′ N; 47°43′ E) at 238 m.

Order: Stomiiformes

Distribution of the order Stomiiformes is plotted in figure 4.12 and listed in Table-1. The order was represented with five families 9 genera and 16 species. *Diplophos taenia* of family Diplophidae was found only in Arabian Sea (09°24′-12°26′ N; 74°07′-75°36′ E) at a depth range of 333-722 m. Three species represented the family Gonostomatidae, *Cyclothone braueri* and *G. elongatum* observed only in Andaman waters (13°18′ N; 93°25′ E) at depth of 538 m and *C. microdon* seen only in Arabian sea (11°07′ N; 74°98′ E) at depth of 670 m. *Argyropelecus affinis* and *A. hemigymnus* (Plate-2o) found only in Andaman waters (13°18′ N; 93°25′ E and 12°75′-13°01′ N; 93°12′-93°25′ E) at a depth of 538 m and 329-538 m respectively. *Polyipnus spinosus* and *P. indicus* of family Sternoptychidae observed only in Arabian Sea (09°24′-10°36′ N; 75°17′-75°36′ E) at depth range of 333-706 m. *Vinciguerria sp.* were found in Arabian Sea only (10°36′-12°08′ N; 74°27′-75°17′ E at the depth range of 168-734 m) from family Phosichthyidae. *Astronesthes indicus* was occurred in Bay of Bengal only at 10°58′ -17°07′ N; 80°19′-83°25′ E depth range of 637-770 m, *A. lucifer* was found at Bay of Bengal and Andaman waters at 17°07′ N; 83°25′ E depth of 770 m 11°43′ N; 92°15′ E depth of 353 m depth, *A. martensii* was found in Andaman waters only at (11°07′-11°33′ N; 74°82′-74°98′ E) depth range of 256-670 m, *A. niger* (Plate-3a) was found at Arabian Sea at (15°13′ N; 72°44′ E) depth of 844 m, *Chauliodus sloani* (Plate-3b)was found in Arabian Sea and Andaman waters at 11°07′-15°13′ N; 72°44′-74°98′ E depth range of 666-918 m, 13°18′-13°27′ N; 93°25′-93°28′ E depth range of 538-695 m, *Idiacanthus fasciola* and *Malacosteus niger* (Plate-3c)was fround only in Andaman waters at 13°18′ N; 93°25′ E depth of 538 m and 13°18′-13°27′ N; 93°25′-93°28′ E depth range of 538-695 m from family Stomiidae.

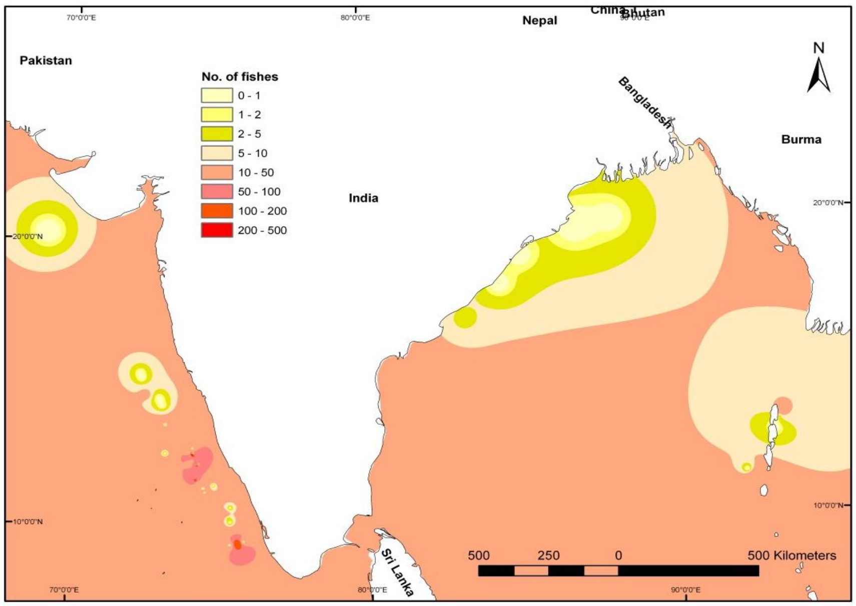


Fig.4.11. Map showing geographical distribution of the order Argentiniformes

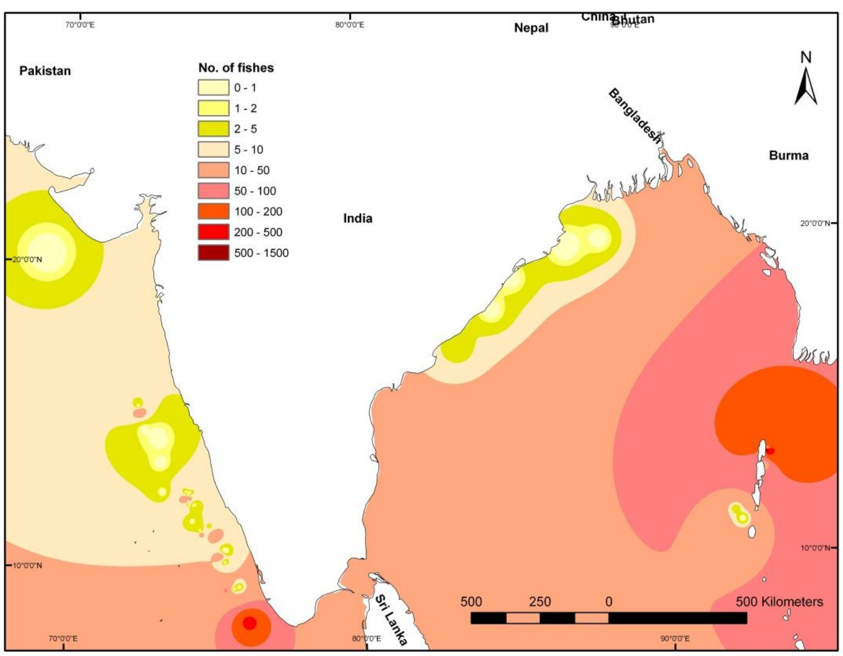


Fig.4.12. Map showing geographical distribution of the order Stomiiformes

Order: Ateleopodiformes

Distribution of the order Ateleopodiformes is plotted in figure 4.13 and listed in Table.1. This order was represented by a single family Ateleopodidae of two genera and two species. *Ateleopus indicus* (Plate-3d) was encountered in Arabian Sea and Andaman waters at 09°24′ N; 75°36′ E of depth 333 m and at 11°12′-13°18′ N; 92°35′-93°15′ E of depth of 320-512 m respectively and *Ijimaia loppei* (Plate-3e) occurred only in Arabian Sea at 09°24′ N; 75°36′ E depth of 333 m.

Order: Aulopiformes

Distribution of the order Aulopiformes is plotted in figure 4.14 and listed in Table.1. The order represented by five families, six genera and nine species. Of family Synodontidae, *Saurida tumbil* (Plate-3f) was recorded only in Bay of Bengal at 18°26′-20°32′ N; 84°46′-88°28′ E of depth 150-214 m and *S. undosquamis* was found in Arabian Sea at 10°55′-12°08′ N; 74°32′-75°37′ E of 256-328 m depth and in Bay of Bengal at 18°26′-20°32′ N; 84°46′-88°28′ E of 150-214 m depth. from Chlorophthalmidae, *Chlorophthalmus agassizi* (Plate-3g) was found only in Arabian Sea at 10°55′-12°08′ N; 74°32′-75°37′ E of 256-328 m depth, *C. bicornis* (Plate-3h) was observed in Arabian Sea at 09°24′-11°33′ N; 73°21′-75°37′ E of 238-333 m depth and Andaman waters at 12°75′-13°18′ N; 93°07′-93°15′ E of 320-369 m, *C. punctatus* was recorded in Arabian sea only at 09°24′-11°33′ N; 73°21′-75°37′ E of depth 238-333 m and *Parasudis truculenta* observed only at Andaman waters at 12° 75′- 13°18′ N; 93°07′-93°15′ E of 320-369 m depth. *Bathypterois atricolor* (Plate-3i) and *B. dubius* from Ipnopidae were found only Andaman at 13°27′ N; 93°28′ E of 695 m depth; *Evermannella indica* (Plate-3j) from Evermannellidae was recorded only in Bay of Bengal at 10°58′ N; 80°19′ E of 637 m depth and

Stemonosudis macrura (Plate-3k) from Paralepididae was found only in Arabian Sea 12°08′ N; 74°32′ E of 328 m depth.

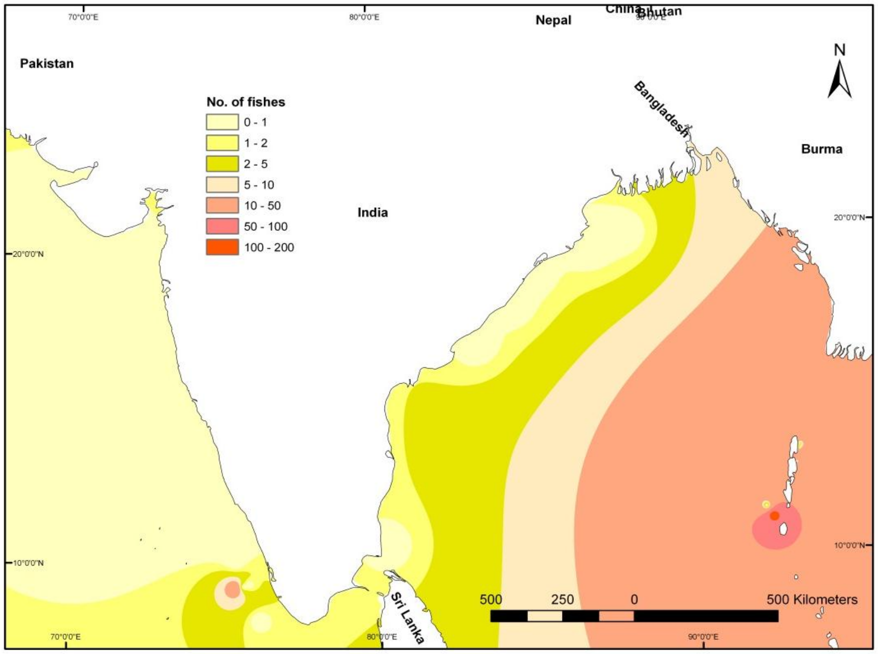


Fig.4.13. Map showing geographical distribution of the order Ateleopodiformes

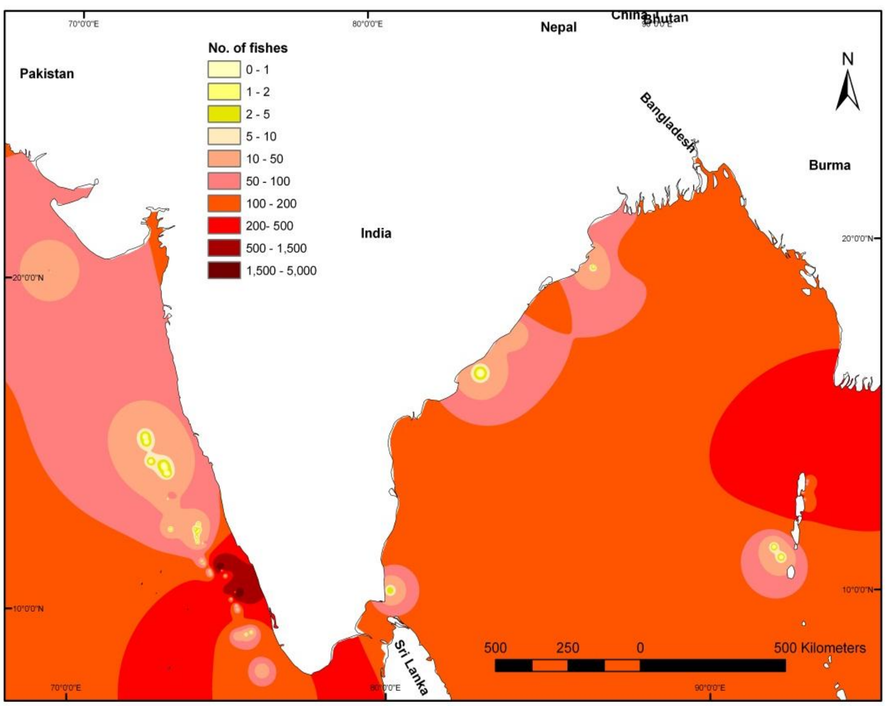


Fig.4.14. Map showing geographical distribution of the order Aulopiformes

Order: Myctophiformes

Distribution of the order Myctophiformes is plotted in figure 4.15 and listed in Table.1. The order represented by two families, five genera and eight species. Of Neoscopelidae, *Neoscopelus microchir* (Plate-3l) was encountered in Arabian Sea at 09°24′ N; 75°36′ E of 333 m depth and Andaman Waters 11°12′-13°01′ N; 92°35′-93°18′ E of 329-512 m depth and *Scopelengys tristis* (Plate-3m) was observed in Arabian Sea at 10°16′ N; 75°33′ E of 777 m depth and in Bay of Bengal at 17°07′ N; 83°25′ E of 770 m depth from; *Benthosema pterotum* (Plate-3n) were noticed only in Arabian Sea at 09°24′ N; 75°36′ E of 333 m depth, *Diaphus knappi* (Plate-3o) was found in Arabian Sea 09°24′N; 75°36′ E of 333 m depth and Andaman Waters at 13°18′ N; 93°25′ E of 649 m depth, *Diaphus lucidus* (Plate-3p) was found only in Andaman at 11°12′-13°18′ N; 92°35′-93°25′ E 320-538 m depth, *Diaphus watasei* (Plate-4a) was observed in Arabian Sea at 09°24′ N; 75°36′ E of 333 m depth and Andaman waters at 13°18′N: 93°25′ E of 649 m depth, *Myctophum obtusirostre* (Plate-4b) and *M. nitidulum* was observed only in Bay of Bengal at 20°32′ N; 88°28′ E of 150 m depth from Myctophidae.

Order: Polymixiiformes

Distribution of the order Polymixiiformes is plotted in figure 4.16 and listed in Table-1. The order represented by single family and order with three species; The particular order was only found in Arabian Sea *Polymixia berndti* at 13°27′ N; 93°28′ E 695 m depth, *P. japonica* and *P. nobilis* (Plate-4c)occurred only in same area at 09°24′-11°44′ N; 74°03′-75°08′ E of 238-333 m depth from Polymixiidae.

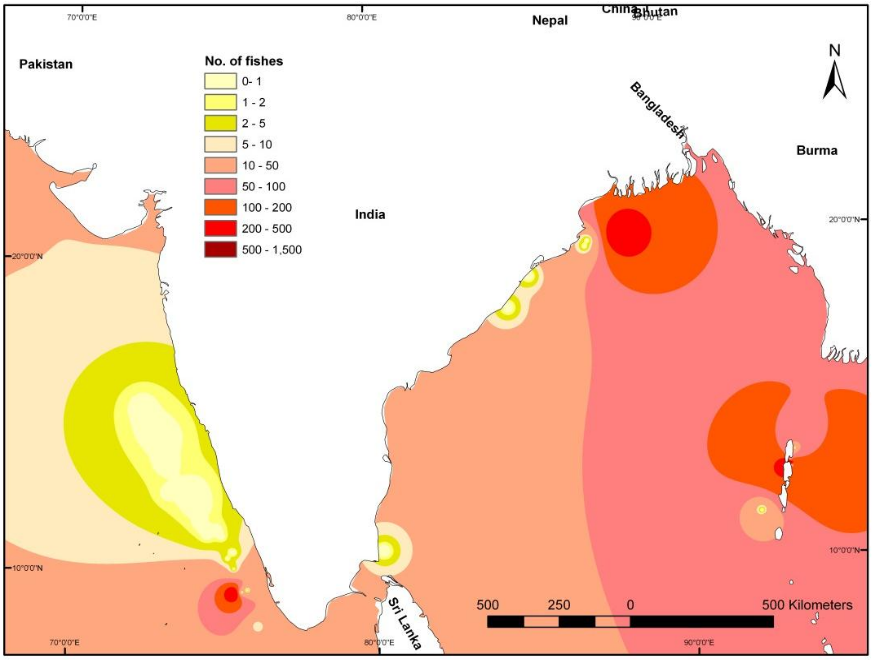


Fig.4.15. Map showing geographical distribution of the order Myctophiformes

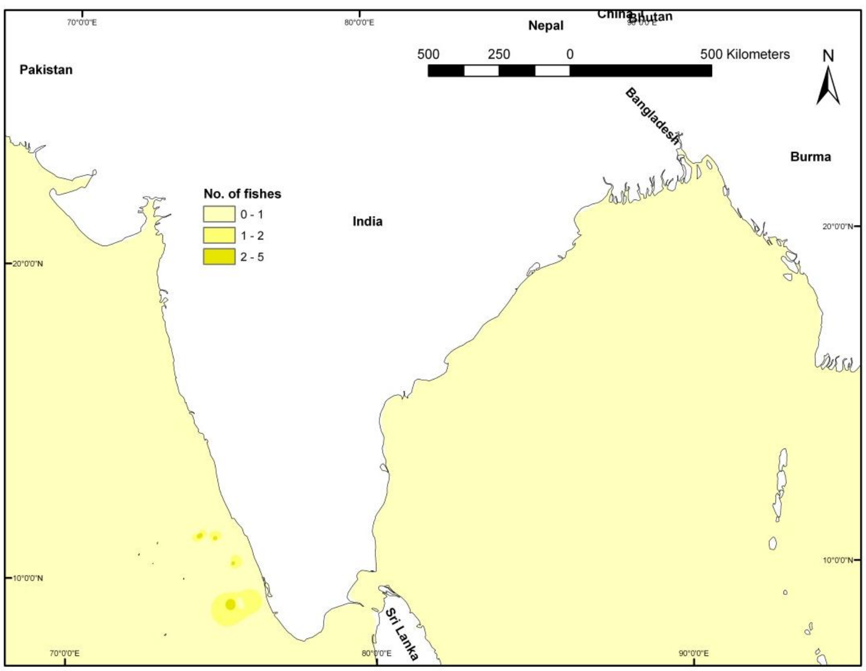


Fig.4.16. Map showing geographical distribution of the order Polymixiiformes

Order: Gadiformes

Distribution of the order Gadiformes is plotted in figure 4.17 and listed in Table-1. The order epresented by two families, eight genera and ten species; *Bathygadus melanobranchus* (Plate-4d)seen only in Arabian sea at 11°11′-13°41′ N; 73°15′-74°53′ E of 630-1070 m depth, *Coelorinchus braueri* occurred only in Andaman at 12°82′-13°18′ N; 93°07′-93°18 E of 320-402 m depth, *Coelorinchus flabellispinnis* were found in Arabian sea at 10°36′ N; 75°17′E at 706 m depth, *Coryphaenoides macrolophus* were noticed in Arabian sea, Bay of Bengal and Andaman at 10° 36′-15°03′ N; 72°04′-75°17′ E at 599-1070 m depth 10°58′ N; 80°19′ E of 637m depth 11°12′- 13°27′ N; 92°35′-93°28′ E at 321-695 m depth respectively, *Gadomus capensis, Gadomus* spp., *Malacocephalus laevis* (Plate-4e) these three were noticed only in Bay of Bengal at 10°58′ N; 80°19′ E 637 m depth, *Nezumia propinqua* (Plate-4f) was found in Arabian Sea12°05′-12°42′ N; 74°12′-74°28′ E of 728-740 m depth and Bay of Bengal 13°01′ N; 93°18′ E 402 m depth and *Macrurus* sp. was found only in Arabian Sea at 10°55′-10°57′ N; 75°03′-75°37′ E 265-649 m depth from Macrouridae*; Physiculus roseus* (Plate-4g) was observed in Arabian Sea only at 09°24′-14°39′ N; 73°01′-75°36′ E of 333-692 m depth from Moridae.

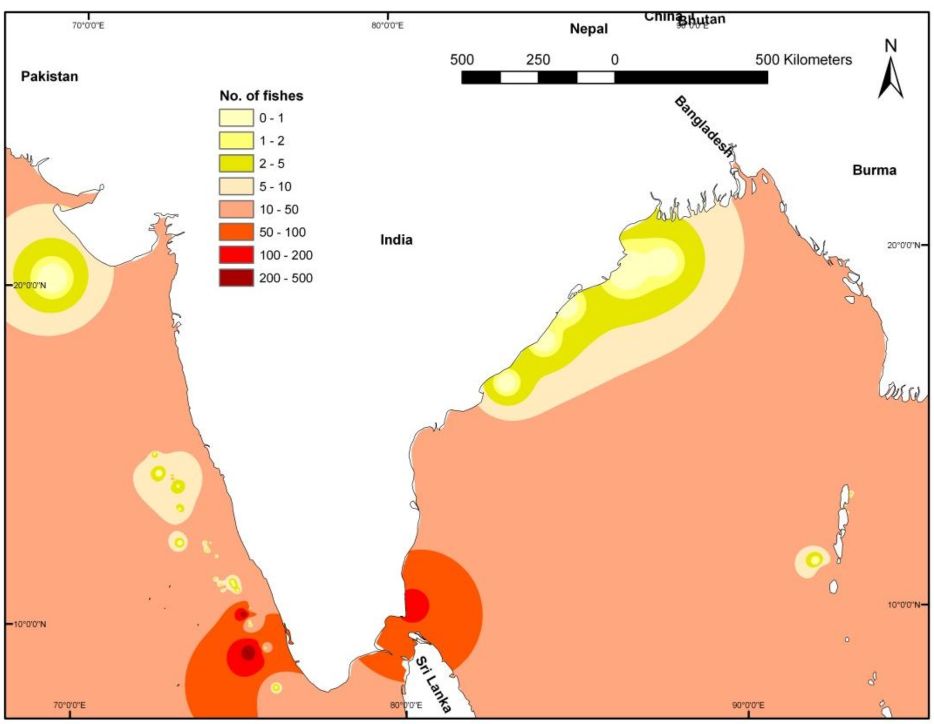


Fig.4.17. Map showing geographical distribution of the order Gadiformes

Order: Ophidiiformes

Distribution of the order Ophidiiformes is plotted in figure 4.18 and listed in Table-1. This order represented by three families, nine genera and fifteen species. *Snyderidia canina* (Plate-4h) from Carapidae found only in Arabian Sea at 09°35′ N; 75°08′ E depth of 282 m; *Bassozetus robustus* and *Dicrolene tristis* were also noticed only in the same sea but the area of occurrence was 12°09′-15°13′ N; 72°44′-74°09′ E of 844-1070 m depth and 09°28′ N; 75°63′ E of 524 m depth respectively. *Dicrolene multifilis* (Plate-4i)occurred in Arabian Sea, Bay of Bengal and Andaman waters at 11°11-15°03′ N; 72°04′-74°53′ E of 602-1070 m depth; 10°58′ N; 80°19′ E at 637 m depth and 11°12′-13°27′ N; 92°35′-93°28′ E 512-695 m depth. *Dicrolene nigricaudis* was observed in Bay of Bengal and Andaman waters 10°58′ N; 80°19′ E 637 m depth; 11°12′-13°01′ N; 92°35′-93°18′ E of 369-512 m depth; *Glyptophidium argenteum, Glyptophidium lucidum* and *Glyptophidium sp.,* three of these species are only found in Arabian Sea at the area of 11°11′-11°52′ N; 74°24′-74°53′ E 599-691m depth 09°24′ N; 75°36′ E 333 m depth and 09°35′-12°08′ N; 74°32′-75°8′ E 265-328 m depth respectively. *Hypopleuron caninum* was found in Arabian Sea at 09°24′-12°22′ N; 74°09′-75°36′ E at depth range of 333-565 m and Bay of Bengal 17°07′ N; 83°25′ E at depth of 770 m, *Lamprogrammus exutus* (Plate-4j) also found in Arabian Sea at 11°11′-15°03′ N; 72°04′-74°53′ E at depth range of 268-905 m and Bay of Bengal 10°58′ N; 80°19′ E depth of 637 m, *Lamprogrammus niger* (Plate-4k) was observed in Arabian Sea 12°05′-12°42′ N; 74°07′-74°28′ E depth range of 722-1070 m and Andaman waters 13°18′ N; 93°13′ E depth of 320 m, *Luciobrotula bartschi* (Plate-4l) was encountered in Arabian Sea 10°55′-15°03′ N; 72°04′-75°37′ E at depth range of 265 m and Bay of Bengal 751 m,10°58′-17°07′ N; 80°19′-83°25′ E at depth range of 637-770 m, *Luciobrotula* sp. and *Neobythites analis* (Plate-4m) was recorded in Arabian sea only but in different areas 12°08′ N; 74°32′ E 328 m depth and 11°52′ N; 74°24′ E 630 m depth respectively from Ophidiidae; *Hephthocara simum* (Plate- 4n) was found in Arabian Sea and Bay of Bengal at 09°28′-12°09′ N; 74°09′-75°63′ E depth of 524-1070 m and 10°58′ N; 80°19′ E depth of 637 m respectively from Bythitidae.

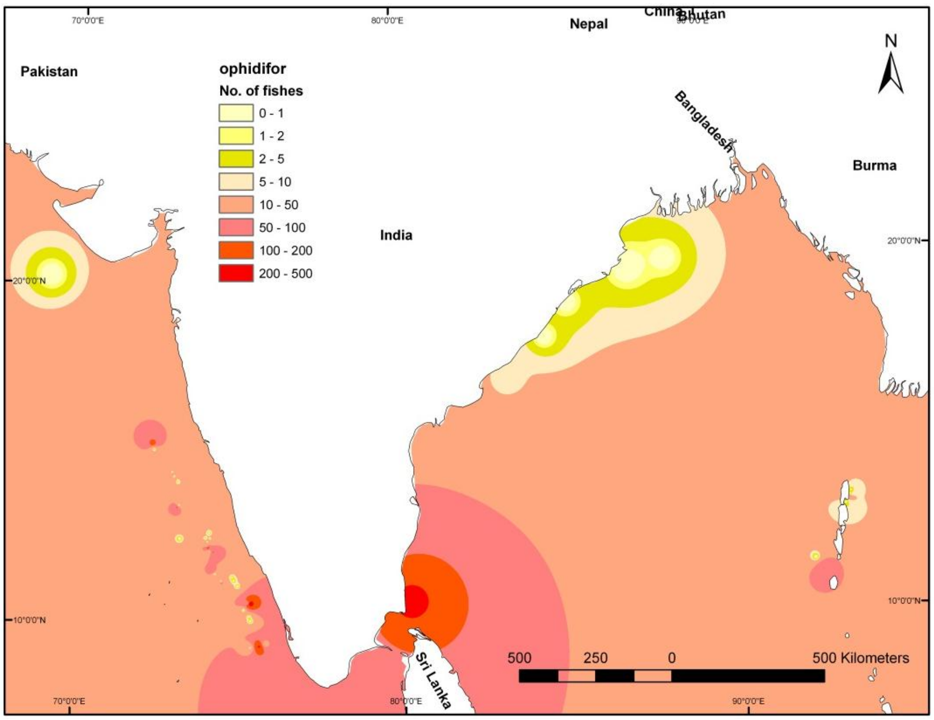


Fig.4.18. Map showing geographical distribution of the order Ophidiiformes

Order: Lophiiformes

Distribution of the order Lophiiformes is plotted in figure 4.19 and listed in Table.1. This order represented by seven families, eight genera and ten species. *Lophiodes mutilus* was found only in Arabian Sea at 10°55′-12°49′ N; 74°02′-75°37′ E depth range of 168-265 m, *L. setigerus* (Plate-4p) was encountered from Arabian Sea 09°35′-12°22′ N; 74°09′-75°08′ E depth range of 238-565 m, Bay of Bengal 10°58′ N; 80°19′ E depth of 637 m and Andaman waters 12°08′ N; 74°32′ E depth of 328 m from Lophiidae; *Chaunax pictus* (Plate-4o) was found in

Arabian Sea at 10°36′-12°47′ N; 74°15′-75°03′ E depth range of 328-706 m and Andaman waters at 11°12′-13°03′ N; 92°15′-93°18′ E depth range of 321-512 m from Chaunacidae; *Coelophrys micropa* was recorded only in Arabian Sea at 09°28′-11°23′ N; 74°87′-75°63′ E depth range of 524-777 m, *Halieutaea coccinea* was found only on Andaman waters at 13°18′ N; 93°25′ E depth of 649 m, were as *H. fumosa* (Plate-5a) occurred only on Arabian Sea 10°55′ N; 75°37′ E depth of 265 m from Ogcocephalidae; *Melanocetus johnsonii* was found in Arabian Sea at 11°11′-12°42′ N; 74°12′-74°53′ E depth range of 691-740 m and Andaman waters at 12°08′ N; 74°32′ E depth of 328 m. from Melanocetidae *Bufoceratias wedli* (Plate-5b) seen only in Arabian Sea at 09°28′-10°16′ N; 75°33′-75°08′ E depth range of 282-777m from Diceratiidae; *Oneirodes kreffti* (Plate-5c) was also found in Arabian sea only at 11°11′ N; 74°53′ E depth of 691 m from Oneirodidae; *Cryptopsaras couesii* was found in Arabian Sea at 10°16′ N; 75°33′ E depth of 777 m and Andaman waters at 13°18′N; 93°25′ E depth of 649 m from Ceratiidae.

Order: Beryciformes

Distribution of the order Beryciformes is plotted in figure 4.20 and listed in Table-1. This order was represented by four families, five genera and eight species. The particular order was represented only in Arabian Sea at different locations and depths. *Anoplogaster cornuta* (Plate-5d) (12°49′ N; 74°02′ E depth of 259 m) from Anoplogastridae; *Gephyroberyx darwinii* (Plate-5e) (10°36′-11°16′ N; 74°51′-75°03′ E depth range of 599-706 m) , *Hoplostethus mediterraneus* (Plate-5f) (10°36′-12°08′ N; 74°32′-75°03′ E depth range of 328-706 m) *Hoplostethus melanopus* (10°16′-12°07′ N; 74°51′-75°33′ E depth range of 599-777 m) Trachichthyidae; *Beryx decadactylus* (12°08′-14°17′ N; 73°08′-74°32′ E depth range of 328-722 m), *Beryx splendens* (Plate-5g) and *Berynx* sp. (10°36′ N; 75°17′ E depth of 706 m) from Berycidae; *Ostichthys kaianus* (Plate-5h) (10°55′-11°33′ N; 74°82′- 75°37′ E depth range 256-265 m) from Holocentridae.

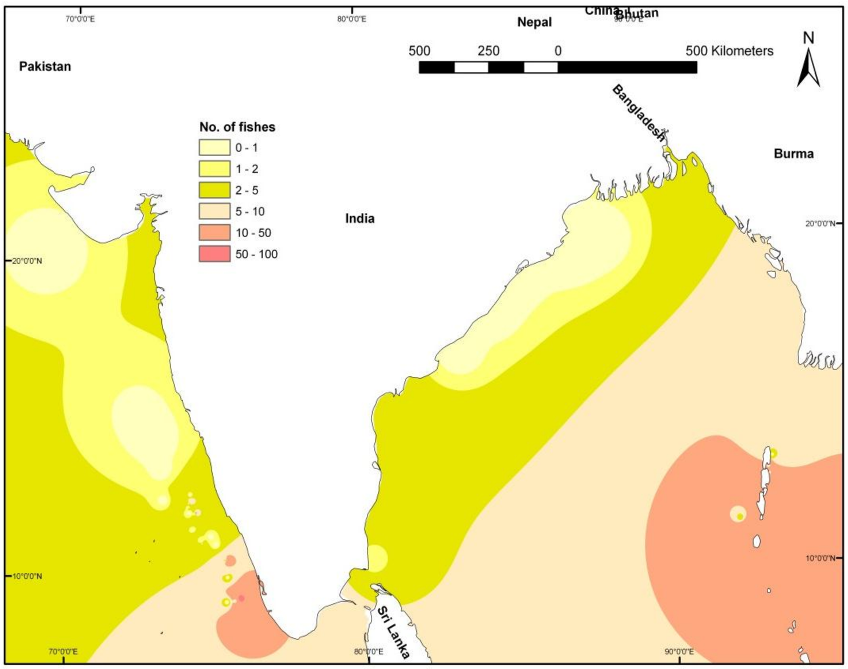


Fig.4.19. Map showing geographical distribution of the order Lophiiformes

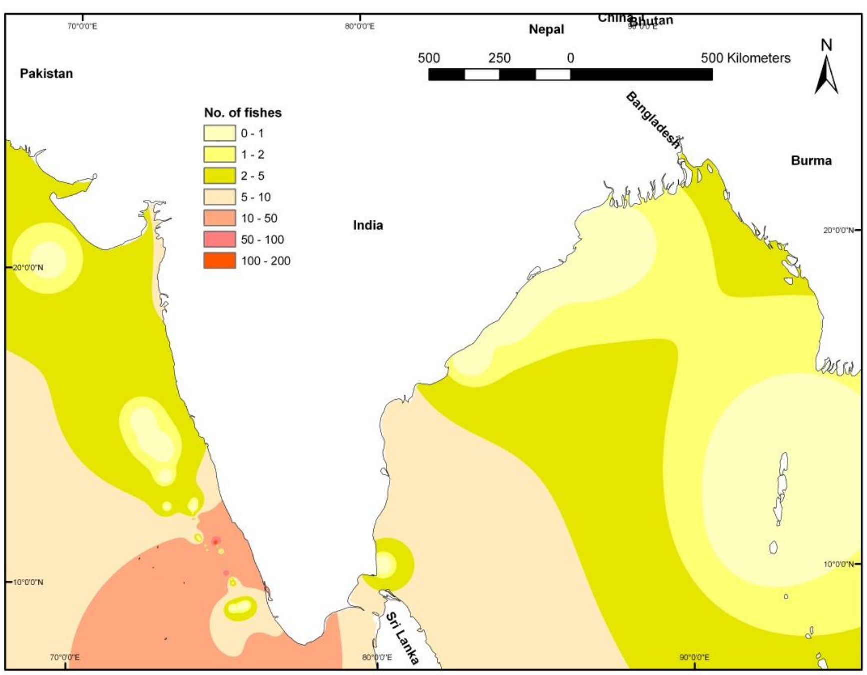


Fig.4.20. Map showing geographical distribution of the order Beryciformes

Order: Zeiformes

Distribution of the order Zeiformes is plotted in figure 4.21 and listed in Table.1. This order represented by two families, two genera and species, this order was represented only in Arabian Sea. The location and depth they encountered are given in brackets *Cyttopsis rosea* (Plate-5i) (09°28′-10°57′ N; 75°03′-75°63′ E depth range of 524-649 m) from Parazenidae; *Zenopsis conchifer* (Plate-5j) (09°24′ N; 75°36′ E depth of 333 m) from Zeidae.

Order: Scorpaeniformes

Distribution of the order Scorpaeniformes is plotted in figure 4.22 and listed in Table.1. This order represented by four families, seven genera and ten species. *Pontinus nigerimum* was found only in Bay of Bengal 10°58′N; 80°19′ E depth of 637 m from Scorpaenidae; *Ectreposebastes imus* (Plate-6a) from Arabian Sea at 10°16′ N; 75°33′ E depth of 777 m and Bay of Bengal at 10°58 N; 80°19′ E depth of 637 m, *Setarches guentheri* was noticed in Bay of Bengal at 10°58′ N; 80°19′ E depth of 637 m and Andaman waters at 12°75′-13°18′ N; 93°07′-93°18′ E depth range of 320-402 m whereas *Setarches longimanus* (Plate-6b) was found only in Andaman waters at 11°12′-13°01′ N; 92°35′-93°25′ E depth range of 329-538 m from Setarchidae; *Lepidotrigla* sp. occurred only in Arabian Sea at 11°44′ N; 74°03′ E depth of 238 m, compared to *Pterygotrigla hemisticta* (Plate-6c) occurred only in all three region Arabian Sea at 11°33′-12°49′ N; 74°02′-74°82′ E depth range of 238-259 m, Bay of Bengal at 20°32′ N; 88°28′ E depth of 150 m and Andaman wasters 12°82′ N; 93°07′ E depth of 321 m whereas *Pterygotrigla* sp. occurred only in Arabian Sea at 11°44′ N; 74°03′ E depth of 238 m from Triglidae; *Peristedion miniatum* (Plate-6d) seen only in Arabian Sea at 10°55′-10°57′ N; 75°03′-75°37′ E depth range of 265-649 m and Andaman waters 12°75′-13°18′ N; 93°07′-93°18′ E depth range of 321-402 m, *Peristedion weberi* (Plate-6e) and *Scalicus investigatoris* was found in Andaman waters only, but in different locations at 11°12′-12°95′ N; 92°35′-93°15′ E depth range of 312-512 m, 13°27′ N; 93°28′ E depth of 695 m respectively from Peristediidae.

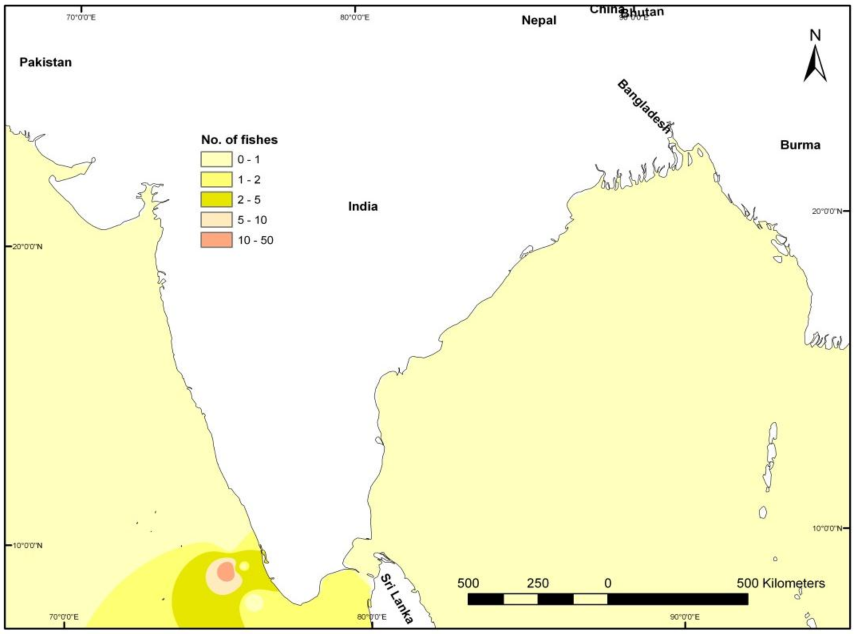


Fig.4.21. Map showing geographical distribution of the order Zeiformes

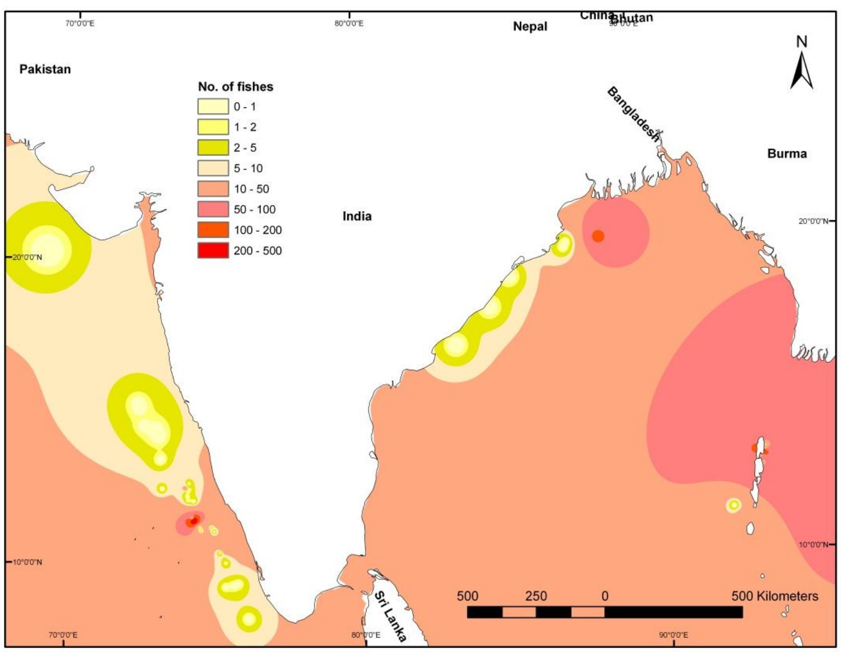


Fig.4.22. Map showing geographical distribution of the order Scorpaeniformes

Order: Perciformes

Distribution of the order Perciformes is plotted in Fig. 4.23 and listed in Table-1. The largest order represented by maximum number of species during the studies consisted of thirty five species belonging to twenty eight genera and seventeen families. Family Acropomatidae was represented by *Acropoma japonicum, Synagrops philippinensis* and *S. pellucidus.* The former two were seen only in Arabian Sea at 09°24′-12°48′ N; 73°24′-75°36′ E depth range of 177-333 m and 09°24′ N; 75°36′ E depth of 333 m respectively whereas, the latter was observed in both Arabian Sea (09°35′-12°09′ N; 74°09′-75°36′ E depth range of 333-1070 m) and Bay of Bengal (10°58′ N; 80°09′ E depth of 637 m). *Chelidoperca investigatoris* (Plate-6f) (Family: Serranidae) was recorded only from Arabian Sea at 11°44′-13°47′ N; 73°21′-74°3′ E of depth range 229-259 m. *Priacanthus hamrur* (Plate-6h)of family Priacanthidae was observed from all along the three seas (Arabian Sea at 12°48 N; 73°24′ E depth of 177 m, Bay of Bengal at 20°06′-20°32′ N; 87°01′-88°28′ E depth range of 150-200 m and Andaman waters at 11°12′-13°01′ N; 92°35′-93°18′ E depth range of 312-512 m) while, *Cookeolus japonicus* (Plate-6g) and *Pristigenys niphonia* (Plate-6i) were found only in Andaman wasters at 12°82′ N; 93°07′ E depth of 321 m and 12°95′ N; 93°12′ E depth of 329 m respectively. *Apogon apogonides* of family Apogonidae occurred only in Arabian Sea (10°36′-11°16′ N; 74°51′-75°17′ E depth range of 599-706 m). Family Epigonidae represented by the single species *Epigonus* sp. (Plate-6j)was observed only in Andaman waters (11°12′-13°18′ N; 92°35′-93°18′ E depth range of 320-512 m) in the present study. *Nemipterus japonicas* occurred only in Bay of Bengal (20°23-20°32 N; 87°02′-88°28′ E depth of 150 m) whereas, *Parascolopsis aspinosa* (Plate-6k)reported only in Arabian Sea at 09°24′- 10°55′ N; 75°36′-75°08′ E of depth range 265-333 m and these two species are coming under the family Nemipteridae. *Bathyclupea elongata* (Plate-6l) (Family: Bathyclupeidae) was found all the three regions, Arabian Sea at 10°36-11°11′ N; 74°53′-75°17′ E depth range of 691-706 m, Bay of Bengal at 10°58′ N; 80°19′ E depth of 637 m and Andaman waters at 12°95′ N; 93°12′ E depth of 329 m whereas, *B. hoskynii* was found only in Arabian Sea at 09°24′-13°47′ N; 73°21′-75°36′ E depth range of 238-565 m. *Owstonia weberi* (Plate-7a) was found only in Andaman waters at 13°18′ N; 93°13′ E of depth 320 m, whereas *Sphenanthias simoterus* was found only in Arabian Sea at 10°16′-11°16′ N; 74°51′-75°33′ E of depth range 599-777m and these two species belong to the family Cepolidae. *Champsodon capensis* (Plate-7b) of family Champsodontidae was found only in Arabian Sea (12°48′-14°39′ N; 73°01′-73°24′ E of depth range 177-602 m). *Bembrops caudimacula* (Plate-7c) and *B. platyrhynchus* (Plate-7d) of family Percophidae were encountered in Arabian Sea (11°33′-12°49′ N; 74°02′-74°82′ E depth range of 238-328 m) and Andaman waters (12°75′-13°01′ N; 93°07′-93°18′ E depth range of 321-402 m). *Uranoscopus archionema* (Plate-7e) (Uranoscopidae) was found only in Arabian Sea at 09°35′-12°49′ N; 74°02′-75°8′ E depth range of 229-565 m while, *Bathygobius sp.* (Plate-7f) (Gobiidae) was found in Arabian Sea and Bay of Bengal (12°39′-13°47′ N; 73°21′-74°08′ E of depth range 177-238 m and 20°32′ N; 88°28′ E of depth 150 m respectively). Six species belonges to family Gempylidae were recorded in the present study. *Gempylus serpens* (Plate-7g) was found only in Arabian Sea (09°24′ N; 75°36′ E depth of 333 m), *Neoepinnula orientalis* (Plate-7h) and *Rexea prometheoides* (Plate-7j) occurred in all three regions (Arabian Sea at 09°24′-14°54′ N; 72°59′-75°08′ E depth range of 229-602 m and 09°24′N; 75° 36′ E depth of 333 m, Bay of Bengal at 10°58′-20°32′ N; 80°19′-88°28′ E depth range of 150-637 m and 10°58′ N; 80°19′ E depth of 637 m and Andaman waters at 11°12′ N; 92°35′ E depth of

512m and 12°82′-13°18′ N; 93°07′-93°13′ E depth range 320-329 m respectively), *Promethichthys prometheus* (Plate-7i) was found in Arabian Sea at 10°55′-14°54′ N; 72°59′-74°82′ E of depth range 238-599 m and Bay of Bengal at 18°26′ N; 84°46′ E of depth 214 m, whereas *Ruvettus pretiosus,* (Plate-7k) and *Thyrsitoides marleyi* were found only in Arabian Sea but in different locations and depth 09°24′ N; 75°36′ E depth of 333 m and 09°28′ N; 75°63′ E depth of 524 m respectively. From Trichiuridae *Benthodesmus tuckeri* was noticed only in Andaman waters at 11°12′ N; 92°3′5 E of 512 m depth, while *Trichiurus auriga* (Plate-8a) and *Trichiurus lepturus* were found in Bay of Bengal (19°23′ N; 85°02′ E depth of 150 m) and Andaman waters (11°12′-13°18′ N; 92°35′-93°25′ E depth range of 512-538 m). *Psenopsis cyanea* (Plate-8b) from Centrolophidae is one of the largest distributed species found in all the three regions of Arabian Sea (09°24′-14°54′ N; 72°59′-75°36′ E depth range of 229-692 m) Bay of Bengal (20°32′ N; 88°28′ E depth of 150 m and Andaman waters (11°12′-12°82′ N; 92°35′-93°07′E depth range of 321-512m). *Cubiceps baxteri* (Plate-8c) (Nomeidae) was found in Arabian Sea (12°42′-14°39′ N; 73°01′-74°12′ E depth of 602-740 m) and Andaman waters (11°12′-13°01′ N; 92°35′-93°18′ E depth range of 312-512m), *C. pauciradiatus* was recorded only in Andaman waters (11°12′-13°01′ N; 92°35′-93°18′ E depth range of 402-512 m), *C. whiteleggii* (Plate-8d) was found in Arabian Sea (12°42′ N; 74°12′ E depth of 740 m) and Andaman waters (12°82′-13°01′ N; 93°07′-93°18′ E depth range of 321-402 m) and *Cubiceps* sp. was represented only in Andaman waters (13°01′ N; 93°18′ E depth of 402 m). *Ariomma indicum* of Ariommatidae were found only in Arabian Sea at 10°36′-11°44′ N; 74°03′-75°17′ E depth range of 238-706 m.

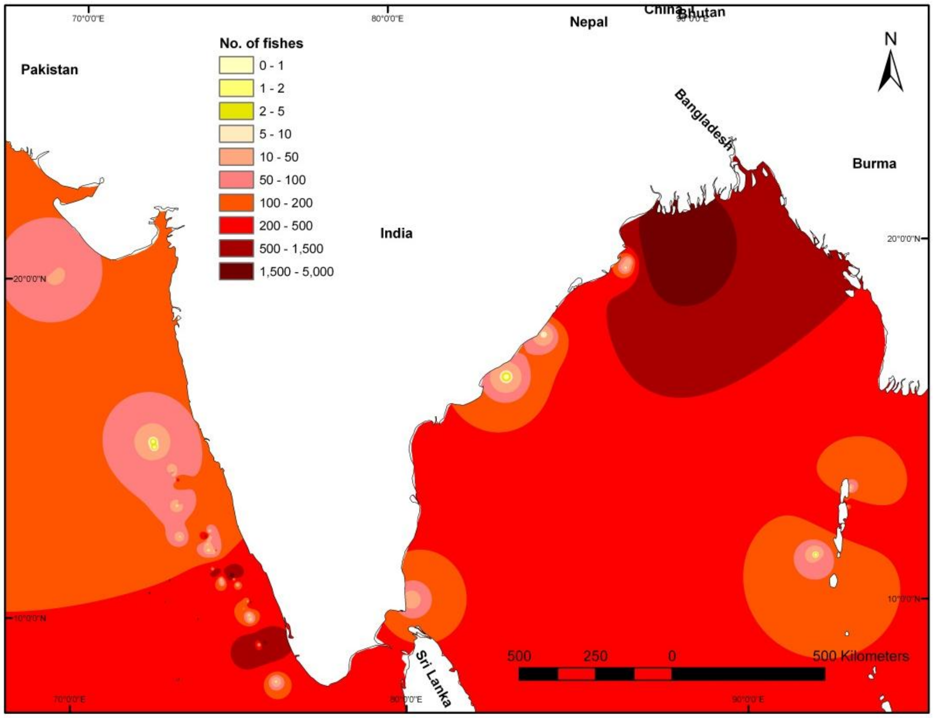


Fig.4.23. Map showing geographical distribution of the order Perciformes

Order: Pleuronectiformes

Distribution of the order Pleuronectiformes is plotted in figure 4.24 and listed in Table-1. This order represented by five families, eight genera and nine species. *Psettodes erumei* (Plate-8e) (Family: Psettodidae) was found only in Arabian Sea at 12°26′ N; 74°07′ E of depth range 722 m. From family Bothidae, *Chascanopsetta lugubris* (Plate-8.f) (11°33′-12°08′ N; 74°03′-74°82′ E depth range of 238-328 m), *Laeops macrophthalmus* (Plate-8g) (11°22′-11°23′ N; 74°49′-74°87′ E depth range of 168-666 m) and *Psettina brevirictis* (12°48′-13°47′ N; 73°21′-73°24′ E depth range of 177-238 m) were found only in Arabian Sea but in different locations and depth ranges whereas, *Neolaeops microphthalmus* was found in Arabian Sea (11°33′-12°49′ N; 74°02′-74°82′ E depth range of 256-259 m) and Andaman waters (12°95′-13°18′ N; 93°12′-93°13′ E of depth range 320-329 m). *Samaris* *cristatus* of family Samaridae and *Aesopia cornuta* (Plate-8h)of family Soleidae were found only in Arabian Sea (11°44′ N; 74°03′ E depth of 238 m and 09°24′-14°54′ N; 72°59′-75°36′ E depth range of 229-333 m respectively). *Cynoglossus arel* of family Cynoglossidae was also found only in Arabian Sea (11°22′ N; 74°49′ E depth of 168 m) whereas, *C. carpenteri* was observed from both Arabian Sea (11°33′-13°47′ N; 73°21′-74°82′ E depth range of 177-259 m) and Bay of Bengal (20°32′ N; 88°28′ E depth of 150 m).

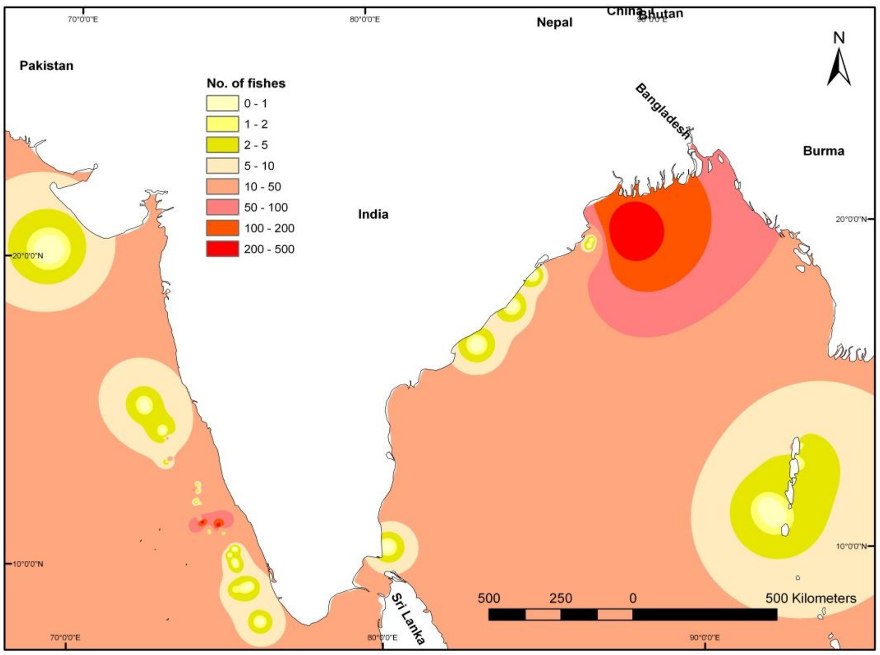


Fig.4.24. Map showing geographical distribution of the order Pleuronectiformes

Order: Tetraodontiformes

Distribution of the order Tetradontiformes is plotted in figure 4.25 and listed in Table-1. This order was represented by a single family (Triacanthodidae) with three genera and three species. The order found only in Andaman waters. *Macrorhamphosodes uradoi* (Plate-8i) and *Tydemania navigatoris* were observed from almost same locations (13°01′-13°18′ N; 93°13′-93°18′ E of depth range 320-402 m) whereas, *Paratriacanthodes retrospinis* was recorded only from a single location (13°18′ N; 93°13′ E depth of 320 m).

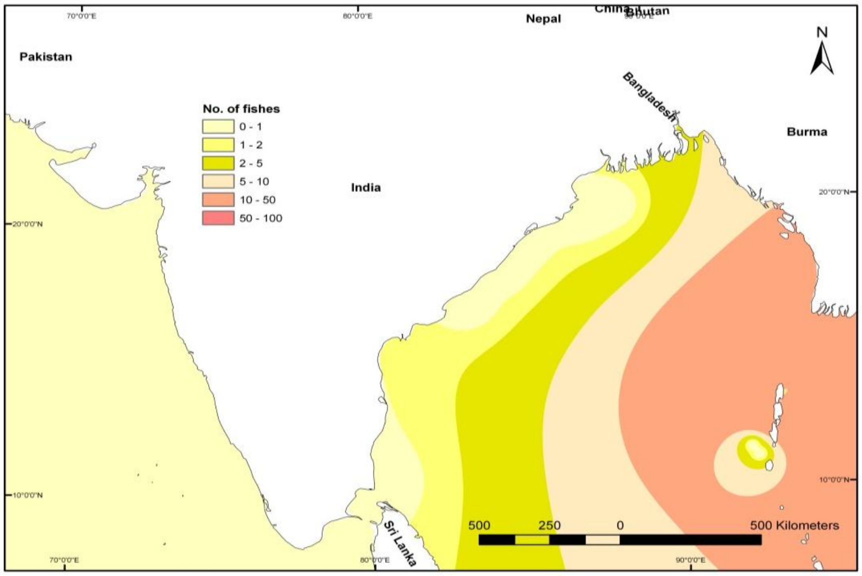


Fig.4.25. Map showing geographical distribution of the order Tetraodontiformes

(ii) Bathymetric Distribution

Six depth strata were selected for studying the depth wise distribution of deep sea fishes Viz. 150-200 m, 201-400 m, 401-600 m, 601-800 m, 801-1000 m and >1000 m. The results showed that maximum number of species was recorded in the 201-400 m (112 species) followed by 601-800 m (101 species) and 401-600 m (82 species). Rest of the depth ranges shows very low number of species Fig. 4.26.

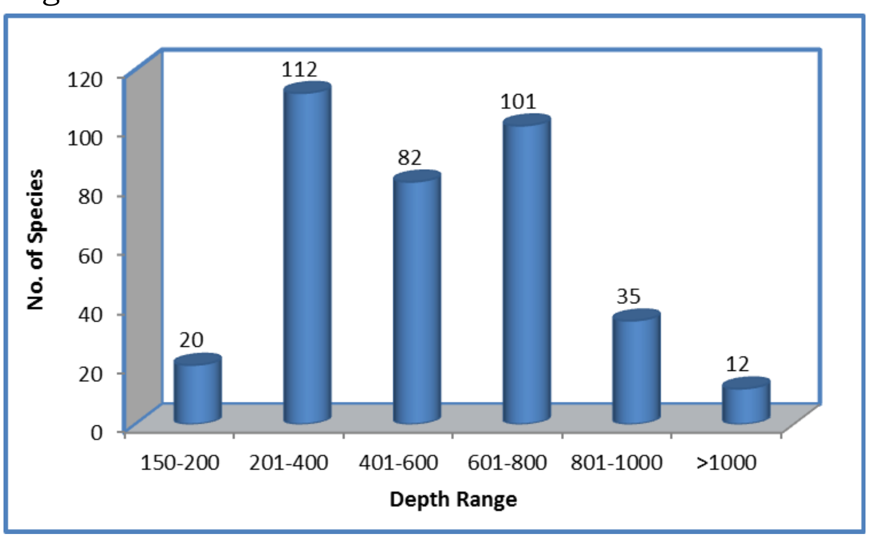


Fig. 4.26 Distribution of deep-sea fishes in different depth ranges.

The most abundant species were *Psenopsis cyanea, Bembrops caudimacula, Chlorophthalmus bicornis, C. agassizi, Uranoscopus archionema, Gavialiceps taeniola, Priacanthus hamrur* and *Neoepinnula orientalis* respectively. No species was found in all the depth ranges. Only two species were found in five depth ranges *Bathyuroconger vicinus* and *Alepocephalus bicolor* in 201-400 m, 401-600 m, 601-800 m, 801-1000 m, >1000 m. Ten Species were found in Four depth ranges – *Benthobatis moresbyi, Chauliodus sloani, Luciobrotula bartschi, Lophiomus setigerus* and *Hoplostethus mediterraneus* in 201-400 m, 401-600 m, 601-800 m and 801-1000 m whereas *Coryphaenoides macrolophus* in 201-400 m, 401-600 m, 601-800 m and > 1000 m and *Psenopsis cyanea* and *Neoepinnula orientalis* 150-200 m, 201-400 m, 401-600 m and 601-800 m. Very restricted distribution was showed by *Anoplogastercornuta* and *Bassozetus robustus* in the depth range of 801-1000 and>1000m only.

4.2.2. Community Structure

(i) Diversity Indices

Different diversity indices calculated from square root transformed deep-sea fish abundance matrix**.** Since the data gathered is so diverse, the data collected from various regions viz. Arabian Sea, Bay of Bengal and Andaman waters (Fig.4.27-4.32) were pooled and used for further analysis. Analysis of pooled data depth-wise (150-200 m, 201-400 m, 401-600 m, 601-800 m, 801-1000 m, >1000 m) (Figs.4.33-4.38) across all stations was also made. Shannon - Wiener diversity index (H'log2), Margalef richness index (d), Pielou's evenness index (J'), Simpson dominance (λ), Average Taxonomic distinctness (∆+) and Variation in taxonomic distinctness (λ+) were calculated with respect to different regions and depth zones.

As indicated by the Shannon - Wiener diversity index, highest diversity was observed in Arabian Sea (4.95) followed by Andaman Waters (4.12) and Bay of Bengal (3.55) (Fig. 4.27). Species Richness also showed the above pattern (Arabian Sea-13.12, Andaman Waters-7.8 and Bay of Bengal -5.67) (Fig. 4.28). Species Evenness was highest in Arabian Sea (0.69), followed by Andaman Waters (0.67) and Bay of Bengal (0.62)(Fig.4.29). The dominance index was highest in Bay of Bengal (0.14) and lower in Andaman Waters (0.10) and Arabian Sea (0.06)(Fig.4.30).

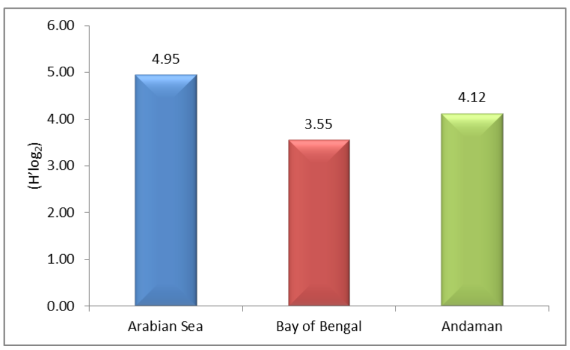


Fig.4.27. Shannon - Wiener diversity index (H'log2) for different Areas

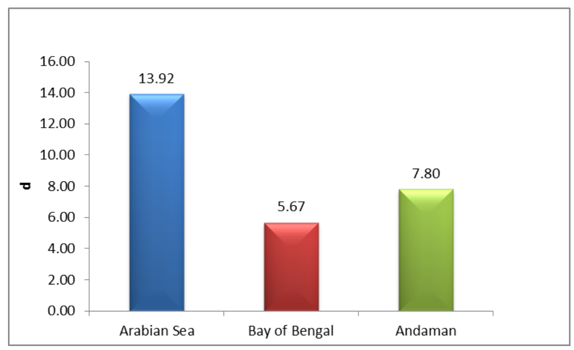


Fig.4.28. Margalef richness index (d) for different Areas

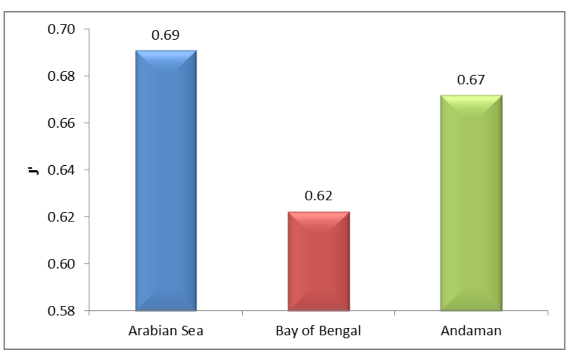


Fig.4.29. Pielou's evenness index (J') for different Areas

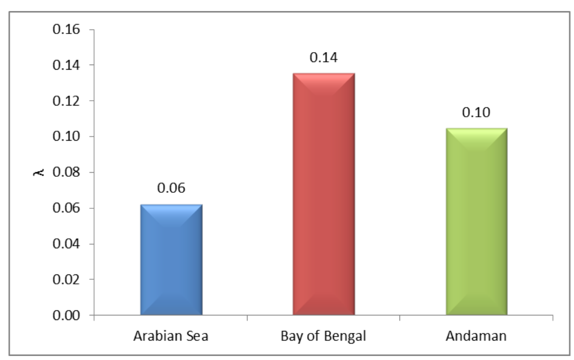


Fig.4.30. Simpson dominance index (λ) for different Areas

Simulation test performed on average taxonomic distinctness (Δ+) using funnel (Fig.4.44) with respect to geographical zones showed all the three regions to fall within the 95% confidence limit. While Δ+ values for the Arabian Sea fell exactly on the mean, those of Bay of Bengal and Andaman deviated slightly from the mean and fell above and below the mean respectively. Variation in taxonomic distinctness (λ+) (Fig.4.45) also showed the λ+ of Andaman and Arabian seas to fall close to the mean and that of Bay of Bengal out of the 95% confidence funnel.

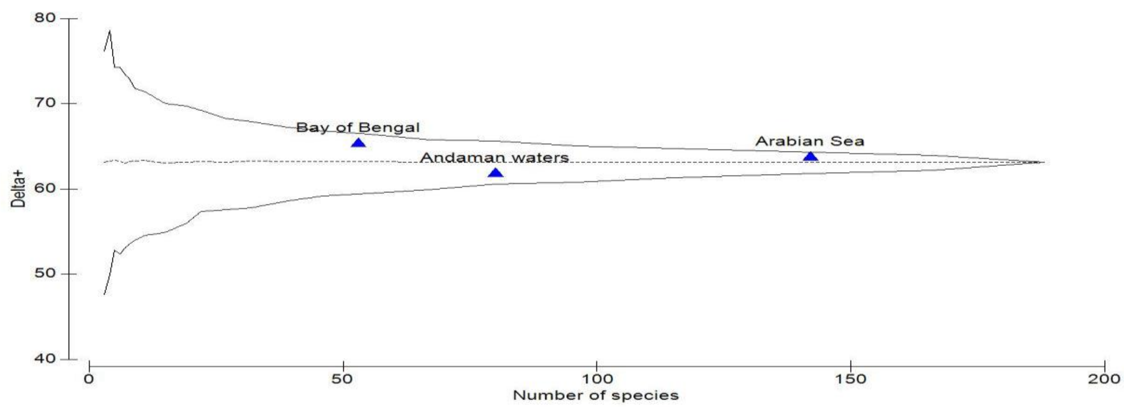


Fig. 4.31. Funnel Plot stimulated for different areas with Average Taxonomic distinctness (Δ+)

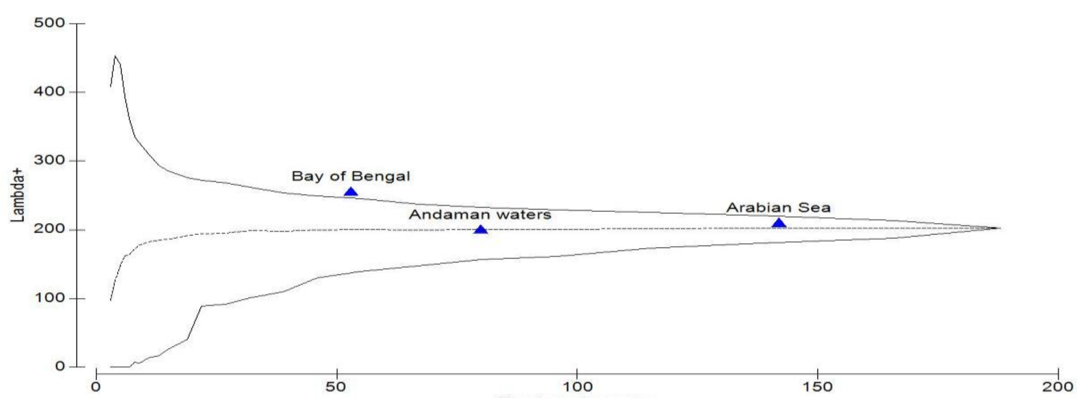


Fig. 4.32. Funnel Plot stimulated for different areas with Variation in taxonomic distinctness (λ+)

Simulation test was also performed with ellipse (Fig. 4.46) combinedly with Δ+ and λ+. This plot showed all the three regions to fall within the 95% confidence ellipse. The skewness of ellipse showed a positive correlation between Δ+ and λ+ ($r = 0.91$; $P<0.05$).

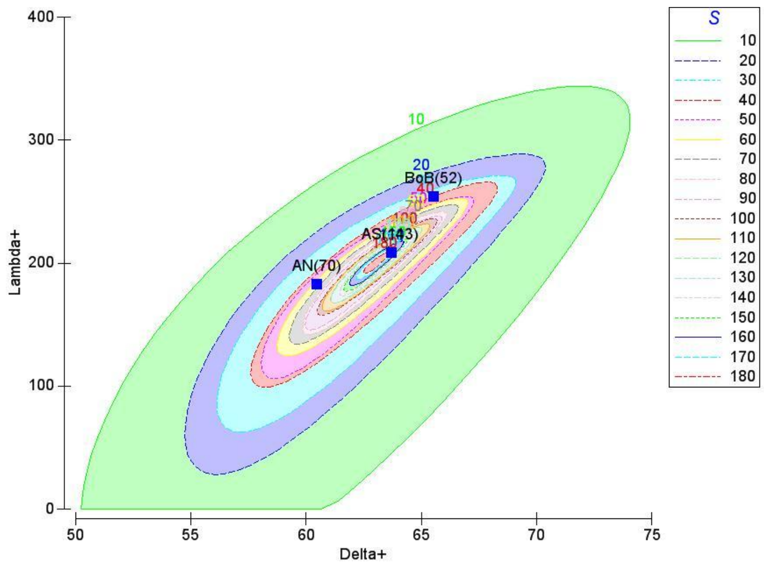


Fig. 4.33.Simulation test performed using ellipses for different areas with Average in taxonomic distinctness (Δ+) and Variation in taxonomic distinctness (λ+)

The diversity indices of various geographical zones of study were compared using ANOVA. Diversity index ($F_{2,56} = 4.13$; $P<0.05$), Species richness ($F_{2,56} = 3.79$; $P<0.05$), Dominance index ($F_{2,56} = 3.34$; $P<0.05$) and Average taxonomic distinctness ($F_{2,56} = 5.34$; $P<0.05$) showed significant differences. However Evenness index ($F_{2,56} = 0.211$; $P>0.05$) and Variation in taxonomic distinctness ($F_{2,56} = 2.91$; $P>0.05$) did not differ significantly among the different geographical zones.

The depth-wise diversity was high in 601-800m (4.87), followed by 401-600m (4.67) and the lowest was recorded in 150-200m (2.75) (Fig.4.34). Same way the species richness was high in 601-800m (11.57) followed by 201-400m (11.00) and the lowest was in 150-200m (2.16)(Fig.4.35). Species evenness was high in >1000m (0.81) followed by 801-1000m (0.78) and the lowest was in 150-200m (0.64)(Fig.4.36).

The species dominance was high in 150-200m (0.20) followed by >1000m (0.19) and the lowest was in 601-800m (0.06) (Fig.4.37).

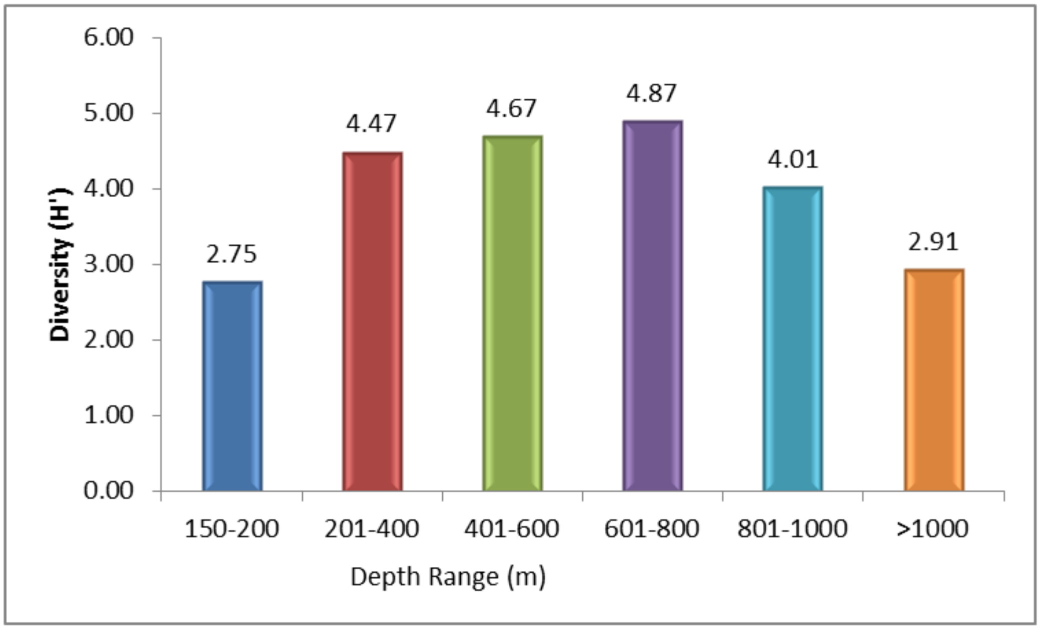


Fig. 4.34. Shannon - Wiener diversity index (H'log2) of deep -sea fishes in different depth ranges

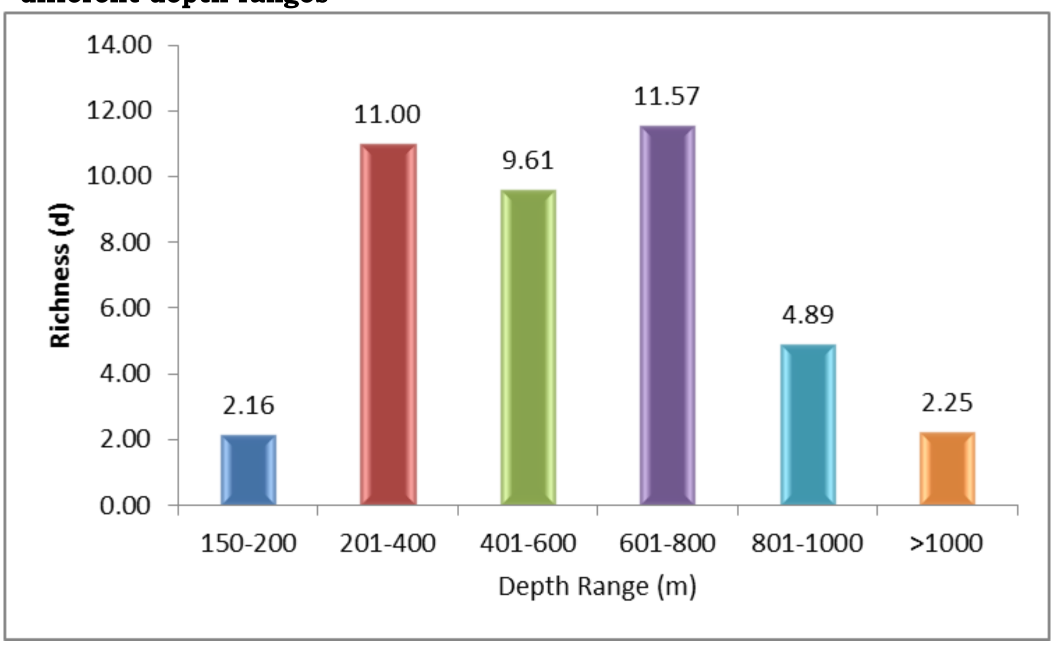


Fig. 4.35.Margalef richness index (d) of deep -sea fishes in different depth ranges

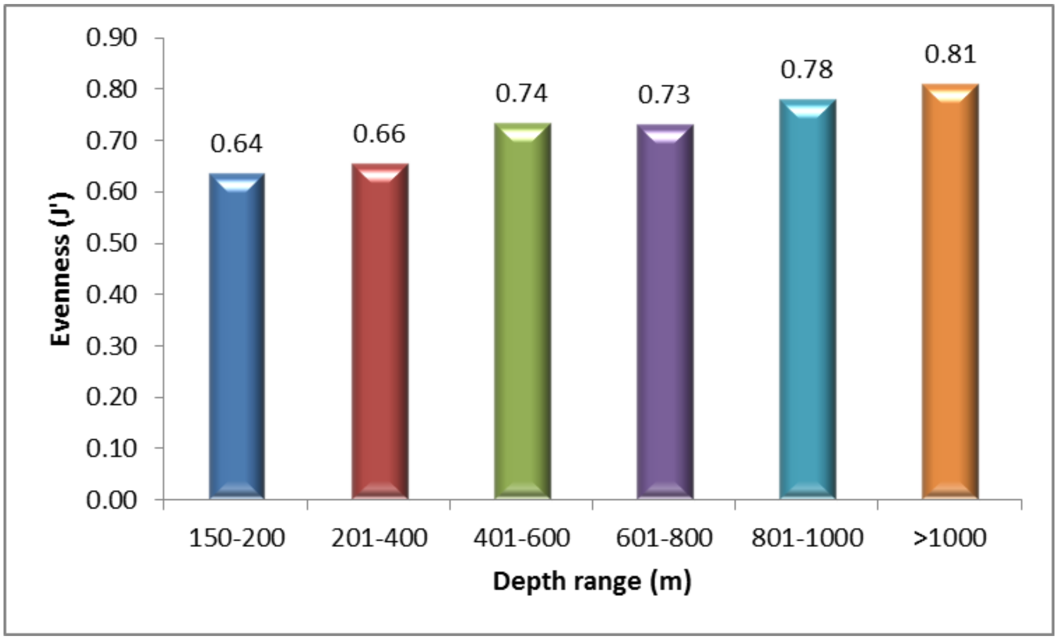


Fig. 4.36.Pielou's evenness index (J′) of deep -sea fishes in different depth ranges

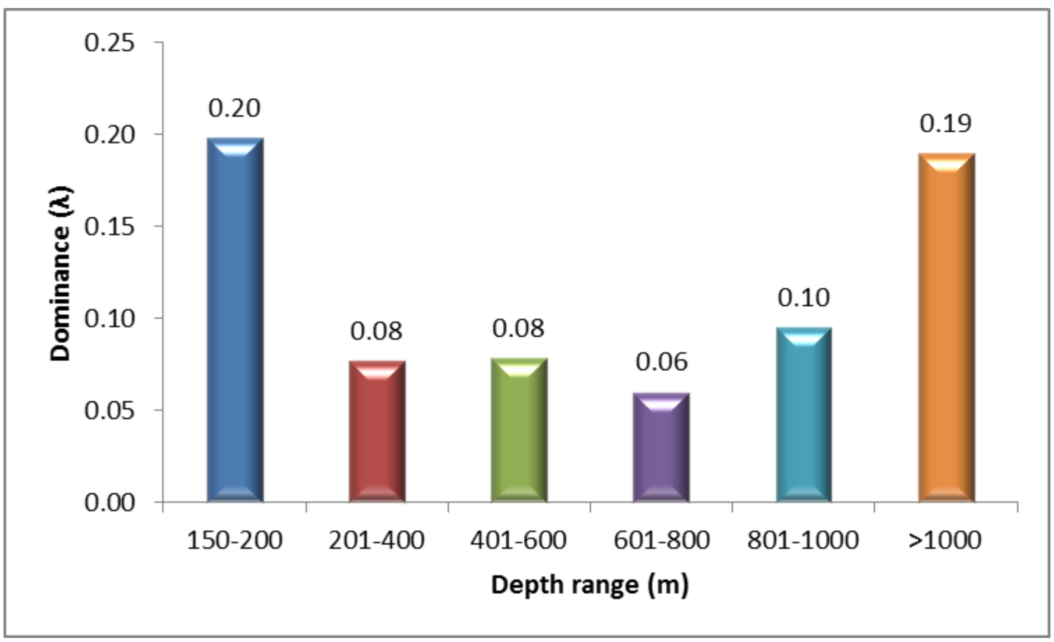


Fig. 4.37. Simpson dominance (λ) of deep -sea fishes in different depth ranges

Funnel plot was drawn by simulation for the various depth zones with average taxonomic distinctness (Δ+) values (Fig.4.38). Results showed all the Δ+ values of the depth ranges to fall within the

95% confidence limit except 601-800 m depth zone, which fell above the funnel. Δ+ values of 401-600 m and >1000 m depth zones were found closer to the mean. Δ+ values of the samples collected from the depths lower than 400m fell below the 95% confidence limit. The variation in taxonomic distinctness (λ+) (Fig.4.39) also showed the above pattern.

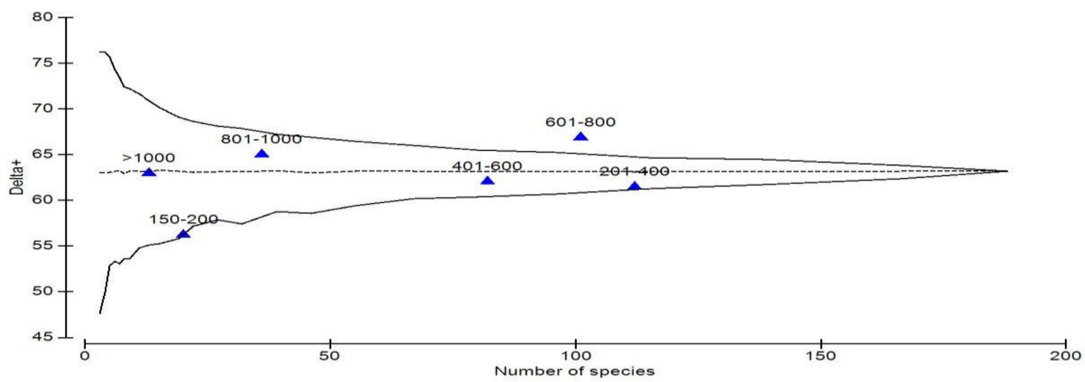


Fig. 4.38. Funnel plot stimulated for different depth ranges with average Taxonomic distinctness (Δ+) values

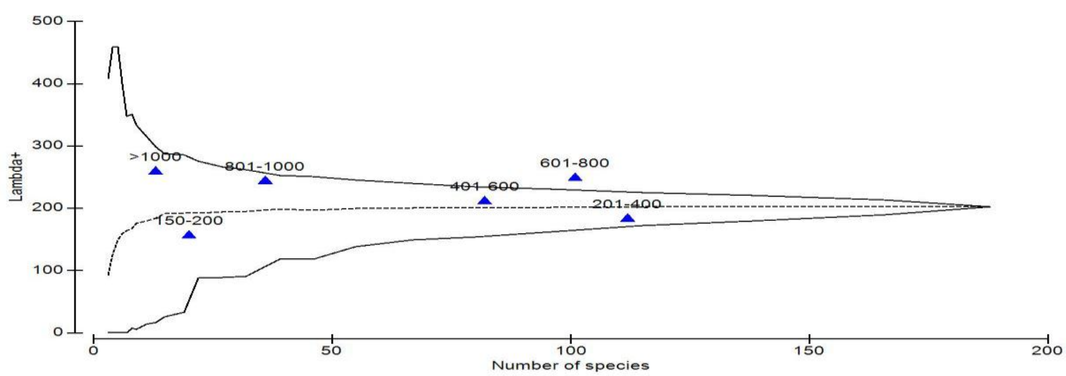


Fig. 4.39.Funnel plot stimulated for different depth ranges with variation in taxonomic distinctness (λ+) values

Simulation test performed with ellipses (Fig.4.40) on Δ+ and λ+ together showed all the six depth zones to fall within the 95% confidence limit. The skewness of ellipse showed a positive correlation between Δ+ and λ+ which was confirmed by high correlation coefficient ($r = 0.87$; $P<0.05$).

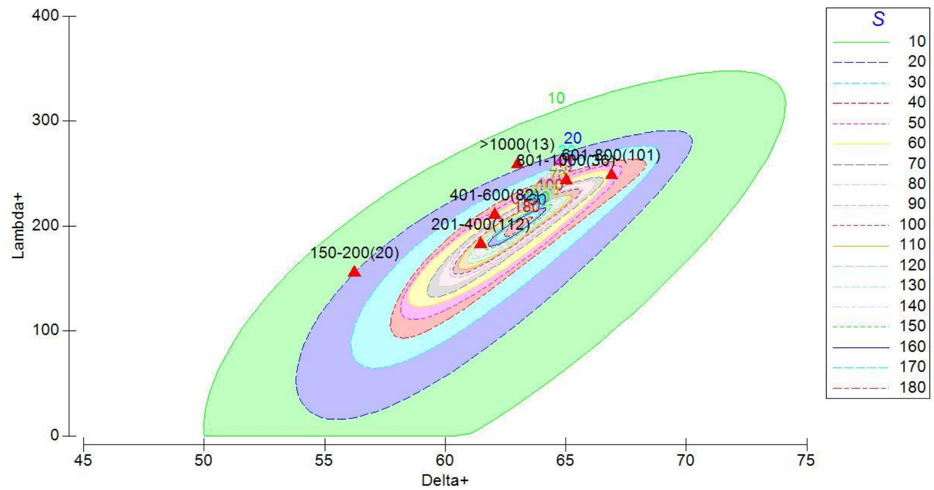


Fig. 4.40.Simulation test performed using ellipse for different depth ranges combinedly with average taxonomic distinctness (Δ+) and variation in taxonomic distinctness (λ+) values

Various indices viz. diversity index ($F_{2,56}$ = 1.77; P > 0.05), Species richness ($F_{2,56}$ = 2.16; P>0.05), dominance index ($F_{2,56}$ = 1.57; P>0.05), Evenness index ($F_{2,56}$ = 1.50; P>0.05) and Variation in taxonomic distinctness ($F_{2,56}$ = 1.75; P>0.05) showed no significant differences between different depth zones. However, Average taxonomic distinctness ($F_{2,56}$ = 4.73; P<0.05) showed significant variation between the various depth zones.

The *k*-dominance curve for different geographical zones revealed that abundance of first ten species contributed about 66.4, 87.3 and 73.6% of the total abundance of Arabian Sea, Bay of Bengal and Andaman waters respectively (Table-4.2, Fig. 4.41). The *k*-dominance plot for all the three geographical zones followed the typical sigmoid pattern.

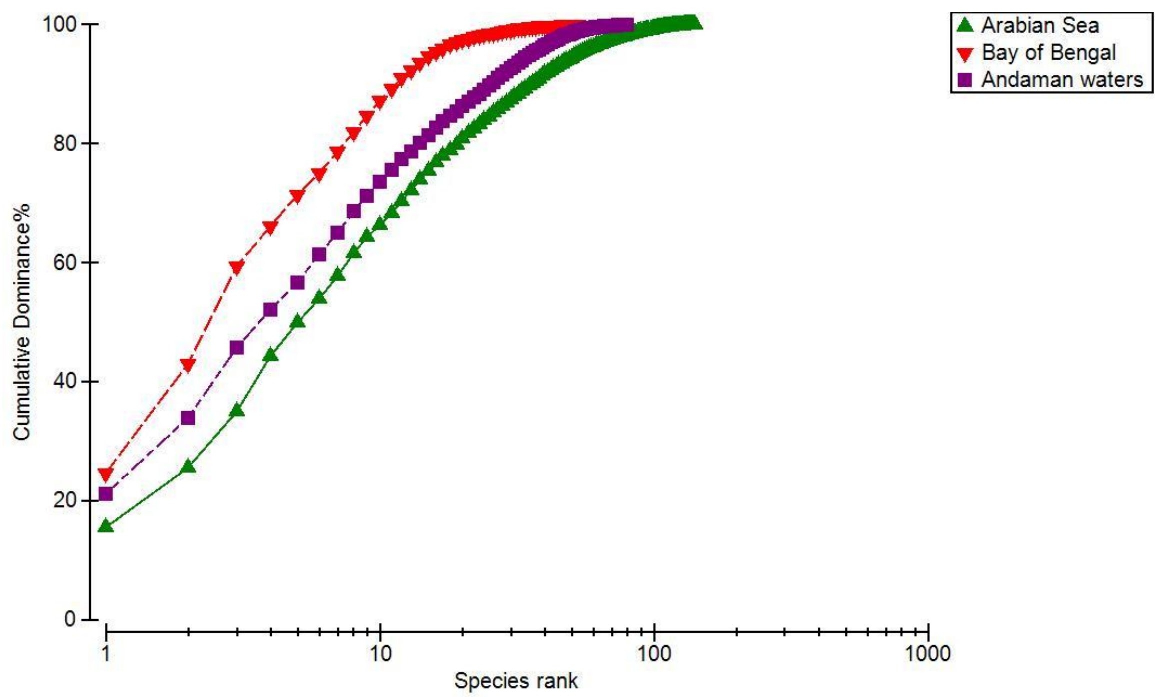


Fig. 4.41.*k*-dominance plot for the three geographical zones

k-dominance of different depth zones was also plotted which revealed that the first ten species accounted for about 97% (>1000 m), 79.2% (801-1000 m), 64.6% (601-800 m), 67.4% (401-600 m), 73.7% (201-400 m), 98.7% (150-200 m) of the total abundance in each depth ranges respectively (Table- 4.3, Fig.4.42). The *k*-dominance plot for all the depth zones also followed the typical sigmoid pattern and confirmed that deep-sea fish population is not exposed to any fishing or environmental pressure. At both the lowest (150-200m) and highest (>1000m) depth ranges, the diversity was found low (the curves are at the top of plot revealing poor diversity). Diversity was found highest at 601-800 m depth range (curve at the bottom of plot) followed by 401-600 m, 201-400 m, 201-400 m and 801-1000 m. With increase in depth from 150-200 m, the diversity increased up to 601-800 m through 201-400 m. 401-600 m depth ranges and decreased through 801-1000 m to >1000 m.

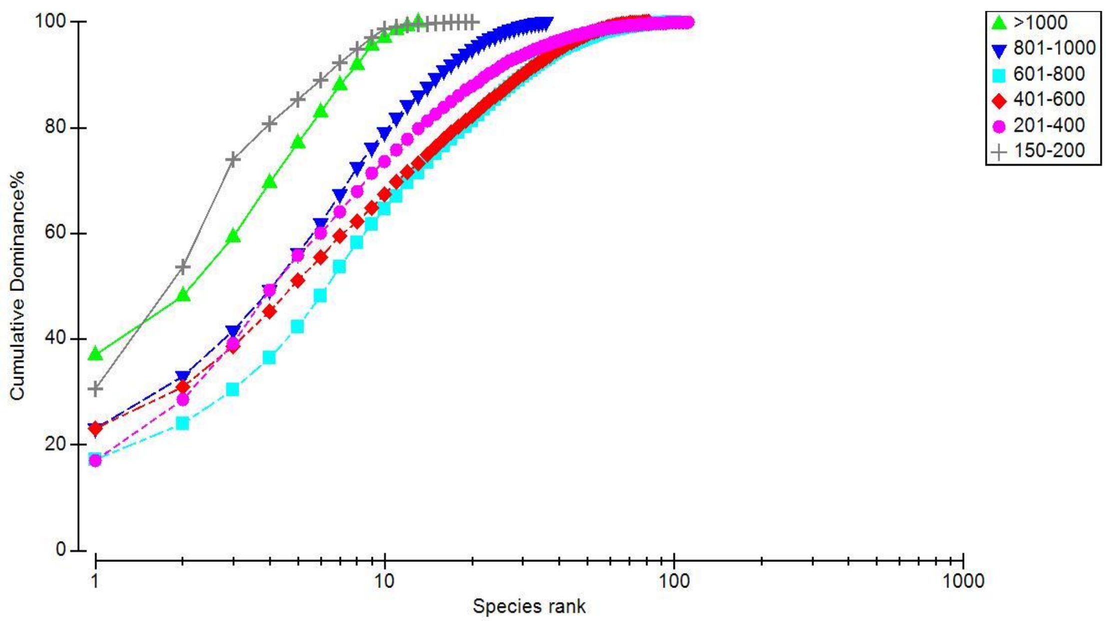


Fig. 4.42. ***k*-dominance plot for the six depth ranges**

(ii) Similarity indices

Cluster analysis adopting Bray-Curtis similarity was performed for comparing the species diversity of deep-sea fishes in different regions and depth zones. Some similarity (26.76%) was observed between Bay of Bengal and Arabian Sea (Fig. 4.43) among the geographical zones. These formed a group to which the Andaman and Nicobar islands joined at a similarity level of around 20%. Changes in species composition were evident from Arabian Sea through Bay of Bengal to Andaman and Nicobar group of islands. Depth-wise, two groups were formed between 401-600m and 601-800m (44.25%) & <200m and 201-400m depth zones (Fig. 4.44). To the first group depth ranges 801-1000m and >1000m joined again revealing a gradual change in species composition with increase in depth. MDS analysis

(Fig. 4.45) also confirmed the above pattern found in dendrogram. When the cluster was superimposed with MDS at the similarity level of 20%, the above pattern became very clear with 3 groups(I group of depths 150-200 m and 201-400 m on the right hand side of the MDS plot, II group of depths with 401-600 m, 601-800 m and 801-1000 m in the middle and III group(>1000m falling on the left hand side of the plot)with 150-200 m on the right hand side and >1000 m on the left hand side of the plot demonstrating the gradual change in species composition. Dendrogram showed 3 groups of depth zones at 20% similarity level. However values of Bray-Curtis Similarity in 401-600 m and 601-800 m fell within 40% similarity contours.

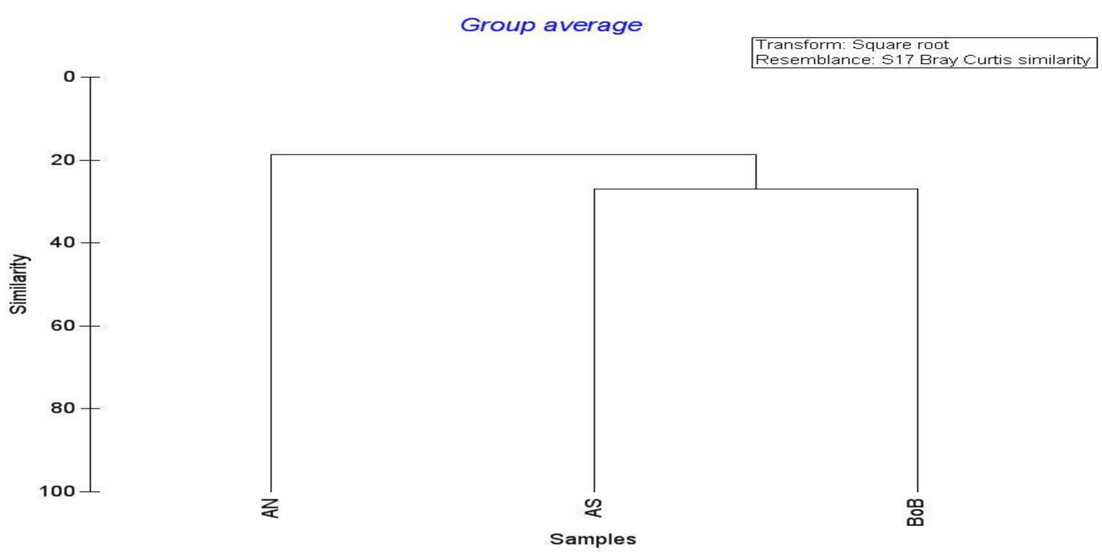


Fig. 4.43. Cluster analysis adopting Bray-Curtis similarity for species diversity of deep-sea fishes in different regions

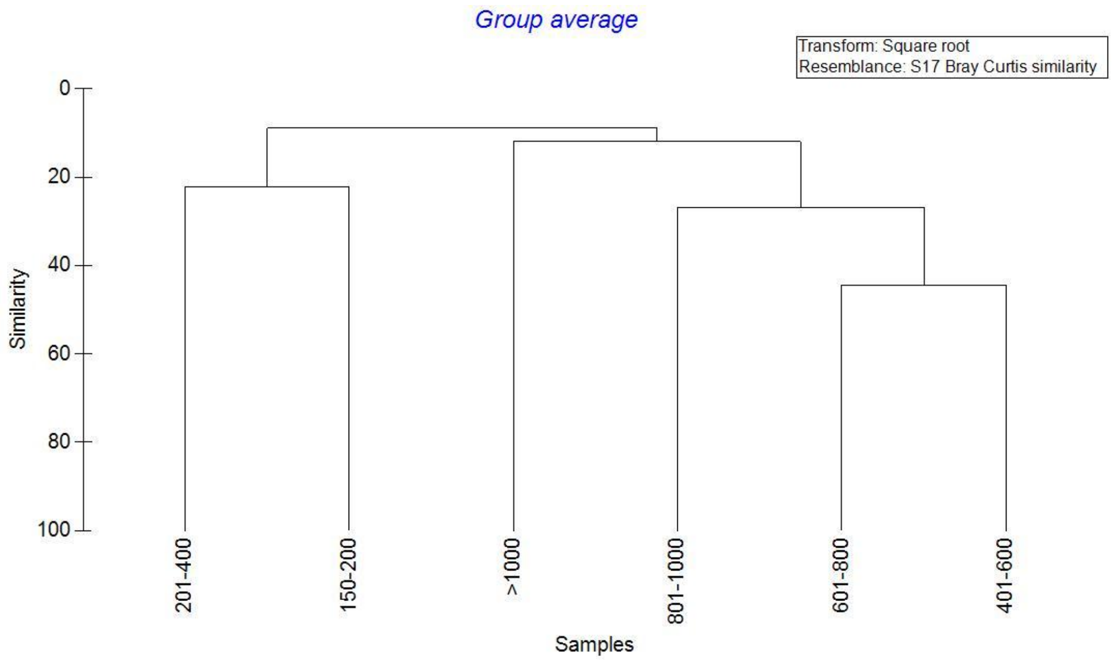


Fig. 4.44. Cluster analysis adopting Bray-Curtis similarity for species diversity of deep-sea fishes in different depth ranges

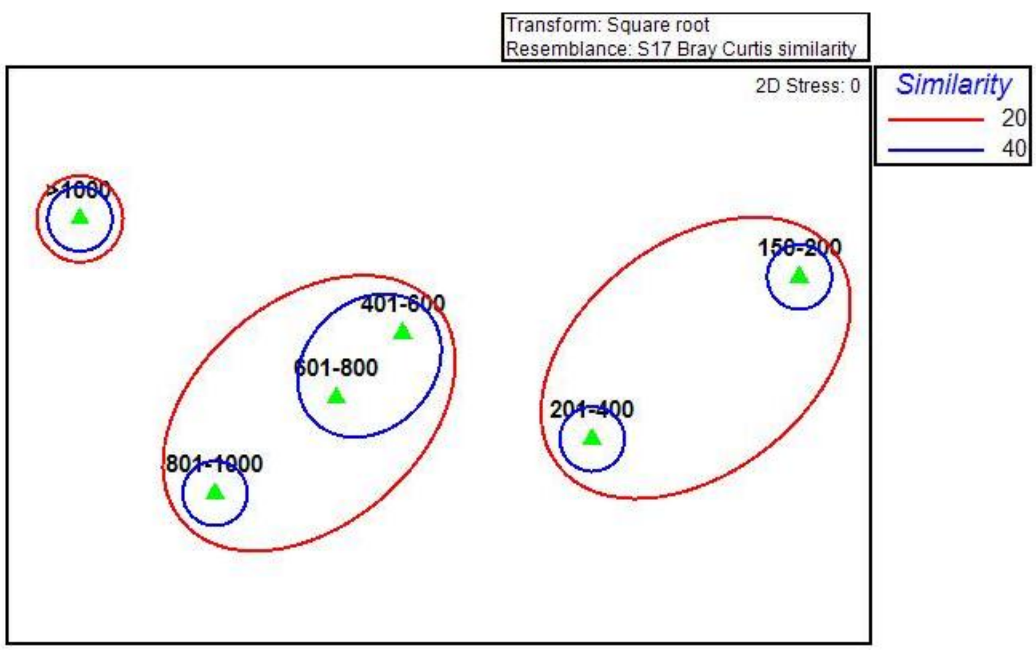


Fig. 4.45.Multi-dimensional Scaling (MDS) adopting Bray-Curtis similarity for species diversity of deep-sea fishes in different depth ranges

4.3. Discussion

Classical works of well-known ichthyologists and naturalists have thrown light on the peculiarities of deep-sea fishes and have also given valuable information on the deep-sea ichthyodiversity of the world. The works of Day (1878), Gunther (1887), Alcock (1889-1905); Goode and Bean (1895), Marshall and Merrett (1977) and Smith and Heemstra (1986) are considered as important scientific contributions to the systematics of deep-sea fishes.

The geographical distribution of deep-sea fishes was explained with distribution maps plotted using *Arc GIS* software for the visualization of the order-wise distribution of deep-sea fishes in the Indian EEZ. Most of the previous studies were confined to a particular area or species. Distribution and diversity of unconventional deep-sea fishery resources of India were studied by few workers viz. Oommen, (1980), Balachandran and Nizar, (1990), Khan *et al.,* (1996), Venu and Kurup, (2002a, 2009a) Jayaprakash *et al.*, (2006), Hashim *et al.*, (2007,2009), Sreedhar *et al.*, (2007) and Sajeevan *et al.*, (2009) done at various depth ranges and geographical areas are given in Table-4.

The diversity indices calculated for individual stations showed significant differences between them. However a specific trend was not evident as the data gathered was so diverse. Therefore, the data was pooled to understand the community structure of deep-sea fishes in the Indian EEZ. The pooling was made based on the geographical location and depth of the operation of nets. The results of classical diversity indices worked out in geographical and bathymetric basis viz. Shannon - Wiener diversity index (H'log2), Margalef richness index (d) and Pielou's evenness index (J') showed similar pattern. Simpson dominance (λ) index showed a reverse pattern to that of other indices.

A total of 188 species were recorded from the Indian EEZ in the present study (Table1). Out of the 188 species recorded, only 12 species were found represented in all the three regions. Eighty two species were observed exclusively in the Arabian Sea only and 29 species were found to have restricted distribution only in Andaman waters. The number of species which were found only in the Bay of Bengal region was 12. The observed highest similarity Bray-Curtis similarity index among the three regions was 26.76% between Arabian Sea and Bay of Bengal. This is comparatively low value suggested considerable difference in the species composition between the three areas. Therefore as far as the deep-sea fishes are concerned, these three areas can be considered as three different zones.

Most of the species were found distributed mainly in the depth between 200 and 800 m. Hence the depth between 200 and 800 m can be considered as the important habitat for deep-sea fishes. The depth-wise distribution showed some species to have a very strict depth preference like *Anoplogaster cornuta* and *Bassozetus robustus* which were found only beyond 800 m depth. At the same time species like *Bathyuroconger vicinus* and *Alepocephalus bicolor* were found to have very wide distribution in terms of depth. The results agree with the observations of Haedrich, (1997) who said that in the deep ocean, great diversity occurs at mid-depths. Also Merrett (1994) listed 80 species in the pelagic region at depths of <400 m and 505 species in deeper water similar to results observed in this study. Shannon - Wiener diversity index was indicated lowest diversity for the <200 m depths, which may probably also due to low sampling in this coastal ecosystem.

Present analysis of community structure showed highest species diversity in the Arabian Sea (4.95) and the lowest in Bay of Bengal

(3.55). Arabian Sea forms one of the most productive regions of Indian EEZ (Prasannakumar, 2000) and supports vast pelagic and benthic fishery resources (Longhurst and Wooster, 1990; Sathyaprakash and Remesh, 2007). Bay of Bengal is less productive (Prasannakumar, 2002), which in turn gets reflected in the lower abundance and diversity of fishes (Haedrich, 1997). The oceanographic conditions differ considerably between these regions (Madhupratap *et al.*, 2001) and the less productive system of Bay of Bengal supports particular species of deep sea fishes such as *Bathygobius* sp., *Priacanthus hamrur* and *Psenopsis cyanea*. Confirming the observations was the trend of Richness index and Dominance index.

Present study revealed the potential of average taxonomic distinctness (Δ+) and variation in taxonomic distinctness (λ+) as perfect tools to describe the spatial pattern of diversity rather than considering occurrence and abundance. These tools explain the environmental or anthropogenic impact on the ecosystem much better than the classical diversity indices. Clarke and Warwick (1998) remarked that these tools can work well with habitats or areas with naturally lower values of average taxonomic distinctness and unless these areas are disturbed in one or other way, their Δ+ values should fall within expectations. In the present study rarely some of the values fell outside the expected limits that too due to uneven sampling effort.

In conclusion, the present study did not encounter any environmental or anthropogenic impact on the deep-sea fish communities as evident in the *k*-dominance curve. The analysis of the community structure; including the diversity and similarity indices of deep-sea fishes revealed that the resources remain virgin and indicate scope for some limited commercial exploitation in a sustainable manner.

Table.4.1. Geographical distribution of deep-sea fishes along the Indian EEZ

S. No	Order/Family/Species	Arabian Sea	Bay of Bengal	Andaman Waters
	Order: Myxiniformes			
I	Family: Myxinidae			
1	*Eptatretus hexatrema* (Müller 1836)		✓	
	Order: Chimaeriformes			
II	Family: Rhinochimaeridae			
2	*Neoharriotta pinnata* (Schnakenbeck 1931)	✓		✓
III	Family: Chimaeridae			
3	*Hydrolagus africanus* (Gilchrist 1922)	✓	✓	
	Order: Carcharhiniformes			
IV	Family: Scyliorhinidae			
4	*Apristurus indicus* (Brauer 1906)	✓	✓	
5	*Apristurus investigatoris*(Misra 1962)	✓	✓	
6	*Apristurus microps* (Gilchrist 1922)		✓	✓
7	*Bythaelurus hispidus* (Alcock 1891)	✓		
8	*Bythaelurus lutarius* (Springer & D'Aubrey 1972)	✓		
9	*Cephaloscyllium silasi* (Talwar 1974)	✓		
10	*Halaelurus* sp.	✓		
V	Family: Proscyllidae			
11	*Eridacnis sinuans* (Smith 1957)	✓	✓	
12	*Eridacnis radcliffei* Smith 1913	✓	✓	✓
	Order: Echinorhiniformes			
VI	Family: Echinorhinidae			
13	*Echinorhinus brucus* (Bonnaterre 1788)	✓		
	Order: Squaliformes			
VII	Family: Centrophoridae			
14	*Centrophorus* cf *granulosus* (Bloch & Schneider 1801)	✓		
15	*Centrophorus* cf *lusitanicus* Barbosa du Bocage & de Brito Capello 1864	✓		
16	*Centrophorus moluccensis* Bleeker 1860	✓		✓
17	*Centrophorus squamosus* (Bonnaterre 1788)	✓		
VIII	Family: Etmopteridae			
18	*Centroscyllium fabricii* (Reinhardt 1825)	✓		
19	*Etmopterus granulosus* (Günther 1880)	✓	✓	
20	*Etmopterus pusillus* (Lowe 1839)		✓	
IX	Family: Somniosidae			

21	*Centroscymnus crepidater* (Barbosa du Bocage & de Brito Capello 1864)	✓		
	Order: Torpediniformes			
X	Family: Narcinidae			
22	*Benthobatis moresbyi* Alcock 1898	✓	✓	✓
	Order: Rajiformes			
XI	Family: Rajidae			
23	*Cruriraja andamanica* (Lloyd 1909)			✓
24	*Dipturus johannisdavisi* (Alcock 1899)		✓	
25	*Leucoraja circularis* (Couch 1838)	✓		
26	*Raja miraletus* Linnaeus 1758	✓		
	Order: Myliobatiformes			
XII	Family: Plesiobatidae			
27	*Plesiobatis daviesi* (Wallace 1967)			✓
XIII	Family: Dasyatidae			
28	*Pteroplatytrygon violacea* (Bonaparte 1832)	✓		
	Order: Albuliformes			
XIV	Family: Notacanthidae			
29	*Notacanthus sexspinis* Richardson 1846	✓		
	Order: Anguilliformes			
XV	Family: Synaphobranchidae			
30	*Ilyophis brunneus* Gilbert 1891	✓		
31	*Synaphobranchus affinis* Günther 1877	✓	✓	
XVI	Family: Colocongridae			
32	*Coloconger raniceps* Alcock 1889	✓	✓	
33	*Coloconger scholesi* Chan, 1967	✓	✓	
XVII	Family: Nemichthyidae			
34	*Avocettina paucipora* Nielsen & Smith, 1978	✓		
35	*Nemichthys scolopaceus* Richardson 1848	✓	✓	✓
XVIII	Family: Congridae			
36	*Bathyuroconger vicinus* (Vaillant 1888)	✓	✓	
37	*Gavialiceps taeniola* Alcock 1889	✓	✓	
38	*Xenomystax trucidans* Alcock 1894	✓		
XIX	Family: Serrivomeridae			
39	*Serrivomer beanii Gill & Ryder, 1883*			✓
	Order: Argentiniformes			
XX	Family: Platytroctidae			
40	*Maulisia mauli* Parr 1960	✓		
41	*Normichthys yahganorum* Lavenberg 1965	✓		

XXI	Family: Alepocephalidae			
42	*Alepocephalus bicolor* Alcock 1891	✓	✓	✓
43	*Alepocephalus blanfordii* Alcock 1892	✓		
44	*Bathytroctes squamosus* Alcock 1890	✓		
45	*Rouleina attrita* (Vaillant 1888)	✓		
46	*Talismania longifilis* (Brauer 1902)	✓		✓
47	*Narcetes lloydi* Fowler 1934	✓		
	Order: Stomiiformes			
XXII	Family: Diplophidae			
48	*Diplophos taenia* Günther 1873	✓		
XXIII	Family: Gonostomatidae			
49	*Cyclothone braueri Jespersen & Tåning, 1926*			✓
50	*Cyclothone microdon* (Günther 1878)			✓
51	*Gonostoma elongatum* Günther 1878	✓		
XXIV	Family: Sternoptychidae			
52	*Argyropelecus affinis* Garman 1899			✓
53	*Argyropelecus hemigymnus* Cocco 1829			✓
54	*Polyipnus indicus* Schultz 1961	✓		
55	*Polyipnus spinosus* Günther 1887	✓		
XXV	Family: Phosichthyidae			
56	*Vinciguerria* sp.	✓		
XXVI	Family: Stomiidae			
57	*Astronesthes indicus* Brauer 1902		✓	
58	*Astronesthes lucifer* Gilbert 1905		✓	✓
59	*Astronesthes martensii* Klunzinger 1871			✓
60	*Astronesthes niger* Richardson 1845	✓		
61	*Chauliodus sloani* Bloch & Schneider 1801	✓		✓
62	*Idiacanthus fasciola* Peters 1877			✓
63	*Malacosteus niger* Ayres 1848			✓
	Order: Ateleopodiformes			
XXVII	Family: Ateleopodidae			
64	*Ateleopus indicus* Alcock 1891	✓		✓
65	*Ijimaia loppei* Roule 1922	✓		
	Order: Aulopiformes			
XXVIII	Family: Synodontidae			
66	*Saurida tumbil (Bloch, 1795)*		✓	
67	*Saurida undosquamis* (Richardson 1848)	✓	✓	
XXIX	Family: Chlorophthalmidae			
68	*Chlorophthalmus agassizi* Bonaparte 1840	✓		
69	*Chlorophthalmus bicornis* Norman 1939	✓		✓
70	*Chlorophthalmus punctatus* Gilchrist	✓		

	1904			
71	*Parasudis truculenta* (Goode & Bean 1896)			✓
XXX	Family: Ipnopidae			
72	*Bathypterois atricolor* Alcock 1896			✓
73	*Bathypterois dubius* Vaillant 1888			✓
XXXI	Family: Evermannellidae			
74	*Evermannella indica* Brauer 1906		✓	
XXXII	Family: Paralepididae			
75	*Stemonosudis macrura* (Ege 1933)	✓		
	Order: Myctophiformes			
XXXIII	Family: Neoscopelidae			
76	*Neoscopelus microchir* Matsubara 1943	✓		✓
77	*Scopelengys tristis* Alcock 1890	✓	✓	
XXXIV	Family: Myctophidae			
78	*Benthosema pterotum* (Alcock 1890)	✓		
79	*Diaphus knappi* Nafpaktitis, 1978			✓
80	*Diaphus lucidus* (Goode & Bean, 1896)			✓
81	*Diaphus watasei* Jordan & Starks 1904	✓		✓
82	*Myctophum obtusirostre* Tåning 1928		✓	
83	*Myctophum nitidulum* Garman 1899		✓	
	Order: Polymixiiformes			
XXXV	Family: Polymixiidae			
84	*Polymixia berndti* Gilbert 1905	✓		
85	*Polymixia japonica* Günther 1877	✓		
86	*Polymixia nobilis* Lowe 1838	✓		
	Order: Gadiformes			
XXXVI	Family: Macrouridae			
87	*Bathygadus melanobranchus* Vaillant 1888	✓		
88	*Coelorinchus braueri Barnard, 1925*			✓
89	*Coelorinchus flabellispinnis* (Alcock 1894)	✓		
90	*Coryphaenoides macrolophus* (Alcock 1889)	✓	✓	✓
91	*Gadomus capensis* (Gilchrist & von Bonde 1924)		✓	
92	*Gadomus* spp.		✓	
93	*Malacocephalus laevis* (Lowe 1843)		✓	
94	*Nezumia propinqua* (Gilbert & Cramer 1897)	✓		✓
95	*Macrurus sp*	✓		
XXXVII	Family: Moridae			
96	*Physiculus roseus* Alcock 1891	✓		

	Order: Ophidiiformes			
XXXVIII	Family: Carapidae			
97	*Snyderidia canina* Gilbert 1905	✓		
XXXIX	Family: Ophidiidae			
98	*Bassozetus robustus* Smith & Radcliffe 1913	✓		
99	*Dicrolene tristis*	✓		
100	*Dicrolene multifilis*(Alcock 1889)	✓	✓	✓
101	*Dicrolene nigricaudis* (Alcock 1891)		✓	✓
102	*Glyptophidium argenteum* Alcock 1889	✓		
103	*Glyptophidium lucidum* Smith & Radcliffe 1913	✓		
104	*Glyptophidium* sp	✓		
105	*Hypopleuron caninum* Smith & Radcliffe 1913	✓	✓	
106	*Lamprogrammus exutus* Nybelin & Poll 1958	✓	✓	
107	*Lamprogrammus niger* Alcock 1891	✓		✓
108	*Luciobrotula bartschi* Smith & Radcliffe 1913	✓	✓	
109	*Luciobrotula sp.*	✓		
110	*Neobythites analis* Barnard 1927	✓		
XL	Family: Bythitidae			
111	*Hephthocara simum* Alcock 1892	✓	✓	
	Order: Lophiiformes			
XLI	Family: Lophiidae			
112	*Lophiodes mutilus* (Alcock 1894)	✓		
113	*Lophiomus setigerus* (Vahl 1797)	✓	✓	✓
XLII	Family: Chaunacidae			
114	*Chaunax pictus* Lowe 1846	✓		✓
XLIII	Family: Ogcocephalidae			
115	*Coelophrys micropa* (Alcock 1891)	✓		
116	*Halieutaea coccinea Alcock, 1889*			✓
117	*Halieutaea fumosa* Alcock 1894	✓		
XLIV	Family: Melanocetidae			
118	*Melanocetus johnsonii* Günther 1864	✓		✓
XLV	Family: Diceratiidae			
119	*Bufoceratias wedli* (Pietschmann 1926)	✓		
XLVI	Family: Oneirodidae			
120	*Oneirodes kreffti* Pietsch 1974	✓		
XLVII	Family: Ceratiidae			
121	*Cryptopsaras couesii* Gill 1883	✓		✓
	Order: Beryciformes			
XLVIII	Family: Anoplogastridae			

122	*Anoplogaster cornuta* (Valenciennes 1833)	✓		
XLIX	Family: Trachichthyidae			
123	*Gephyroberyx darwinii* (Johnson 1866)	✓		
124	*Hoplostethus mediterraneus* Cuvier 1829	✓		
125	*Hoplostethus melanopus* (Weber 1913)	✓		
L	Family: Berycidae			
126	*Beryx decadactylus* Cuvier 182	✓		
127	*Beryx splendens* Lowe 1834	✓		
128	*Berynx* sp.	✓		
LI	Family: Holocentridae			
129	*Ostichthys kaianus* (Günther 1880)	✓		
	Order: Zeiformes			
LII	Family: Parazenidae			
130	*Cyttopsis rosea* (Lowe 1843)	✓		
LIII	Family: Zeidae			
131	*Zenopsis conchifer* (Lowe 1852)	✓		
	Order: Scorpaeniformes			
LIV	Family: Scorpaenidae			
132	*Pontinus nigerimum* Eschmeyer 1983		✓	
LV	Family: Setarchidae			
133	*Ectreposebastes imus* Garman 1899	✓	✓	
134	*Setarches guentheri* Johnson 1862		✓	✓
135	*Setarches longimanus (Alcock, 1894)*			✓
LVI	Family: Triglidae			
136	*Lepidotrigla* sp.	✓		
137	*Pterygotrigla hemisticta* (Temminck & Schlegel 1843)	✓	✓	✓
138	*Pterygotrigla* sp.	✓		
LVII	Family: Peristediidae			
139	*Peristedion miniatum* Goode 1880	✓		✓
140	*Peristedion weberi* Smith 1934			✓
141	*Scalicus investigatoris* (Alcock 1898)			✓
	Order: Perciformes			
LVIII	Family: Acropomatidae			
142	*Acropoma japonicum* Günther 1859	✓		
143	*Synagrops philippinensis* (Günther 1880)	✓		
144	*Synagrops pellucidus*(Alcock 1889)	✓	✓	
LIX	Family: Serranidae			
145	*Chelidoperca investigatoris* (Alcock 1890)	✓		
LX	Family: Priacanthidae			
146	*Cookeolus japonicus (Cuvier, 1829)*			✓

147	*Priacanthus hamrur* (Forsskål 1775)	✓	✓	✓
148	*Pristigenys niphonia* (Cuvier 1829)			✓
LXI	Family: Apogonidae			
149	*Apogon apogonides* (Bleeker 1856)	✓		
LXII	Family: Epigonidae			
150	*Epigonus sp.*			✓
LXIII	Family: Nemipteridae			
151	*Nemipterus japonicus* (Bloch 1791)		✓	
152	*Parascolopsis aspinosa* (Rao & Rao 1981)	✓		
LXIV	Family: Bathyclupeidae			
153	*Bathyclupea elongata* Trunov 1975	✓	✓	✓
154	*Bathyclupea hoskynii* Alcock 1891	✓		
LXV	Family: Cepolidae			
155	*Owstonia weberi* (Gilchrist 1922)			✓
156	*Sphenanthias simoterus* Smith 1968	✓		
LXVI	Family: Champsodontidae			
157	*Champsodon capensis* Regan 1908	✓		
LXVII	Family: Percophidae			
158	*Bembrops caudimacula* Steindachner 1876	✓		✓
159	*Bembrops platyrhynchus* (Alcock 1894)	✓		✓
LXVIII	Family: Uranoscopidae			
160	*Uranoscopus archionema* Regan 1921	✓		
LXIX	Family: Gobiidae			
161	*Bathygobius* sp.	✓	✓	
LXX	Family: Gempylidae			
162	*Gempylus serpens* Cuvier 1829	✓		
163	*Neoepinnula orientalis* (Gilchrist & von Bonde 1924)	✓	✓	✓
164	*Promethichthys prometheus* (Cuvier 1832)	✓	✓	
165	*Rexea prometheoides* (Bleeker 1856)	✓	✓	✓
166	*Ruvettus pretiosus* Cocco 1833	✓		
167	*Thyrsitoides marleyi* Fowler 1929	✓		
LXXI	Family: Trichiuridae			
168	*Benthodesmus tuckeri* Parin & Becker 1970			✓
169	*Trichiurus auriga* Klunzinger 1884		✓	✓
170	*Trichiurus lepturus* Linnaeus 1758		✓	✓
LXXII	Family: Centrolophidae			
171	*Psenopsis cyanea* (Alcock 1890)	✓	✓	✓
LXXIII	Family: Nomeidae			
172	*Cubiceps baxteri* McCulloch 1923	✓		✓

173	*Cubiceps pauciradiatus* Günther 1872			✓
174	*Cubiceps whiteleggii* (Waite 1894)	✓		✓
175	*Cubiceps* sp.			✓
LXXIV	Family: Ariommatidae			
176	*Ariomma indicum* (Day 1871)	✓		
	Order: Pleuronectiformes			
LXXV	Family: Psettodidae			
177	*Psettodes erumei* (Bloch & Schneider 1801)	✓		
LXXVI	Family: Bothidae			
178	*Chascanopsetta lugubris* Alcock 1894	✓		
179	*Laeops macrophthalmus* (Alcock, 1889)	✓		
180	*Neolaeops microphthalmus* (von Bonde 1922)	✓		✓
181	*Psettina brevirictis* (Alcock 1890)	✓		
LXXVII	Family: Samaridae			
182	*Samaris cristatus* Gray 1831	✓		
LXXVIII	Family: Soleidae			
183	*Aesopia cornuta* Kaup 1858	✓		
LXXIX	Family: Cynoglossidae			
184	*Cynoglossus arel* (Bloch & Schneider 1801)	✓		
185	*Cynoglossus carpenteri* Alcock 1889	✓	✓	
	Order: Tetraodontiformes			
LXXX	Family: Triacanthodidae			
186	*Macrorhamphosodes uradoi* (Kamohara 1933)			✓
187	*Paratriacanthodes retrospinis* Fowler, 1934			✓
188	*Tydemania navigatoris* Weber 1913			✓

Table. 4.2. First ten species ranked (based on numbers caught) in different Areas

Rank	Arabian Sea	Bay of Bengal	Andaman
1	*C. agassizi*	*Bathygobius sp.*	*P. truculenta*
2	*C. bicornis*	*P. hamrur*	*P. hamrur*
3	*B. caudimacula*	*P. cyanea*	*D. lucidus*
4	*U. archionema*	*G. taeniola*	*S. guentheri*
5	*G. taeniola*	*C. carpenteri*	*C. braueri*
6	*P. cyanea*	*B. vicinus*	*C. microdon*
7	*N. orientalis*	*T. lepturus*	*Epigonus sp.*
8	*B. moresbyi*	*S. tumbil*	*A. indicus*
9	*E. radcliffei*	*L. exutus*	*R. attrita*
10	*A. bicolor*	*M. obtusirostre*	*C. bicornis*

Table. 4.3. First ten species ranked (based on numbers caught) in different depth ranges.

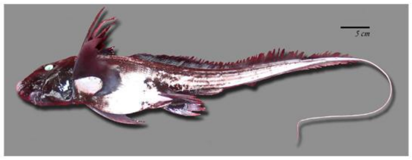
		Depth Ranges	
Rank	**150-200 m**	**201-400 m**	**401-600 m**
1	*Bathygobius sp.*	*C. agassizi*	*G. taeniola*
2	*P. hamrur*	*C. bicornis*	*C. braueri*
3	*P. cyanea*	*B. caudimacula*	*C. microdon*
4	*C. carpenteri*	*U. archionema*	*S. guentheri*
5	*T. lepturus*	*P. truculenta*	*A. bicolor*
6	*S. tumbil*	*P. cyanea*	*E. radcliffei*
7	*M. obtusirostre*	*N. orientalis*	*D. tristis*
8	*N. japonicus*	*P. hamrur*	*Macrurus sp*
9	*M. nitidulum*	*D. lucidus*	*A. indicus*
10	*P. hemisticta*	*S. philippinensis*	*Epigonus sp.*
		Depth Ranges	
Rank	**601-800 m**	**801-1000 m**	**>1000 m**
1	*G. taeniola*	*G. elongatum*	*C. macrolophus*
2	*C. macrolophus*	*L. exutus*	*A. bicolor*
3	*L. exutus*	*G. taeniola*	*A. cornuta*
4	*B. moresbyi*	*B. moresbyi*	*H. simum*
5	*A. bicolor*	*B. melanobranchus*	*L. niger*
6	*B. vicinus*	*A. bicolor*	*D. multifilis*
7	*R. attrita*	*N. scolopaceus*	*B. squamosus*
8	*E. radcliffei*	*G. argenteum*	*B. vicinus*
9	*C. scholesi*	*B. vicinus*	*B. robustus*
10	*D. multifilis*	*M. mauli*	*E. granulosus*

Table. 4.4. Distribution and diversity of nonconventional deep-sea fishery resources of India reported by various authors.

Authors	**Area**	**Depth (m)**	**No. of species**	**Remarks**
Oommen, 1980	Quilon Bank (8-9°N lat.)	175-370	63	Include 5 species of Elasmobranchs
Balachandran and Nizar, 1990	Indian EEZ	100-4524	87	Include both pelagic demersal deep-sea finfishes
Khan *et al.*, 1996	Southeastern Arabian Sea (8-13°N lat.)	170-777	34	Demersal fin fishes
Venu and Kurup, 2002a	West coast of India	201-750	23	Demersal fin fishes
Jayaprakash *et al.,* 2006	Southwest coast 9-16°N lat	115-1070	77	fin fishes and Elasmobranchs
Hashim *et al.*, 2007	North Andaman Seas	300-700	63	fin fishes
Sreedhar *et al.*, 2007	South-west coast of India10-15°N lat	160-770	39	Fin fishes and Elasmobranchs
Sajeevan *et al.*, 2009	South-west coast of India (7-10°N lat.)	100-500	98	Non-conventional demersal fin fishes
Venu and Kurup 2009a	South-west coast of India7-15°N lat	>200	27	Perciformes only
Hashim *et al.*, 2009	Indian EEZ	200-1000	126	Fin fishes and Elasmobranchs
Present study	Indian EEZ	150-1070	188	Fin fishes and Elasmobranchs

a. *Eptatretus hexatrema* (Müller 1836)

b. *Neoharriotta pinnata* (Schnakenbeck 1931)



c. *Hydrolagus africanus* (Gilchrist 1922)

d. *Apristurus indicus* (Brauer 1906)

e. *Apristurus investigatoris*(Misra 1962)

f. *Bythaelurus hispidus* (Alcock 1891)

g. *Eridacnis radcliffei* Smith 1913

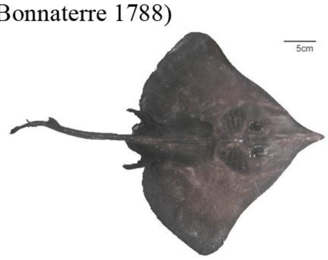
h. *Echinorhinus brucus* (Bonnaterre 1788)

i. *Centrophorus cf granulosus*
(Bloch & Schneider 1801)

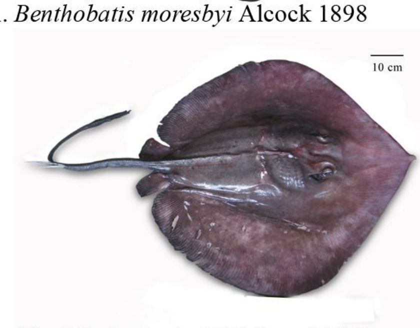
j. *Centrophorus moluccensis* Bleeker 1860

k. *Centrophorus squamosus*
(Bonnaterre 1788)

l. *Benthobatis moresbyi* Alcock 1898

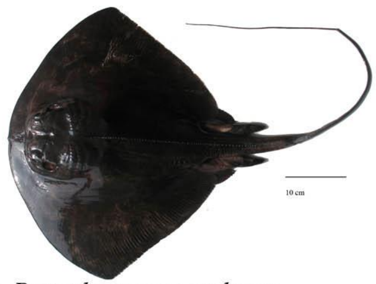


m. *Cruriraja andamanica* (Lloyd 1909)



n. *Plesiobatis daviesi* (Wallace 1967)

PLATE - 1



a. *Pteroplatytrygon violacea* (Bonaparte 1832)

b. *Notacanthus sexspinis* Richardson 1846

c. *Coloconger raniceps* Alcock 1889

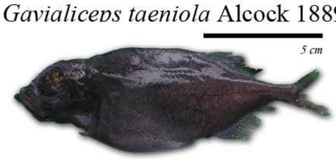
d. *Avocettina paucipora* Nielsen & Smith, 1978

e. *Nemichthys scolopaceus* Richardson 1848

f. *Bathyuroconger vicinus* (Vaillant 1888)

g. *Gavialiceps taeniola* Alcock 1889

h. *Xenomystax trucidans* Alcock 1894

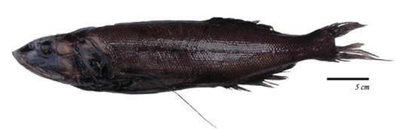


i. *Normichthys yahganorum* Lavenberg 1965

j. *Alepocephalus bicolor* Alcock 1891

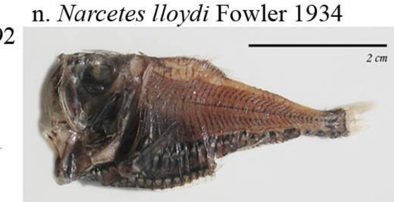
k. *Alepocephalus blanfordii* Alcock 1892

l. *Rouleina attrita* (Vaillant 1888)



m. *Talismania longifilis* (Brauer 1902)

n. *Narcetes lloydi* Fowler 1934



o. *Argyropelecus hemigymnus* Cocco 1829

PLATE - 2

a. *Astronesthes niger* Richardson 1845

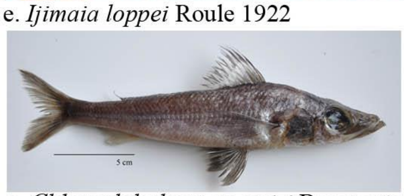
b. *Chauliodus sloani* Bloch & Schneider 1801

c. *Malacosteus niger* Ayres 1848

d. *Ateleopus indicus* Alcock 1891

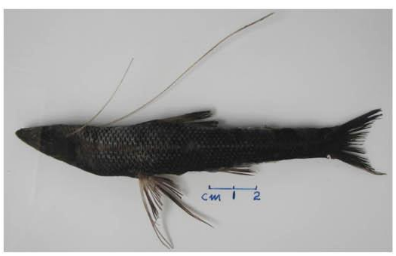
e. *Ijimaia loppei* Roule 1922

f. *Saurida tumbil* (Bloch, 1795)

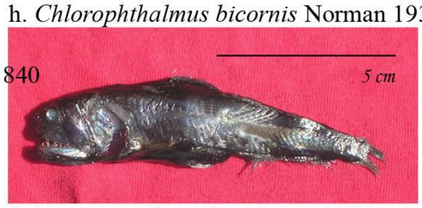


g. *Chlorophthalmus agassizi* Bonaparte 1840

h. *Chlorophthalmus bicornis* Norman 1939



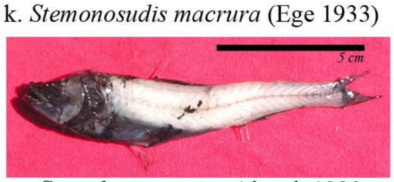
i. *Bathypterois atricolor* Alcock 1896



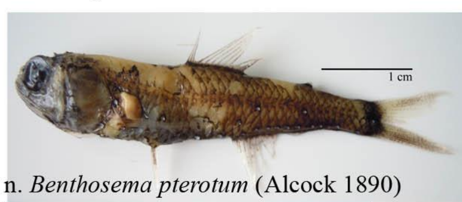
j. *Evermannella indica* Brauer 1906

k. *Stemonosudis macrura* (Ege 1933)

l. *Neoscopelus microchir* Matsubara 1943

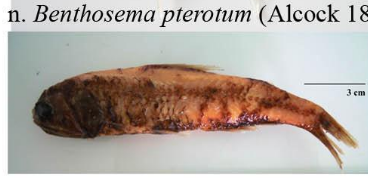


m. *Scopelengys tristis* Alcock 1890



n. *Benthosema pterotum* (Alcock 1890)

o. *Diaphus knappi* Nafpaktitis, 1978



p. *Diaphus lucidus* (Goode & Bean, 1896)

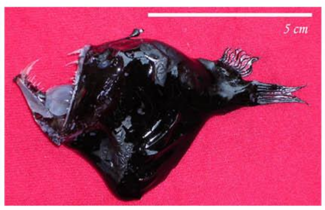
PLATE - 3

a. *Diaphus watasei* Jordan & Starks 1904

b. *Myctophum obtusirostre* Tåning 1928

c. *Polymixia nobilis* Lowe 1838

d. *Bathygadus melanobranchus* Vaillant 1888

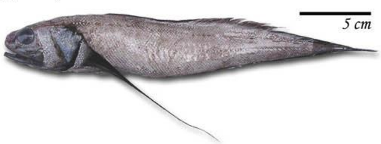


e. *Malacocephalus laevis* (Lowe 1843)

f. *Nezumia propinqua* (Gilbert & Cramer 1897)

g. *Physiculus roseus* Alcock 1891

h. *Snyderidia canina* Gilbert 1905

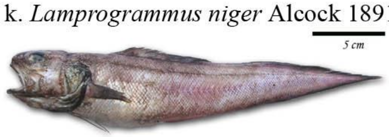


i. *Dicrolene multifilis*(Alcock 1889)

j. *Lamprogrammus exutus* Nybelin & Poll 1958

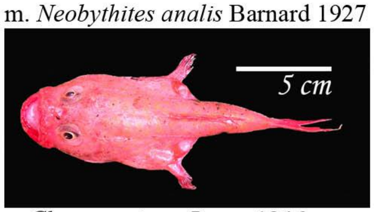
k. *Lamprogrammus niger* Alcock 1891

l. *Luciobrotula bartschi* Smith & Radcliffe 1913



m. *Neobythites analis* Barnard 1927

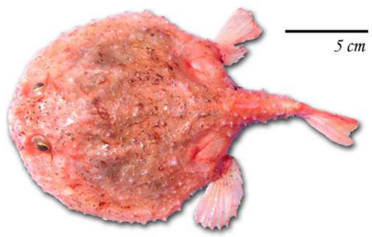
n. *Hephthocara simum Alcock 1892*



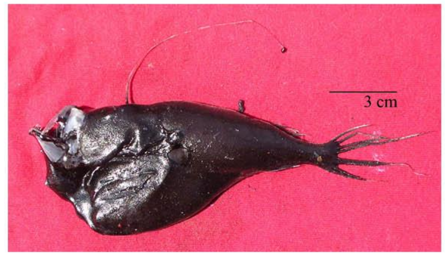
o. *Chaunax pictus* Lowe 1846

p. *Lophiomus setigerus* (Vahl 1797)

PLATE - 4



a. *Halieutaea fumosa* Alcock 1894



b. *Bufoceratias wedli* (Pietschmann 1926)

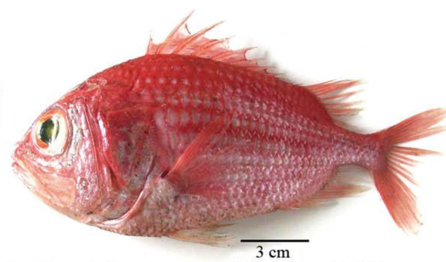
c. *Oneirodes kreffti* Pietsch 1974

d. *Anoplogaster cornuta* (Valenciennes 1833)

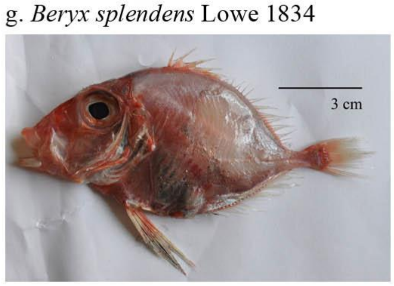
e. *Gephyroberyx darwinii* (Johnson 1866)

f. *Hoplostethus mediterraneus* Cuvier 1829

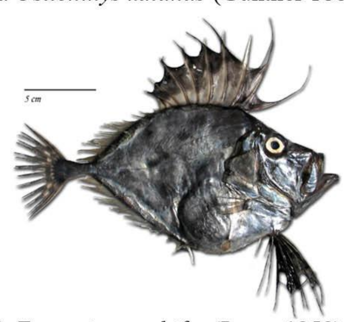
g. *Beryx splendens* Lowe 1834



h. *Ostichthys kaianus* (Günther 1880)



i. *Cyttopsis rosea* (Lowe 1843)



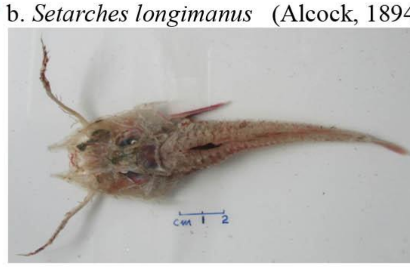
j. *Zenopsis conchifer* (Lowe 1852)

PLATE - 5

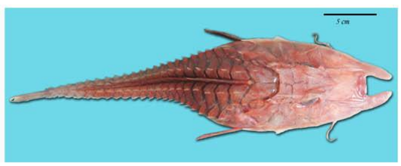
a. *Ectreposebastes imus* Garman 1899

b. *Setarches longimanus* (Alcock, 1894)

c. *Pterygotrigla hemisticta*
(Temminck & Schlegel 1843)



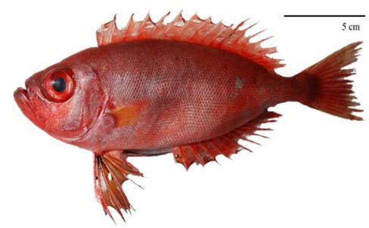
d. *Peristedion miniatum* Goode 1880



e. *Peristedion weberi* Smith 1934

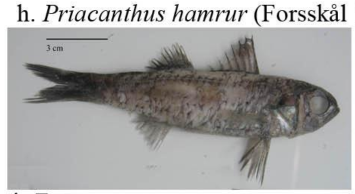
f. *Chelidoperca investigatoris* (Alcock 1890)

g. *Cookeolus japonicus* (Cuvier, 1829)



h. *Priacanthus hamrur* (Forsskål 1775)

i. *Pristigenys niphonia* (Cuvier 1829)



j. *Epigonus sp.*

k. *Parascolopsis aspinosa*
(Rao & Rao 1981)

l. *Bathyclupea elongata* Trunov 1975

PLATE - 6

a. *Owstonia weberi* (Gilchrist 1922)

b. *Champsodon capensis* Regan 1908

c. *Bembrops caudimacula* Steindachner 1876

d. *Bembrops platyrhynchus* (Alcock 1894)

e. *Uranoscopus archionema* Regan 1921

g. *Gempylus serpens* Cuvier 1829

f. *Bathygobius sp.*

i. *Promethichthys prometheus* (Cuvier 1832)

h. *Neoepinnula orientalis* (Gilchrist & von Bonde 1924)

k. *Ruvettus pretiosus* Cocco 1833

j. *Rexea prometheoides* (Bleeker 1856)

PLATE - 7

a. *Trichiurus auriga* Klunzinger 1884

b. *Psenopsis cyanea* (Alcock 1890)

c. *Cubiceps baxteri* McCulloch 1923

d. *Cubiceps whiteleggii* (Waite 1894)

e. *Psettodes erumei*
(Bloch & Schneider 1801)

f. *Chascanopsetta lugubris* Alcock 1894

g. *Laeops macrophthalmus*
(Alcock, 1889)

h. *Aesopia cornuta* Kaup 1858

i. *Macrorhamphosodes uradoi*
(Kamohara 1933)

PLATE - 8

Chapter V

Deep-sea fishes: Biological characteristics

5.1. Introduction

The management of the natural resources is one of the most challenging tasks. In the case of marine resources, it is much more difficult to ensure a sustainable production because of its obscured nature. Fishes are considered as one of the largest exploited natural resources and to ensure their sustainable production a proper management plan is required. For this, study of their biological characteristics is required to understand the dynamics of the particular population. The reproductive biology, growth, food and feeding are the major aspects to be assessed to understand the population dynamics.

Length-weight relationship reveals the growth pattern of the fishes is an important factor for estimation of the stock. Length-weight relationships of fishes are important in fisheries biology because they allow the estimation of the average weight of the fish of a given length group by establishing a mathematical relation between the two (Beyer 1987). Variability in size has important implications for diverse aspects of fisheries science and population dynamics (Erzini, 1994). Size has more biological relevance than age, mainly because the size is more depended on ecological and physiological factors than age (Kalayc *et al.,* 2007). The length-weight relationship can be used in setting yield equations for estimating the number of fish landed and comparing the population in space and time (Beverton and Holt 1957). Length-weight regressions have been used frequently to estimate weight from length because direct weight measurements can be time-consuming in the field (Sinovcic *et al.*, 2004). Length-weight of deep-sea fishes in Indian seas were reported by Philip and Mathew, 1996; Khan *et al.*, 1996; Venu and Kurup, 2002a&b; 2006a&b; Thomas *et al.*, 2003; Kurup *et al.*, 2005; Jayaprakash *et al.*, 2006; Kurup and Venu, 2006; Kurup *et al.*, 2006; Deepu *et al.*, 2007, Divya *et al.*,2007 and Abdussamad *et al.*, 2011. Size related fishing mortality can be assessed among sexes which have important application in fisheries science.

Food is one among the basic needs of an organism which regulates and influences the growth, reproduction, migration and abundance of fish stocks. Seasonal and diurnal abundance of food organisms of preference may be responsible for the horizontal and vertical migration of the fish stocks (Philip, 1998). Defining interaction between organisms and their prey is very important for describing the food web in an ecosystem. The presence of preferred food item makes a place favorable feeding ground for the given fish. Metabolism is strongly related to size and food consumption (Margalef, 1977). The analysis of food and feeding has a lot of importance in understanding its habitat, food preferences and also its interaction with other trophic levels of the immediate habitat.

Deep-sea demersal fishes play an important role in the horizontal energy pathway as it constitutes prey as well as predator in the deep-sea realm (Kishiko, 2004). Literature available on the feeding in deep-sea fishes is primarily focussed on the nature of diet (feeding habits), feeding chronology and analysis of selectivity patterns with relatively fewer contributions on chemical composition, feeding behaviours and structural and physiological adaptations of feeding at depth (Gartner *et al.,* 1997). Food and feeding of deep-sea fishes have been reported by Marshall, (1965), Percy and Ambler (1974), Marshall and Merrett (1977), Golovan (1978), Mauchline and Gordon (1984), Gordon and Duncan (1985, 1987), Sulak (1986), Gartner Jr. and Musick (1989) and Crabtree *et al.*, (1991). Durr and Gonzalez (2002) studied food and feeding habits of *Beryx splendens* and *B. decadactylus* (Berycidae) off Canary Islands. Food and feeding of the ten species of Macrouridae were studied by Anderson (2005). Whereas, only a very few studies were carried out in Indian waters in deep-sea fishes. Nair and Appukuttan (1973) studied food and feeding habits of deep-sea sharks. Philip (1994) studied on the food and feeding habits of *Priacanthus hamrur* Khan *et al.* (1996) studied on the catch, abundance and some aspects of biology of deep-sea fishes in the southeastern Arabian Sea. Venu and Kurup (2002a&b, 2006 a&b) studied the biology of *Psenopsis cyanea, Hoplostethus mediterraneus, Priacanthus hamrur, Psenes whiteleggi, Hephthocara simum, Neoepinnula orientalis* and *Psenes squamiceps*. Kurup *et al.* (2005) studied the biology of *Chlorophthalmus bicornis*, Deepu *et al.* (2007) studied the biology of *Alepocephalus bicolor*. Divya *et al.* (2007) studied the distribution and biology off the deep-sea eel, *Gavialiceps taeniola* while diet composition of deep-sea fishes from eastern Arabian Sea was reported by Karuppasamy *et al.* (2008).

Based on the abundance and availability of samples, five species were selected in the present investigation for biological studies viz., *Gavialiceps taeniola, Bembrops caudimacula*, *Priacanthus hamrur, Neoepinnula orientalis* and *Chlorophthalmus agassizi.*

5.2. Results

5.2.1. Length-weight relationship

The analysis was done for male and female separately to find out any difference in growth in both sexes and also using pooled data subsequently. Log converted data were used to fit the regression analysis.

Length-weight measurements of 234 specimens of *Gavialiceps taeniola* were recorded. The regression analysis showed a linear relationship between length and weight (R^2=0.84 for males and R^2=0.90 for Females) Fig.5.1-5.3. The regression equations for male, female and pooled for *G. taeniola* can be expressed as follows

Male : Log W = -4.1804+ 2.240 Log L (R^2 = 0.84)

Female : Log W = -6.4972+ 3.069 Log L (R^2 = 0.90)

Pooled : Log W = -5.4524+ 2.696 Log L (R^2 =0.89)

In *G. taeniola* significant differences (F=35.22; P<0.05) were observed between the regression coefficients of males and females. Considering the slopes, the growth of female fish is positively allometric and males are negatively allometric.

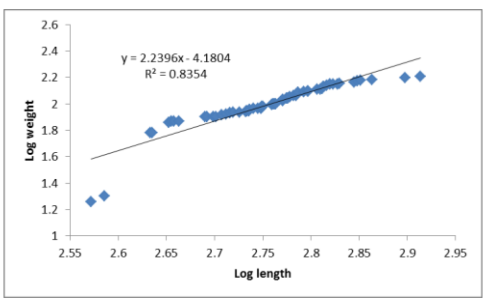


Fig.5.1. Length-weight relationship of male *G. taeniola*

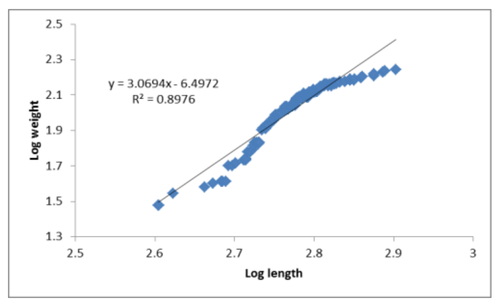


Fig.5.2. Length-weight relationship of female *G. taeniola*

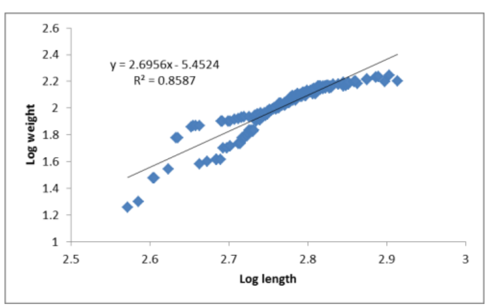


Fig.5.3. Length-weight relationship of male and female pooled *G. taeniola*

In *Bembrops caudimacula* (n=258) a linear relationship was tested between length and weight (in male R^2=0.86 and female R^2=0.88) Fig.5.4-5.6 as follows

Males : Log W = -5.5591+ 3.163 Log L (R^2 = 0.86)

Females : Log W = -5.3009+ 3.052 Log L (R^2 = 0.88)

Pooled : Log W = -5.2509+ 3.027 Log L (R^2 = 0.87)

The regression coefficients of males and females showed no significant variation (F=0.48; P>0.05) and therefore the regression equation developed from the pooled data can be used for the interpretation of the growth pattern and condition factor of the species *B. caudimacula*. The slopes show that the growth of males and females are positively allometric.

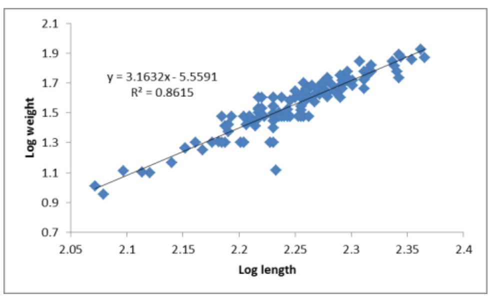


Fig.5.4. Length-weight relationship of male *B. caudimacula*

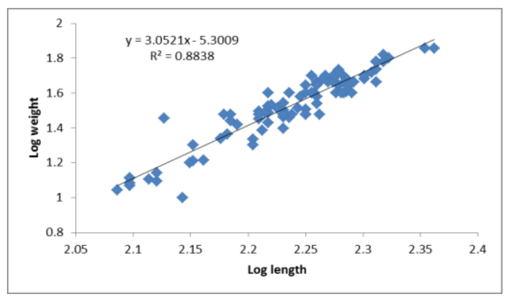


Fig.5.5. Length-weight relationship of female *B. caudimacula*

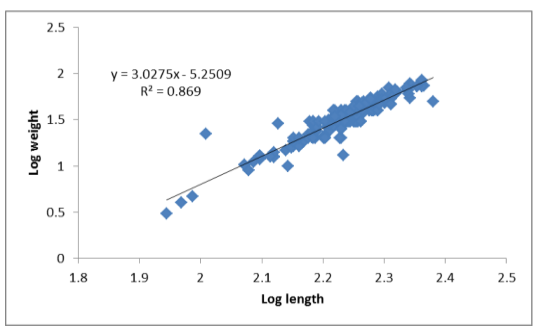


Fig.5.6. Length-weight relationship of male and female pooled *B. caudimacula*

In *Priacanthus hamrur* (n=153) also a linear relationship between length and weight was observed (males R^2=0.91 and Females R^2=0.97) Fig. 5.7-5.9 as follows

Males : Log W = -4.4459+ 2.777 Log L (R^2 = 0.91)

Females : Log W = -4.2246+ 2.679 Log L (R^2 = 0.97)

Pooled : Log W = -4.5921+ 2.842 Log L (R^2 = 0.92)

As the regression coefficients of males and females showed no significant variation (F=2.84; P>0.05) the regression equation developed from the pooled data can be used for the interpretation of the growth pattern and condition factor of the species *P. hamrur*. Here the slopes shows growth of males and females are negatively allometric.

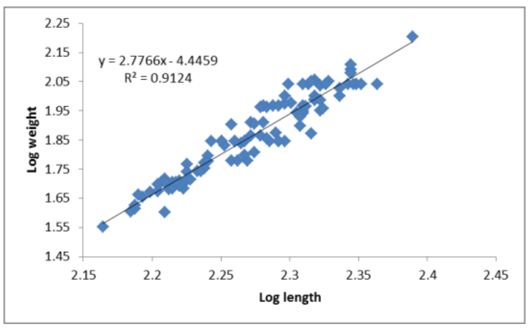


Fig.5.7. Length-weight relationship of male *P. hamrur*

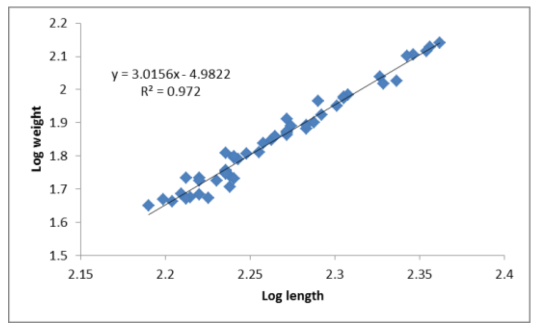


Fig.5.8. Length-weight relationship of female *P. hamrur*

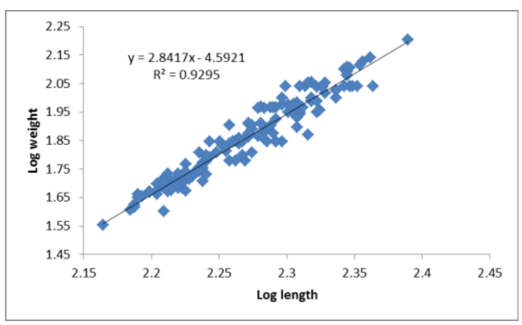


Fig.5.9. Length-weight relationship of male and female pooled *P. hamrur*

The regression coefficients of male and female *Neoepinnula orientalis* (n=159) showed a linear relationship between length and weight (R^2=0.97 for males and R^2=0.96 for Females) Fig. 5.10-5.12. The regression equations generated for male, female and pooled *N. orientalis* can be expressed as follows

Males : Log W = -5.6223+ 3.199 Log L (R^2 = 0.97)

Females : Log W = -5.5135+ 3.157 Log L (R^2 = 0.96)

Pooled : Log W = -5.8201+ 3.289 Log L (R^2 = 0.97)

The regression coefficients of males and females also showed no significant variation (F=0.18; P>0.05) and therefore the regression equation developed from the pooled data can be used for the interpretation of the growth pattern and condition factor. The slope values articulate the growth of males and females are positively allometric.

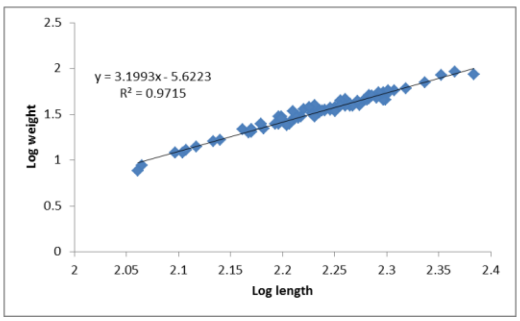


Fig.5.10. Length-weight relationship of male *N. orientalis*

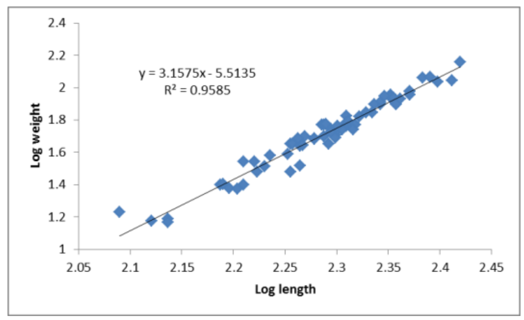


Fig.5.11. Length-weight relationship of female *N. orientalis*

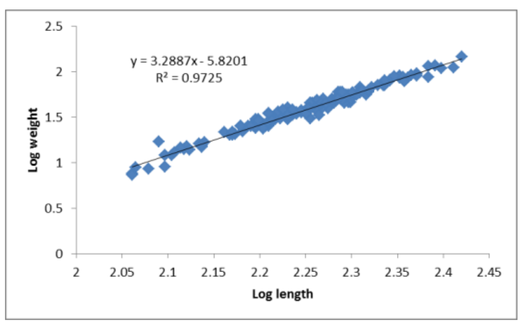


Fig.5.12. Length-weight relationship of male and female pooled *N. orientalis*

The regression lines were fitted for *Chlorophthalmus agassizi* (n=175) and observed a linear relationship between length and weight (R^2=0.89) Fig. 13. Since the species is hermaphroditic, length-weight relation was not made separately for male and female. There for the regression equations for *C. agassizi* can be expressed as follows. The growth of this species is negatively allometric.

Pooled : Log W = -5.0938+ 2.988 Log L (R^2 = 0.89)

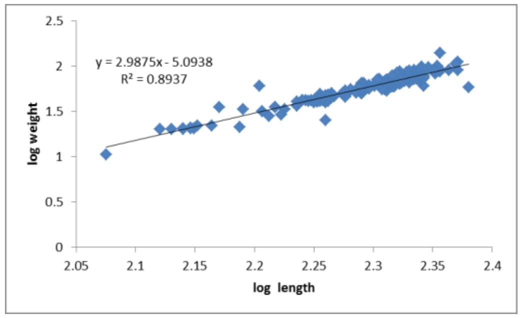


Fig.5.13. Length-weight relationship of male and female pooled *C. agassizi*

5.2.2. Sex ratio

Sex ratio was calculated for the four species *Gavialiceps taeniola, Bembrops caudimacula*, *Priacanthus hamrur* and *Neoepinnula orientalis.*

Gavialiceps taeniola - 234 specimens were examined, in which 71 were males and 187 were females. The male female sex ratio was found to be 1:2.6. The calculated chi-square value (52.16) is higher than the table value (3.00) which indicates that the sex ratio deviates significantly from the hypothetical ratio.

Bembrops caudimacula - 258 specimens were examined in that 131were males, 100 were females and three were immature. The male female sex ratio was found to be 1:076. The calculated chi-square value (4.16) is higher than the table value (3.00) which indicates that the sex ratio deviates significantly from the hypothetical ratio.

Priacanthus hamrur - 153 specimens were examined in that 103were males and 50 were females. The male female sex ratio was found to be 1:0.49. The calculated chi-square value (18.36) is higher than the table value (3.00) which indicates that the sex ratio deviates significantly from the hypothetical ratio.

Neoepinnula orientalis - 159 specimens were examined in that 83 were males and 66 were females. The sex ratio was found to be 1:0.8. The calculated chi-square value (1.94) is lower than the table value (3.00) which indicates that the sex ratio is not deviating significantly from the hypothetical ratio.

5.2.3. Food and Feeding

A major proportion of the fishes analysed for gut contents were of empty stomach. In *Priacanthus hamrur* 45% (Fig. 5.14) of the fishes observed were empty stomach while, relatively higher proportion was observed in *Gavialiceps taeniola* (90%) (Fig. 5.15), *Bembrops caudimacula* (76%) (Fig. 5.16), *Neoepinnula orientalis* (78%) (Fig. 5.17) and *Chlorophthalmus agassizi* (76%) (Fig. 5.18). Gut content analysis showed that fishes constitute major component food in *C. agassizi* and *N. orientalis* whereas crustaceans were predominant in the *G. taeniola* and *B. caudimacula. P. hamrur,* showed a varied diet composition with shrimp (40.39%), fishes (28.95%), squid (30.46%) and octopus (0.2%).

Index of Relative Importance (IRI) was worked out for each species which is presented in Table-5.1. Semi digested fishes (IRI-2557) ranked first in prey groups of *C. agassizi* followed by myctophid, squid, elver, leptocephalus and flat fishes. Similarly, in *N. orientalis* also semi digested fishes (IRI-3662) topped in the gut content followed by squid, *Cubiceps*, myctophid and octopus. Shrimp (IRI-4704) dominated in *G. taeniola* followed by *Nemicthys* and Leptocephalus. In *B. caudimacula* crustaceans other than shrimp (IRI-3067), shrimp and squid dominated the gut content. In *P. hamrur* shrimp (IRI-1813) dominated as the prey followed by squid, semi digested fishes, myctophid, *Neopinnula*, eel and octopus.

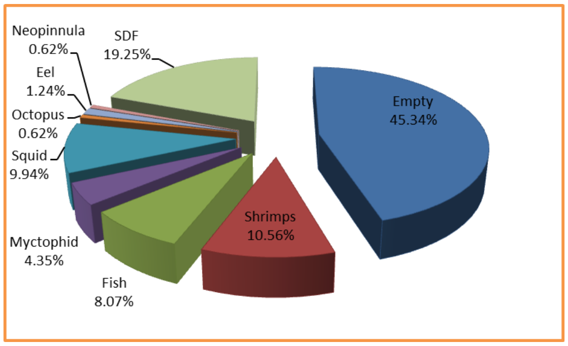


Fig.5.14. Percentage of food composition of *P. hamrur*

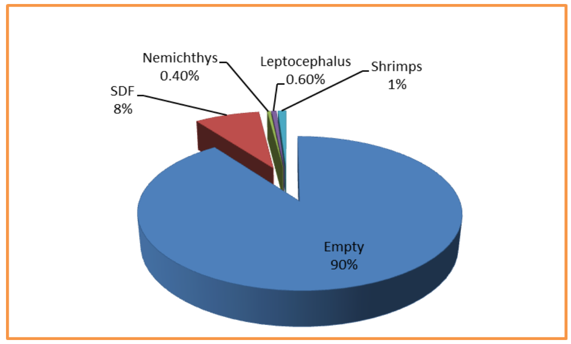


Fig.5.15. Percentage of food composition of *G. taeniola*

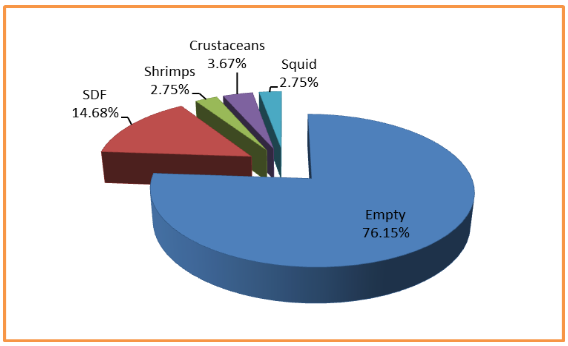


Fig.5.16. Percentage of food composition of *B. caudimacula*

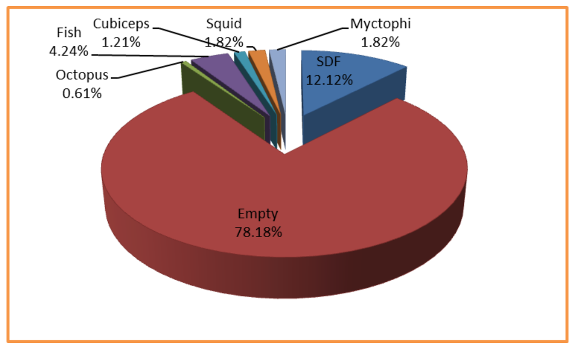


Fig.5.17. Percentage of food composition of *N. orientalis*

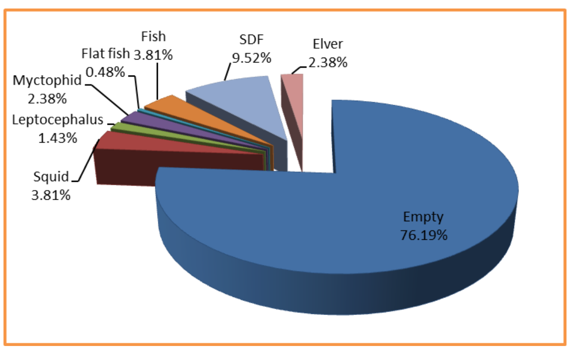


Fig.5.18. Percentage of food composition of *C. agassizi*

Table - 5.1. IRI value and percentage of IRI of prey groups of species studied.

Species		Prey groups	IRI value	% of IRI
Chlorophthalmus agassizi	1	Fish	2557	78.0
	2	Squid	273	8.3
	3	Leptocephalus	16	0.5
	4	Myctophid	308	9.4
	5	Flat fish	15	0.5
	6	Elver	107	3.3
Neoepinnula orientalis	1	Octopus	91	2.0
	2	Fish	3662	80.7
	3	Cubiceps	244	5.4
	4	Squid	323	7.1
	5	Myctophi	216	4.8
Gavialiceps taeniola	1	Shrimp	4704	67.1
	2	Nemicthys	1331	19.0
	3	Leptocephalus	977	13.9
Bembrops caudimacula	1	Shrimp	1200	17.7
	2	Crustaceans	3067	45.3
	3	Squid	2500	36.9
Priacanthus hamrur	1	Shrimps	1813	40.4
	2	Fish	979	21.8
	3	Myctophid	271	6.0
	4	Squid	1368	30.5
	5	Octopus	9	0.2
	6	Eel	29	0.7
	7	*Neopinnula*	21	0.5

5.3. Discussion

The Length-weight relationship developed for five species in the present study agrees with the previous studies (Sivakami *et al.,* 2001 on *Priacanthus hamrur;* Thomas *et al.*, 2003 on *Chlorophthalmus agassizi, Bembrops caudimacula* and *Priacanthus hamrur;* Jayaprakash *et al.*, 2006 on *Neoepinnula orientalis* and *Bembrops caudimacula* and Divya *et al.*, 2007 on *Gavialiceps taeniola*) with minor variations. Significant difference in growth of the male and female is observed in *G. taeniola.* In slope-dwelling deep-sea species, female fishes become mature only after they reach adult size and when somatic growth has slowed or ceased (Gordon *et al.,* 1995), it may be the reason for the changes in growth pattern of male and female. The growth of the species *P. hamrur* is negatively allometric as described by previous workers (Sivakami *et al.,* 2001; Thomas *et al.*, 2003).

Sex allocation theory describes how organisms should divide their resources between male and female for reproduction (Charnov, 1982). Some of the most striking successes of sex allocation theory have been explained cases in which individuals facultatively adjust their offspring sex ratios (proportion of male) in response to local conditions (Trivers and Willard, 1973; Charnov, 1982; Hardy, 2002; West *et al.*, 2002). In deep-sea realm the chances for finding a pair is uncertain and male dominant population and hermaphroditism are believed to be a great advantage (Randall and Farrell, 1997). Therefore, the reproductive strategy of deep-sea fishes is manifested by sex ratio adjustment in favour of male (Allsop and West, 2004). The present study reveals that the species *Bembrops caudimacula* and *Priacanthus hamrur* are dominated by males and with highly skewed sex ratio. However the sex ratio of *P. hamrur* skewed towards female was reported from the coastal waters of India (Sivakami *et al.,* 2001) agreeing with this study. These fishes are more mobile and widely distributed and hence the chance of meeting a pair is higher. *Gavialiceps taeniola* was also dominated by females. This species is burrowing and do not move over long distances and hence finding a pair may not be a difficult task for this species. In the case of *Chlorophthalmus agassizi* the reproductive strategy is hermaphroditism, which helps greatly reduced energy expenditure for finding a compatible pair in the deep-sea. The sex ratio of *N. orientalis* showed equal dominance of males and females. This was probably because this species is highly abundant, mobile and hence higher probability of finding a mate exists for this species.

In oceanic food web, fishes usually form the dominant top carnivores, and certainly in the deep-sea realm (Randall and Farrell, 1997). Preliminary examination of the food and feeding of the deep-sea fishes selected in this study showed that most of them are carnivores. In the present study the gut content of *P. hamrur* was dominated by shrimps, squid and fishes and they formed the most favored food items. Similar observations were made in *P. hamrur* collected from the continental shelf (Philip, 1998; Premalatha, 1997 and Sivakami *et al.,* 2001), in *P. tayenus* (Rao, 1967) and in *P. macracanthus* (Rao, 1984). According to Philip (1998), the food item of *P. hamrur* is represented by mesopelagic fishes, while Bande *et al.* (1989) reported voracious feeding of *P. hamrur* on pelagic shrimps. The diverse food items (myctophids, eels, octopus) recorded in this study from *P. hamrur* when compared to the other deep-sea fishes might be following the general model of non-selective predation for mobile deep-sea bottom fishes especially under conditions of low food availability (Percy and Ambler, 1974).

Abdussamad *et al.* (2011) reported that the food of the *N. orientalis* collected from deep-sea trawls and gill nets of east coast of India was composed of myctophids, small mesopelagic fishes, deep-sea prawns, small crabs and cephalopods in their gut. In the present study also the gut contents of *N. orientalis* were represented by fishes, squid, *Cubiceps*, myctophids and octopus. Occurrence of epipelagic myctophids as food in *N. orientalis* guts indicate that the fish occupies epipelagic realm also for feeding.

The present study observed a varied diet composition constituted by unidentified fishes, myctophid, squid, elver, leptocephalus and flat fishes in *C. agassizi*. The general body morphology of the *C. agassizi* and *N. orientalis* are similar to that of pelagic fishes pointing to its feeding in the epipelagic realm. Anastasopoulou and Kapiris (2008) have also reported that, *Chlorophthalmus agassizi* showed a mixed feeding strategy, exploiting a wide range of prey including mesopelagic, benthic and endobenthic organisms supporting the results of this study.

The studies on the food and feeding of deep-sea eel *G. taeniola* are limited to Divya *et al.,* (2007). The absence of myctophids in the gut content of exclusively bottom dwelling deep-sea eels like *G. taeniola* with limited locomotion, unlike in other fishes also confirm that habitats can be critical in determining food preferences in fishes. In the present study, 90% of the specimens analysed had empty guts and the diet composition of the species were constituted with shrimp, *Nemicthys* and Leptocephalus.

Food and feeding of *B. caudimacula* is studied for the first time from Indian waters. *B. caudimacula* indicated that it was a selective feeder on crustaceans, especially shrimp and squid. The study thus concludes that, the gut content of the fishes explains about its habitat.

Observations on stomach fullness indicated that the incidence of empty stomachs especially in the species like *G. taeniola* caught at 200-1000 m depth was higher compared to *P. hamrur* caught at lesser depths. Observations on the trawl fisheries have provided evidence that fishes regurgitate when caught in trawls at great depths and is species dependent (Bowman, 1986). Regurgitation is thus probably important factor in causing higher percentage of empty stomach in the fishes from more deeper water as observed in this study.

In conclusion, this study indicates that as per the classification into 10 major guilds of trophic specialization in deep-sea fishes, the species selected in this study fall in trophic guild of 'macronekton foragers' whose prey include a varied diet of nektonic crustaceans (mysids, euphausiids, decapods), cephalopods, chaetognaths and mid-water fishes. Macronekton foragers are supposed to be most prevalent on the upper and middle slopes where prey concentrations facilitate predation on large numbers of small individuals (Gartner *et al.,* 1997). The results of this study which was made mostly of species inhabiting 200-500 m depth *ie.* the upper continental slope corroborate this observation. The study also confirms the observations that piscivory is the most common form of predation among larger meso and bathypelagic species while cephalopods are less common probably owing to their relatively larger sizes and faster locomotory speed of many deep-sea squid species which allows them to escape or are avoided by the predator (Gartner *et al.,* 1997).

Chapter VI

Commercial exploitation and utilization of deep-sea fishes: A SWOL analysis

6.1. Introduction

Fisheries play a pivotal role in the economic development of all maritime nations. The fisheries sector contributes as foreign exchange earner, ensures nutritional security and generates employment opportunities. Among the total world fish production India contributes more than 4 per cent. Even though the country unable to reach the annual per capita fish consumption of 11kg/yr, the present per capita consumption is around 9 kg, it shows the need for an immediate additional nutritional requirement of the country (Balachandran *et al.,* 1996). India is the largest country in the Indian Ocean region comprising a coastline of 8129 km. With absolute rights on the EEZ, India has also acquired the responsibility to conserve, develop and optimally exploit the marine resources up to 200 nautical miles off our coastline (Planning Commission, 2007). The current exploitation from the marine capture sector is 3.07 million tonnes in 2010 (CMFRI, 2011) as against the potential of 3.9 million tonnes.

Indian marine fish harvest mostly centers around coastal waters up to 80 m depth and about 90 per cent of the catch comes from up to 50m (Balachandran *et al.,* 1996). A recent revalidation of marine fisheries potential has shown that the fishing pressure on the stock in near shore waters has gone up considerably and signs of over exploitation of species is becoming increasingly evident and further increase in effort in the coastal sector would be detrimental to sustainable yield. The impact of undeterred mechanized trawling and purse seining has also caused resource depletion. Sustainable resources exploitation from this sector is still possible through regulatory management strategies and concerted policy efforts for different species and for different regions.

Technological lag and financial constraints had been the major bottlenecks in the delayed take off of the deep-sea fishing industry in India. The maritime states of Gujarat, Kerala and Tamil Nadu have already demonstrated their ability to harvest deep-sea fisheries resources in the Indian EEZ using vessels below 20 m. Nevertheless the major contribution in fish production still continues to be from coastal waters (Mathew, 2003).

As the coastal fishery faces issues like the sustainability, resources conservation and management; there is an imperative need for finding an alternative resource for the nutritional security. Exploitation of under exploited non-conventional resources from the distant waters of the Indian EEZ will be the only solution. There is ample scope of increasing production by venturing into deeper waters of the EEZ, which holds a potential of 1.7 million tonnes of under exploited and unexploited finfishes and shellfishes (ICAR, 2011).

The occurrence of fishable concentrations of deep-sea resources together with stagnating coastal production necessitated the need to recognize the deep-sea fishing as a priority area for developing the industry. Accordingly Government has approved projects for investment and development of importing larger ocean going fishing vessels and joint venture and charter programs for increasing the marine fish production (Planning commission, 2011). In 1991, the Government formulated a deep-sea Fishing Policy in which the Indian seas were opened up to the foreign factory fishing ships under the guise of Joint Venture and Lease and test fishing besides allowing continuing the vessels chartered under 1986 Charter Policy till the validity of their permits lasted. From the beginning of 1994, the deep-sea fishing policy was criticized by various fisher groups, mechanized fishing vessel owners, fish processors etc. (Comprehensive Marine Fishing Policy, 2004). The Murari Committee came up with 21 recommendations that included cancellation of all the licenses of the chartered/joint venture fishing vessels. The next concern had been the lack of enacting a sound deep-sea fishing policy, oriented around operation of Indian vessels in the deep-sea zone. Another constraint relates to the strengthening of the existing Indian fleet.

The deep-sea fishing in India, which began in 1970s, had hitherto been confined to the upper east coast for shrimp and other valuable species. However many studies have indicated that there is an ample amount of unexploited and non-conventional resources in the Indian EEZ. In this context, the aim of the present study was to analyse the commercial viability of deep-sea fishing with the help of a stakeholder's survey using Strengths, Weaknesses, Opportunities and Limitations (SWOL) analysis.

6.2. Results and Discussion

The results and discussion are detailed under the following heads.

6.2.1. Strengths

i) Unutilized and underutilized resources: The current level of commercial exploitation is limited only to deep-sea shrimps like *Metapenaeopsis andamanensis, Aristeus alcocki, Plesionika spinipes, Heterocarpus gibbossus and H. woodmasoni* and deep-sea sharks mainly *Echinorhinus brucus* and *Centrophorus* spp. Apart from this some non-conventional fishes like *Neopinnula* sp. and

Chlorophthalmus sp. were marketed for domestic consumption in Kerala and Tamilnadu. There exist huge amount of unutilized and underutilized resources like *Psenopsis cyanea, Bembrops caudimacula, Chlorophthalmus bicornis*, *C. agassizi*, *Uranoscopus archionema, Gavialiceps taeniola, Priacanthus hamrur* and *Neoepinnula orientalis* are revealed by the study based on the exploratory surveys conducted in Indian waters. Pillai *et al.* (2009) has identified deep-sea fishes from deep-sea shrimp trawlers operating off Kollam, Kerala, India and Akhilesh *et al.,* (2011) reported more than 20 species of deep-sea sharks landing from Cochin fisheries harbor, Kerala, India.

ii) Unexploited large fishing area: With a coastline of 8,129 km and an exclusive economic zone (EEZ) of 2 million square km, and with an area of about 30,000 square km under aquaculture, India produces close to six million tonnes of fish, over 4 per cent of the world fish production. While the coastal waters up to 50 m. depth are fully exploited, the waters beyond this depth are believed to be under-exploited. There have been various unsuccessful efforts since 1959 to maximise fish production in deep waters under the aegis of the Union Government. The Agriculture Ministry has issued the Guidelines for fishing operations in the Indian EEZ. A recent revalidation of marine fisheries potential has shown that the fishing pressure on the stock in near shore waters has gone up considerably and signs of over exploitation in respect of more number of species is becoming increasingly evident (ICAR, 2011). Majority of the fish landings occurred from the 100 m depth. The exploratory fishing cruises by FORV *Sagar Sampada* in the Indian seas clearly revealed the occurrence and abundance of fish even at a depth of 1000 m (Chapter-4. Fig. 4.26).

iii) Distribution of Diversified species: The study reported and documented the occurrence of 188 species of deep-sea fishes (Chapter-4., Table-4.1) from Indian EEZ during the exploratory surveys. Deep-sea fish species like *Psenopsis cyanea, Bembrops caudimacula, Chlorophthalmus bicornis*, *C. agassizi*, *Uranoscopus archionema, Gavialiceps taeniola*, *Priacanthus hamrur* and *Neoepinnula orientalis* were found to be the most abundant and can be considered as the promising resources for commercial exploitation found during the study. The highest diversity was observed in Arabian Sea (4.95) followed by Andaman Waters (4.12) and Bay of Bengal (3.55) (Chapter-4. Fig. 4.29). The depth wise diversity was high in 601-800m (4.87), followed by 401-600m (4.67) and lowest was recorded in 150-200m (2.75) (Chapter-4. Fig. 4.34).

iv) Presence of Vast Research Linkages/ Governmental initiatives: There exist a vast network of research organisation like Fisheries Survey of India (FSI), Ministry of Earth Sciences (MoES), Central Marine Fisheries Research Institute (CMFRI), Central Institute of Fisheries Technology (CIFT), Central Institute of Fisheries Nautical and Engineering Training (CIFNET), Central Institute of Coastal Engineering for Fisheries (CICEF) and State Universities which are engaged the deep-sea fisheries research in India. These research organisations had clearly spelt out the need of harnessing the deep-sea resources and included it in its mandate with funding earmarked for priority areas.

6.2.2. Weakness

i) Null/inefficient marketing system: The study on the existing marketing system is indicated that the marketing system is dismal without any forward or backward linkages. Most of the resources exploited are discarded except for resource like shrimps and shark (Some of the non-conventional fishes are marketed internally). 79 per cent of the traders dealing with the deep-sea resources felt that the existing marketing system is dismal for deep-sea fishes and has been a growing concern (Fig.6.1).

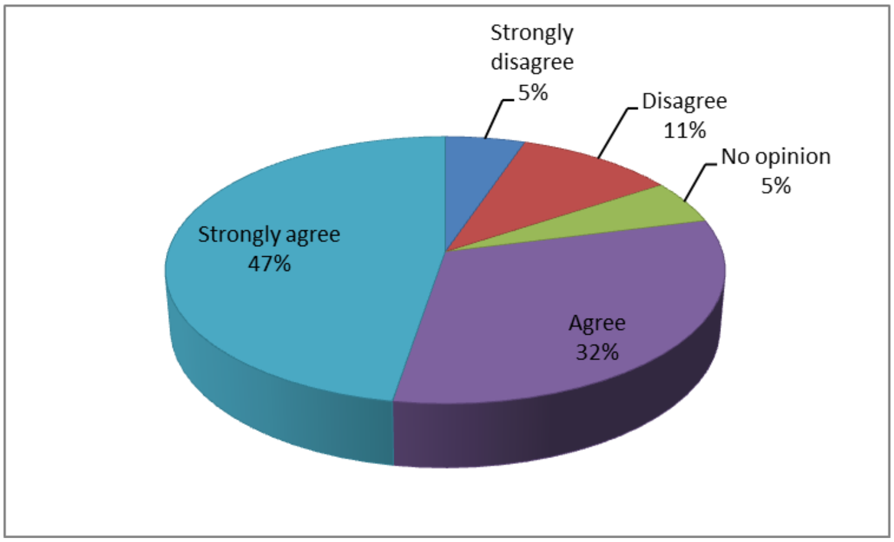


Fig. 6.1. Opinion polled by fish traders on fish marketing system

ii) Inadequate data about the resources: Even though deep-sea resources are being studied, no seasonal and periodic data is available. The databases on occurrence, distribution and stock assessment aren't perfected thereby resulting it paucity of reliable data. The research on deep-sea resources done in Indian waters are confined to species specific or location specific (Venu and Kurup, 2002a&b, 2006a&b, 2009a&b; Thomas *et al.*, 2003; Jayaprakash *et al.*, 2006; Sreedhar *et al.*, 2007; Sajeevan *et al.*, 2007 and Hashim *et al.*, 2007, 2009 and Abdussamad *et al.*, 2011). There exists an immense scope of collecting spatial and temporal data across Indian waters to analyze the diversity, abundance and availability of deep-sea resources for proper exploitation and management of these resources.

iii) Exorbitant cost of fishing: The operational cost of coastal trawlers *vis-a-vis* deep-sea trawlers indicated that compared with the coastal fisheries the deep-sea fishing is expensive. The huge cost of fishing coupled with resources which have got lesser demand and low consumer preferences leads to fishing enterprises being less lucrative. 90 per cent of the boat owners opined that the cost of the deep-sea fishing exploitation is expensive compared with the coastal trawling operations. Most of the unfamiliar resources exploited are discarded except those resources like shrimps and shark.

iv) Lack of skilled manpower: Adequate manpower with suitable training, scientific knowledge, years of expertise and technical competency are limiting factors in the deep-sea fishing sector. Almost all the boat owners who surveyed felt that the skilled manpower for exploiting the deep-sea resources exploitations is not available on account of longer duration of fishing, inadequate training and less remuneration (Fig.6.2). 44 per cent of boat owners opined that the longer duration of the fishing voyages is restricting the fisherman to go for deep-sea fishing while 22 per cent opined lesser remuneration and 34 per cent opined lack of trained fisherman as constraints for deep-sea fishing activities. At present the fishermen of Thoothoor-Colachel region are the major group engaged in deep-sea fishing activities mainly targeting sharks and large pelagics like tunas and billfishes. The skills of this indigenous deep-sea fishermen community can be tapped efficiently for developing the deep-sea fishery sector.

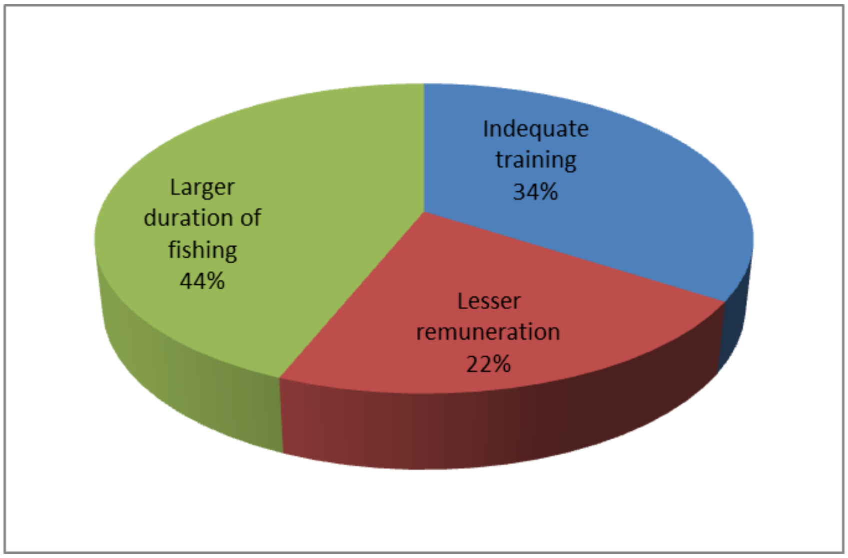


Fig. 6.2. Stakeholders opinion on the availability of the skilled manpower

v) Intrinsic life history traits: Compared to the coastal fishes Deep-sea fishes are generally considered to have high longevity, slow growth, late maturity, and low fecundity (Morato *et al.,* 2006). Hence the commercial exploitation of deep-sea resources needs a precautionary approach to ensure its sustainability.

6.2.3. Opportunities

i) Development of value added products: Considering the acute shortage of fish at affordable prices there exists an immediate need of improving fish availability. The deep-sea resources need not be attracting high consumer preference on account of its unfamiliar appearance, taste and texture. But there exist a huge scope of development of value added products from deep-sea fishes for ensuring food security. Considering the spiraling of the domestic pricing the deep-sea resources can act as a buffer for the consumers by providing a cheap protein source. According to Viswanatha *et al.*,

(2012) the preferences of consumers are heterogeneous, but it is possible to identify the segments with distinct preferences for particular fish attributes; the price of the fish was found to be the most important attribute that explained consumers preference followed by fat content, texture and length of the fish. The protein content of some of the myctophids are higher than the coastal fishes (Manju *et al.*, 2011). Nicholas *et al.*, (1994) mentioned that the oils derived from Southern ocean myctophids have some industrial uses and have potential similar to that of jojoba oil.

ii) Constituent as pharmaceutical industries: The deep-sea fish resources can be utilized as constituent of pharmaceutical industry considering its potential for providing certain specialized products. Squalene is a pharmaceutical compound extracted from shark liver oil and is high in deep-sea sharks.

iii) Input for the animal food and fish meal: Fish meal is an important ingredient for the aquaculture sector and its demand is mostly met by imports. 85 per cent of the traders felt that the deep-sea fish resources could evolve and substitute as an important ingredient for the animal food and fish meal.

iv) Huge prospects for Government support by way of different schemes: As the Indian deep-sea fishing industry has not been fully equipped in terms of technology and finance, to take up this venture by itself, the Government of India had been taking several steps in the past to finance deep-sea fishing ventures, to bring in appropriate technologies and to build up trained technical man power etc. As a result of these efforts, several joint venture initiatives and Indian owned deep-sea fishing ventures have come up.

6.2.4. Limitations

i) Dearth of investments: The funding from the government needs to be improved considering the importance and scope of the deep-sea sector in the coming years.

ii) Lack of awareness among the consumers: The consumers are reluctant to consume the deep-sea fishes due to lack of information about the resources. The survey revealed that, only less than 40 per cent of the consumers are aware about the deep-sea resources even deep-sea shrimps (Fig.6.3). Apart from a few places in Tamil Nadu and Kerala the deep-sea fishes are not consumed anywhere in India.

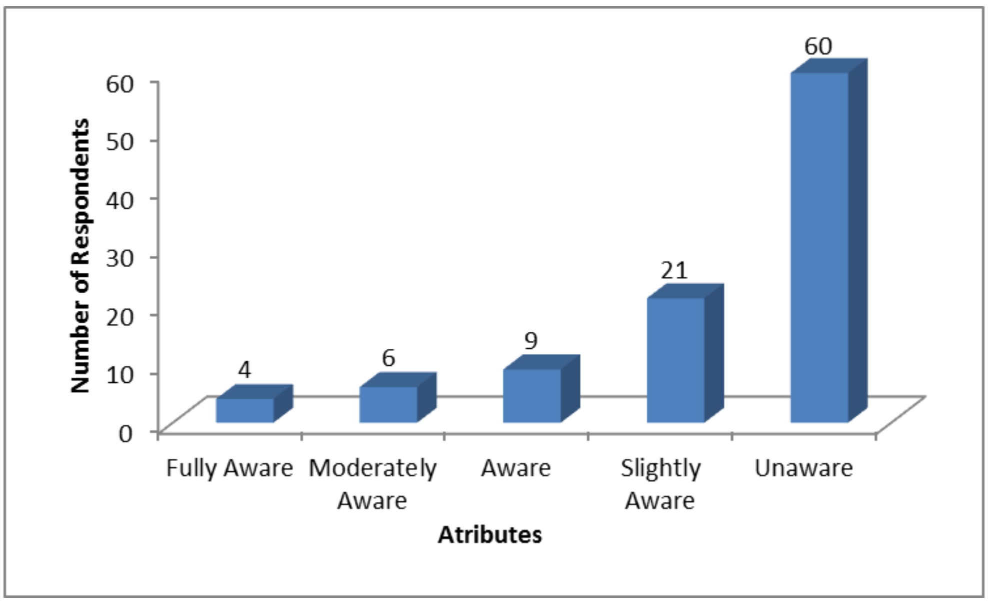


Fig. 6.3. Consumer awareness about deep-sea resources

iii) Low market acceptability: The most grappling problem faced in the exploitation of the deep-sea resources has been its acceptability in the market. The resources aren't included in the existing market channel and are often traded by limited number of sellers. 90 per cent of the traders opined that there is no demand for the deep-sea resources on account of the appearance, texture and unfamiliar taste.

iv) Technology gap for exploitation: Harvest technology has to ensure significant and sustainable exploitation level starting from identification of suitable fishing grounds. It should also include catch limits determination, gears that permit minimum discards and suitable utilization and value addition to catches made.

v) Lack of adept technology for value addition: Currently, Central Institute of Fisheries Technology (CIFT) is working on the development of value added products from deep-sea non-conventional fisheries resources. The technologies need to be standardized for ensuring that the value addition process is successful.

vi) National security issues: Security concerns have to be adequately addressed while developing a deep-sea fishing fleet. Empowerment of fishing boats with the Vessel Management System (VMS) will be needed.

vii) Sustainability/Sectoral concerns: To ensure conflict-free operation of deep-sea fishing vessels, it has to be ensured that deep-sea fishing operations compile with the requirements of Code of Conduct for Responsible Fisheries (CCRF) and other such national/ international rules and regulations.

viii) Policy bottlenecks: Development of a Deep-Sea Fishing Policy taking into consideration the resource base, manpower and prospects to earn suitable revenue and create employment avenues is urgently required.

6.3. Conclusion

Fishing rights and responsibilities it entails in the deep-sea sector has been a vexed issue since the mid-nineties and various stakeholders have different opinion on the modalities of harnessing the marine fisheries wealth, especially from the oceanic and deeper waters. The exploitation and utilization of these resources requires technology development and upgradation in harvest and post-harvest areas; besides shore infrastructure for berthing, handling, storing and processing facilities. At present, although deep-sea fishes don't have any ready market in our country it can be converted into value added products.

Many problems have so far confronted the deep-sea fishing sector not allowing it to reach its full potential. Hence, there should be a sound deep-sea fishing policy revolving round the upgradation of the capabilities of small scale fishermen, who have the inherent skills but do not have adequate support to develop themselves and to acquire vessels having the capability to operate in farther and deeper waters. Sustainable fisheries based on longlining operations and like are to be developed. Another step is to provide required training programmes for the upgradation of the skills and capacity building of the fishermen. It is also important for Development agencies to provide shore cold storage facilities at identified ports, harbours, landing centers and fish markets to enable the fishermen to store their catches and if necessary to process and export their catches to get the highest economic returns for their fishing efforts.

Government should develop a bottom up approach in terms of developing deep-sea fishing in our EEZ. This could involve development of the capabilities of small-scale fishermen operatives. If the Government gives necessary attention to the deep-sea fishing sector, which is at its nascent stage, it will be a great help in sustainably managing the fishery by reducing fishing pressure in coastal waters as well as boosting the marine fish production through exploitation of offshore waters there by ensuring food and nutritional security.

Chapter VII

Summary and Recommendations

7.1. Summary

- ✓ The samples were collected during deep-sea trawling surveys onboard *FORV Sagar Sampada* during the Cruise No. 241, 250, 281 (Arabian Sea), Cruise No. 247 (Bay of Bengal) and Cruise No. 252 (Andaman Sea).

- ✓ A total of 188 species of fishes, which belong to 136 genera, 80 families and 25 orders were recorded from 68 stations distributed in three geographical regions (Arabian Sea, Bay of Bengal and Andaman waters) and at 6 depth ranges (150-200 m, 201-400 m, 401-600 m, 601-800 m, 801-1000 m and >1000 m).

- ✓ From Arabian Sea – 139 species, Bay of Bengal - 53 species and Andaman waters – 68 species were recorded.

- ✓ Out of the 188 species recorded, only 12 species were found in all the three regions. Eighty two species were observed exclusively in the Arabian Sea only and 29 species were found to have restricted distribution only in Andaman waters. The number of species found only in the Bay of Bengal was 12.

- ✓ The most abundant species in terms of catch were *Psenopsis cyanea*, *Bembrops caudimacula, Chlorophthalmus bicornis, C. agassizi, Uranoscopus archionema, Gavialiceps taeniola, Priacanthus hamrur* and *Neoepinnula orientalis* as constituted in the top 10 list across the entire region.

- ✓ The species ranked first in terms of number are *Bathygobius sp.* in 150-200 m, *C. agassizi* in 201-400 m, *G. taeniola* in 401-600 and 601-800 m, *G. elongatum* in 801-1000 m, *C. macrolophus* in >1000 m.

- ✓ *Anoplogaster cornuta* and *Bassozetus robustus* showed very strict depth preference and found only beyond 800 m depth.

- ✓ *Bathyuroconger vicinus* and *Alepocephalus bicolor* were found to have very wide distribution in terms of depth and found in five depth ranges ranging from 150 to 1000 m depths. *P. hamrur* also occurred over a wide range of depths extending from 150 – 600 m depths.

- ✓ Most of the species were found distributed mainly in the depth between 200 and 800 m and this depth can be considered where maximum diversity of deep-sea fishes is observed.

- ✓ Maximum number of species were recorded from the depth range of 201-400 m (112 species) followed by 601-800m (101 species). From the depth >1000m showed lowest number of species (12 species).

- ✓ Bathymetrically highest diversity (4.87) and richness (11.57) was recorded in 601-800 m depth where more diverse families were recorded.

- ✓ Geographically highest species diversity (4.95), Richness (13.92) and Evenness (0.69) were recorded in Arabian Sea.

- ✓ Bray-Curtis Similarity index showed 26.76% similarity between the abundance of deep-sea fishes in Arabian Sea and Bay of Bengal indicating two different ecosystems.

- ✓ k - Dominance curve showed a typical S curve in all three seas and in all depth ranges indicating minimum stress in the ecosystem.

- ✓ Bray – Curtis Similarity Plot showed 44.25 % similarity between the abundance of deep-sea fishes from the depth range 401-600 and 601-800 m indicating a more homogenous habitat.

- ✓ MDS plot for bathymetrical aspects showed three clusters 150-400m, 401-1000 m and >1000 m.

- ✓ Five species deep-sea fishes were selected for biological studies viz. *Priacanthus hamrur, Gavialiceps taeniola, Bembrops caudimacula, Neoepinnula orientalis* and *Chlorophthalmus agassizi*. Length weight relationship, sex ratio and food and feeding were studied.

- ✓ A major proportion of the fishes analysed for gut contents showed empty stomach. In *P. hamrur,* 45% of the fishes observed had empty stomachs while, relatively higher proportion was observed in *G. taeniola* (90%), *B. caudimacula* (76%)*, N. orientalis* (78%) and *C. agassizi* (76%).

- ✓ Occurrence of higher incidence of empty stomach in fishes caught at greater depths indicates probable influence of regurgitation, as well as prey availability.

- ✓ Most of the deep-sea fishes of the continental slope in the 200-800 m depths belonging to the trophic guild of macronekton foragers.

- ✓ Prospects for the commercial exploitation and utilization of deep-sea fishes were analyzed using SWOL analysis.

7.2. Recommendations

- ➢ Economically viable technology for the exploitation of deep-sea fishes has to be adopted.

- ➢ Licensing for commercial fishing in deep-sea area should be followed strictly for proper monitoring of the resources, sustainable exploitation and national security.

- ➢ Deep-sea fishery resources need to be exploited to ensure availability of fishes to the increasing population to fill the gap in nutritional imbalance.

- ➢ Exploratory surveys for new fishing areas to be continued, map the potential fishing ground on a GIS platform and the data should be provided to the commercial entrepreneurs.

- ➢ Commercial viability of the deep-sea fishing in the Indian waters has to be workout.

- ➢ Post-harvest technology and value addition for the resource need to be enhanced for better profit from this sector.

- ➢ Intensified studies on the nutritional value of different deep-sea fish resources has to be made.

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Annexure I

SURVEY SCHEDULE

FOR

STAKEHOLDERS PERCEPTION ON THE COMMERCIAL UTILIZATION OF DEEP-SEA RESOURCES

I. General Particulars

1. Name of the Stakeholder: ______________________________________
2. Category -Fishermen/Boat owner/Middle men/Consumers/Producer (VAP)
3. Age: _________________________ years
4. Gender: Male / Female
5. Address____

____

____

6. Experience in fishing operation/business: _______________years

II. Stakeholders perception

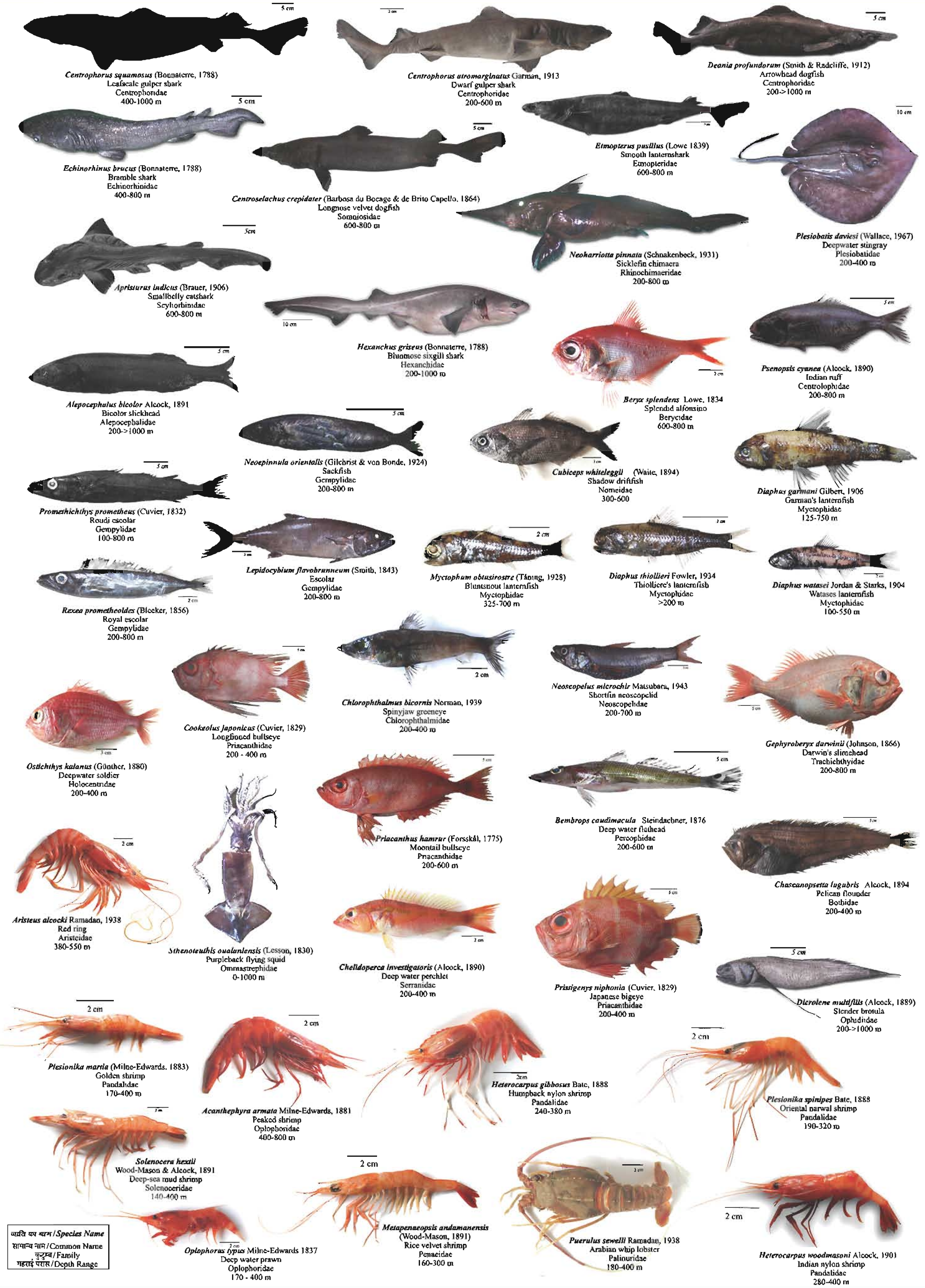
Sl.No:	Statement	Perception
1.	The deep-sea fishing is expensive when compare to coastal fishing	Strongly Agree/ Agree/ Unaware/ Disagree/ Strongly Disagree
2..	The level of awareness about deep-sea resources	Fully Aware/Moderately Aware/Aware/Slightly Aware/Unaware
3.	That marketing system in deep-sea resources is dismal	Strongly Disagree/Disagree/No opinion/Agree/Strongly Agree
4.	Skilled manpower is a limiting factor for deep-sea fishing operation	Strongly Agree/ Agree/ Unaware/ Disagree/ Strongly Disagree
5.	The scope for the development of value added products from deep-	Strongly Agree/ Agree/ Unaware/ Disagree/ Strongly

	sea fishes is high	Disagree
6.	The scope for adding deep-sea fish resources as an ingredient in the animal food and fish meal is good	Strongly Agree/ Agree/ Unaware/ Disagree/ Strongly Disagree
7..	The level of investment for the deep-sea fisheries resource sector is adequate	Strongly Agree/ Agree/ Unaware/ Disagree/ Strongly Disagree
8.	Do you find that the deep-sea resources faces low market acceptability in the market on account of the appearance, texture and unpalatable taste	Strongly Agree/ Agree/ Unaware/ Disagree/ Strongly Disagree
9.	The technology for value addition of deep-sea resources is adequate	Strongly Agree/ Agree/ Unaware/ Disagree/ Strongly disagree

I. Rank the major problems encountered in the supply of trained manpower

Sl.No:	Problem	Rank
1.	Inadequate training	
2.	Longer duration of fishing	
3.	Lesser remuneration	
4.	Any Others	

भारत की गभीर सागर मात्स्यिकी संपदाएं
DEEP-SEA FISHERY RESOURCES OF INDIA



Centrophorus squamosus (Bonnaterre, 1788)
Leafscale gulper shark
Centrophoridae
400-1000 m

Centrophorus atromarginatus Garman, 1913
Dwarf gulper shark
Centrophoridae
200-600 m

Deania profundorum (Smith & Radcliffe, 1912)
Arrowhead dogfish
Centrophoridae
200->1000 m

Echinorhinus brucus (Bonnaterre, 1788)
Bramble shark
Echinorhinidae
400-800 m

Etmopterus pusillus (Lowe 1839)
Smooth lanternshark
Etmopteridae
600-800 m

Centroselachus crepidater (Barbosa du Bocage & de Brito Capello, 1864)
Longnose velvet dogfish
Somniosidae
600-800 m

Plesiobatis daviesi (Wallace, 1967)
Deepwater stingray
Plesiobatidae
200-400 m

Neoharriotta pinnata (Schnakenbeck, 1931)
Sicklefin chimaera
Rhinochimaeridae
200-800 m

Apristurus indicus (Brauer, 1906)
Smallbelly catshark
Scyliorhinidae
600-800 m

Hexanchus griseus (Bonnaterre, 1788)
Bluntnose sixgill shark
Hexanchidae
200-1000 m

Beryx splendens Lowe, 1834
Splendid alfonsino
Berycidae
600-800 m

Psenopsis cyanea (Alcock, 1890)
Indian ruff
Centrolophidae
200-800 m

Alepocephalus bicolor Alcock, 1891
Bicolor slickhead
Alepocephalidae
200->1000 m

Neoepinnula orientalis (Gilchrist & von Bonde, 1924)
Sackfish
Gempylidae
200-800 m

Cubiceps whiteleggii (Waite, 1894)
Shadow driftfish
Nomeidae
300-600

Diaphus garmani Gilbert, 1906
Garman's lanternfish
Myctophidae
125-750 m

Promethichthys prometheus (Cuvier, 1832)
Roudi escolar
Gempylidae
100-800 m

Lepidocybium flavobrunneum (Smith, 1843)
Escolar
Gempylidae
200-800 m

Myctophum obtusirostre (Tåning, 1928)
Bluntsnout lanternfish
Myctophidae
325-700 m

Diaphus thiollieri Fowler, 1934
Thiolliere's lanternfish
Myctophidae
>200 m

Diaphus watasei Jordan & Starks, 1904
Watases lanternfish
Myctophidae
100-550 m

Rexea prometheoides (Bleeker, 1856)
Royal escolar
Gempylidae
200-800 m

Cookeolus japonicus (Cuvier, 1829)
Longfinned bullseye
Priacanthidae
200 - 400 m

Chlorophthalmus bicornis Norman, 1939
Spinyjaw greeneye
Chlorophthalmidae
200-400 m

Neoscopelus microchir Matsubara, 1943
Shortfin neoscopelid
Neoscopelidae
200-700 m

Gephyroberyx darwinii (Johnson, 1866)
Darwin's slimehead
Trachichthyidae
200-800 m

Ostichthys kaianus (Günther, 1880)
Deepwater soldier
Holocentridae
200-400 m

Priacanthus hamrur (Forsskål, 1775)
Moontail bullseye
Priacanthidae
200-600 m

Bembrops caudimacula Steindachner, 1876
Deep water flathead
Percophidae
200-600 m

Chascanopsetta lugubris Alcock, 1894
Pelican flounder
Bothidae
200-400 m

Aristeus alcocki Ramadan, 1938
Red ring
Aristeidae
380-550 m

Sthenoteuthis oualaniensis (Lesson, 1830)
Purpleback flying squid
Ommastrephidae
0-1000 m

Chelidoperca investigatoris (Alcock, 1890)
Deep water perchlet
Serranidae
200-400 m

Pristigenys niphonia (Cuvier, 1829)
Japanese bigeye
Priacanthidae
200-400 m

Dicrolene multifilis (Alcock, 1889)
Slender brotula
Ophidiidae
200->1000 m

Plesionika martia (Milne-Edwards, 1883)
Golden shrimp
Pandalidae
170-400 m

Acanthephyra armata Milne-Edwards, 1881
Peaked shrimp
Oplophoridae
400-800 m

Heterocarpus gibbosus Bate, 1888
Humpback nylon shrimp
Pandalidae
240-380 m

Plesionika spinipes Bate, 1888
Oriental narwal shrimp
Pandalidae
190-320 m

Solenocera hextii Wood-Mason & Alcock, 1891
Deep-sea mud shrimp
Solenoceridae
140-400 m

Oplophorus typus Milne-Edwards 1837
Deep water prawn
Oplophoridae
170 - 400 m

Metapenaeopsis andamanensis (Wood-Mason, 1891)
Rice velvet shrimp
Penaeidae
160-300 m

Puerulus sewelli Ramadan, 1938
Arabian whip lobster
Palinuridae
180-400 m

Heterocarpus woodmasoni Alcock, 1901
Indian nylon shrimp
Pandalidae
280-400 m

जाति का नाम / *Species Name*
सामान्य नाम / Common Name
कुटुम्ब / Family
गहराई परास / Depth Range

तैयारी : डॉ. एन. जी. के. पिल्लै, यू. गंगा, हाषिम मंजक्रयाकत, सी.पी. रजूल षानिस, के. के. बिनीष, के. वी. अखिलेश, मंजु सेबास्टियन और एन. बेनी. वेलापवर्ती मात्स्यिकी प्रभाग, केंद्रीय समुद्री मात्स्यिकी अनुसंधान संस्थान, पी. बी. सं. 1603, कोच्ची -682 018
Prepared by: Dr. N. G. K. Pillai, U. Ganga, Hashim Manjebrayakath, C.P. Rajool Shanis, K.K. Bineesh, K.V. Akhilesh, Manju Sebastine and N.Beni
Pelagic Fisheries Division, Central Marine Fisheries Research Institute, P.B.No.1603, Cochin-682 018

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Report of *Apogonichthyoides sialis* (Perciformes: Apogonidae) from the west coast of India

HASHIM MANJEBRAYAKATH, K.V. AKHILESH AND N.G.K. PILLAI

Central Marine Fisheries Research Institute, PB No. 1603, Ernakulam North PO, Cochin-683 018, Kerala, India

The cardinal fish, Apogonichthyoides sialis, *previously known from the eastern Indian Ocean and western Pacific, is reported from the south-west coast of India (Kerala coast). The specimens are described and figured.*

Keywords: *Apogonichthyoides sialis*, distribution extension, Arabian Sea, south-western India

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Cardinalfish (Apogonidae) is a speciose family of marine teleosts with about 23 genera and 347 valid species, of which most occur in shallow water in tropical and subtropical marine environments and a few species occur in brackish and fresh water environments (Nelson, 2006; Fraser & Allen, 2010). Apogonid fish are usually small in size (<100 mm total length) but a few species in the genera *Apogon*, *Holapogon*, *Apogonichthyoides*, *Cheilodipterus*, *Glossamia* and *Pseudamia* grow to larger sizes (Fraser, 1973; Froese & Pauly, 2011).

The genus *Apogonichthyoides*, which was resurrected from *Apogon*, contains 19 valid species (Fraser & Allen, 2010). The characteristics of the genus are: body colour brown to brownish-black; head and body usually with dark (brown or black) spots which are sometimes stripe-like; a dark cheek line and usually two body bars. An ocellus may be present below the lateral line on the body; one or more bars on the caudal peduncle or a spot on the base of the caudal fin are often present (Fraser & Allen, 2010).

Species of the '*Apogonichthyoides nigripinnis*' complex have a similar colour pattern with a dark colour and a spot on the caudal peduncle. The species known from the western Indian Ocean '*A. nigripinnis*' group are *A. enigmaticus*, *A. heptastygma*, *A. pharaonis*, *A. pseudotaeniatus*, *A. taeniatus* and *A. nigripinnis* from the Indo-West Pacific (Fraser & Allen, 2010; Froese & Pauly, 2011).

Apogonichthyoides sialis (Jordan & Thompson, 1914), originally described as *Amia sialis* from Suruga Bay (Japan) is distributed from the western Pacific (including Japan, Taiwan and China) to the east coast of India (Gon, 2000). On 3 August 2011 five specimens of *A. sialis* were collected from demersal fish trawl landings at Munambam Fisheries Harbour, south-western India. The main part of the catch comprised *Nemipterus randalli* and *N. japonicus*. The morphometric and meristic characters of the specimens collected agree well with the description of Gon (2000), but a few characteristics overlapped with the present specimens which were: colour variants, probably due to habitat; dark colour of the dorsal, anal and caudal fins versus paler in the living photographs of *A. sialis*. The present work extends the distribution of *A. sialis* to the west coast of India.

Corresponding author:
H. Manjebrayakath
Email: hashimaqua@gmail.com

SYSTEMATICS

APOGONIDAE

Apogonichthyoides sialis (Jordan & Thompson, 1914)

MATERIALS EXAMINED

Apogonichthyoides sialis (DNR CMFRI. GB. 31. 9. 2. 1), (5 specimens, 89.4–102.8 mm standard length), trawls, off Cochin, Kerala, India, 20–70 m depth.

DIAGNOSIS

Dorsal fin rays VII + I, 9; anal fin rays II, 8; pectoral fin rays 15–16; lateral-line scales 23–24 + 2–4; predorsal scales 4, dorsal origin to LL 3 scales. Rudiments and gill-rakers 3 + 2 – 8–9 + 4–6, 10–11 rakers, total 5 + 12–15; two dark body bars from base of each dorsal fin; small basicaudal spot.

DESCRIPTION

Proportional measurements in percentage of standard length (SL) are given (Tables 1 & 2). A medium sized *Apogon*, with dark colour and very small spots and a black spot on caudal (Figure 1). Body depth 2.3–2.4 in SL; head length (HL) 41.9–45% SL, 2.2–2.4 in SL; snout length 4.1–4.5 in HL; upper jaw length 19.2–19.7% SL; third dorsal-fin spine 22.3–23.6% SL; second dorsal spine 18.7–20.4% SL; pelvic-fin spine 15.6–18.0% SL; caudal peduncle depth (CPD) 16.1–17.5% SL; caudal peduncle length (CPL) 19.5–24.8% SL, 4–5.6 in SL; caudal spot diameter 4.8–5.6% SL. Eye diameter 3.5–3.9; interorbital 4.2–4.7; upper jaw 2.1–2.4; third dorsal spine 1.8–2.0; second anal spine 4.6–6.1; pelvic spine 2.4–2.9, all in HL (Tables 1 & 2). Preoperculum finely serrated. Pelvic bases connected by a membrane (interpelvic space

Fig. 1. *Apogonichthyoides sialis*, Arabian Sea, collected off Cochin, India.

covered). Large mouth, villiform teeth. Pectoral fin nearly reaches to anal fin origin in vertical. Caudal fin emarginate.

COLOUR

Colour in alcohol: body grey-brown with minute small dark spots and with two distinct dark bars, one under anterior base of each dorsal fin; intestine pale.

Colour of fresh specimens: body dark; dark bars from dorsal to ventral side, reaching to level of lower pectoral-fin base or slightly lower; a distinct dark caudal spot.

REMARKS

A similar species from western Indian Ocean, *A. pseudotaeniatus* (Gon, 1986) described from the Red Sea can be confused with *A. sialis* in colour pattern and morphometry, except for a few characters such as: third dorsal spine 1.9–2 in HL (2.0–2.45 in *A. pseudotaeniatus*) and smaller dark basicaudal spot, spot diameter 3.5–5.2 in CPD (4.6–6.1 in *A. pseudotaeniatus*). Moreover *A. pseudotaeniatus* has a blackish intestine and usually 14–15 pectoral fin rays, whereas *A. sialis* has a pale intestine and usually 15 pectoral fin rays.

Day's (1875) *Fishes of India*, plate 16 figure 9 misidentified as *A. bifasciatus* is *A. sialis*. There are no specimens of *A. pseudotaeniatus* reported from the eastern Indian coastline, but Gon (1986) suggested Day's (1875) report of *A. taeniatus* was *A. pseudotaeniatus* with abnormality which could be *A. sialis*. *Apogonichthyoides pseudotaeniatus* is probably restricted to the Red Sea, Arabian coast and the Persian Gulf and prefers reefs found at 5–30 m depth (Gon & Randall, 2003), whereas present *A. sialis* specimens were collected from the south-western coast of India, 20–70 m depth. Suresh & Thomas (2006) reported *A. pseudotaeniatus* from the west coast of India which also could be *A. sialis*. This report of *A. sialis* from the south-western coast of India indicates an extension of distribution from its known localities.

Table 1. Morphometric measurements of *Apogonichthyoides sialis* (Jordan & Thompson, 1914) from south-west coast of India (in % standard length).

Characters	Range
Total length (mm)	115.2–133.6
Standard length (mm)	89.4–102.8
Head length	41.9–45.3
Body depth	41.4–44.4
Width of the body	17–17.9
Snout length	10–10.7
Eye diameter	11–12.5
Inter orbital width	9.4–10.3
Length of upper jaw	19.2–19.7
First dorsal fin base length	17.4–20.1
First dorsal spine length	2.1–4.4
Second dorsal spine length	7.1–9.3
Longest dorsal spine length (3)	22.3–22.6
Second dorsal fin base length	15.5–17
Second dorsal fin spine length	18.7–20.4
Longest dorsal ray	21.9–31.3
Anal fin base length	14.8–16
Anal fin length	26.4–28.3
First anal spine length	3.4–5.1
Second anal spine length	15.6–16.7
Longest anal ray length	24.2–29.8
Pectoral fin length	25.8–28.3
Pelvic fin length	25–31.5
Pelvic spine length	15.6–18
Caudal peduncle length	19.5–24.8
Depth of caudal peduncle	16.1–17.5
Snout to first dorsal-length	44.6–48.3
Snout to second dorsal-length	65.1–68.2
Snout to pelvic origin-length	39.2–42.3
Caudal spot diameter	4.8–5.6

Table 2. Ranges of measurements (in % standard length) of five *Apogonichthyoides sialis* 89.4 – 102.8 mm (present study) and *Apogonichthyoides sialis*, 61.4 – 96.7 mm and four *Apogonichthyoides pseudotaeniatus*, 56.9 – 110 mm from Gon, 2000.

	A. sialis	*A. pseudotaeniatus*	*A. sialis* (present study)
Head length	40 – 43	42 – 46	41.9 – 45.3
Upper jaw	18 – 20	20 – 22	19.2 – 19.7
Third dorsal-fin spine	21 – 27	18 – 22	22.3 – 23.6
Second dorsal spine	19 – 23	15 – 19	18.7 – 20.4
Pelvic-fin spine	18 – 19	16 – 17	15.6 – 18.0
Caudal peduncle depth	16 – 19	14 – 17	16.1 – 17.5
Caudal peduncle length	24 – 24	21 – 23	19.5 – 24.8
Caudal spot diameter	3.5 – 6.7	2.6 – 3.6	4.8 – 5.6

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Correspondence should be addressed to:
H. Manjebrayakath
Central Marine Fisheries Research Institute
PB No. 1603, Ernakulam North PO
Cochin-683 018, Kerala
India
email: hashimaqua@gmail.com

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An account on the deepsea shrimp *Aristaeopsis edwardsiana* (Johnson, 1867) from the Indian EEZ

U. GANGA, C. P. RAJOOL SHANIS, HASHIM MANJEBRAYAKATH AND K. V. AKHILESH

Central Marine Fisheries Research Institute, P. B. No.1603, Kochi - 682 018, Kerala, India
e-mail: ganga@cmfri.org.in

ABSTRACT

Aristaeopsis edwardsiana (Johnson,1867) is a deepsea shrimp of the continental slope that has not yet been reported in the targeted deepsea crustacean fishery along the Indian coast. An exploratory survey on-board FORV *Sagar Sampada* in the Arabian sea at a depth of 950 m off Trivandrum (lat. 8 ^{0} 28' N and long. 76 ^{0}14' E) yielded a catch of *A. edwardsiana* at a high catch per unit effort (CPUE) of 14 kg h^{-1}. The biological aspects of this less known deepsea shrimp species such as length frequency distribution, morphometric relations, sex ratio and the additional sexual dimorphism manifested in the antennal scale of males are reported.

Keywords: *Aristaeopsis edwardsiana*, Aristeidae, Deepsea shrimp, Indian EEZ

Introduction

The aristeid shrimp *Aristaeopsis edwardsiana* (Johnson, 1867) popularly known as the scarlet shrimp (formerly *Plesiopenaeus edwardsianus*) was reported in the Indian EEZ by Alcock (1910) and its occurrence off Trivandrum (lat. 8 ^{0} 28' N and long. 76 ^{0}14' E) at depths > 800 m, based on four specimens caught was confirmed by Suseelan and George (1990). In the present study, during an exploratory survey in the same region (lat. 8 ^{0}24' N and long. 76 ^{0} 07' E) the CPUE of *A. edwardsiana* was 14 kg h^{-1} which was quite high in comparison to reports of catch rates of 2 kg h^{-1} off the Portugal continental slope (Figueiredo *et al*., 2001) and 3.7 – 10 kg h^{-1} reported off Brazilian coast where a sustainable targeted deep-sea fishing for aristaeid shrimps is prevalent (Pezzuto *et al*., 2006).

A. edwardsiana is characterised by features like the absence of exopods on the first to fifth pereopods, first and second pereopod without distal meral spine and the absence of hepatic spine (Farfante and Kensley, 1997). Molecular phylogenetic analysis has established that *Aristaeopsis* is distinct from the *Plesiopenaeus* but closely related to *Aristaeomorpha*, another important genus in the family aristeidae (Ma *et al*., 2009). Considering the fact that deepsea shrimps in general have biological traits such as slow growth, late maturity and low fecundity making them especially vulnerable to over-exploitation as compared to coastal shrimp species (Nandakumar *et al*., 2001), detailed studies on the biology of the species are necessary before its exploitation by commercial vessels are allowed. The present study therefore explores a sample of *A. edwardsiana* caught during the exploratory deep-water fish survey for biological details.

Materials and methods

Samples were collected during an exploratory deepwater research survey (FORV *Sagar Sampada* cruise No.281) using High Speed Demersal Trawl - Crustacean Version (HSDT CV) net at a depth of 950 m. The species appeared in a catch mix consisting of finfish, crustacean and chondrichthyans and was identified based on distinguishing characters as given by Farfante and Kensley (1997) and Poore and Ahyong (2004). Standard morphometric measurements of the sample included total length (TL) as measured (in mm) from tip of rostrum to tip of telson; and carapace length (CL) from posterior margin of the orbit to posterior dorsal margin of carapace (Dall *et al*., 1990). The specimens (n = 224) were differentiated among sexes using the characters of presence of petasma (males) or thelycum (females) and the relationship between TL and CL was derived using the linear relationship, Y= a + bX for males and females separately. Besides this, sexual dimorphism manifested as appearance of antennal scales in males in certain aristeid shrimps is described for this species in Indian waters for the first time.

Results

Length Frequency distribution and sex ratio

The total length (TL) varied from 168 to 295 mm and carapace length (CL) from 51 - 95 mm. The minimum and maximum TL were 168 and 246 mm (males) and 190 and 295 mm (females) respectively with mean TL of 195 and 254 mm for males and females respectively (Fig. 1). Significant correlation between CL and TL was observed as TL = 0.1284 + 3.39 CL (R^2 =0.933) in males and TL = 6.123 + 2.45 CL (R^2 = 0.946) in females (Fig. 2).

Among a total 224 specimens of *A. edwardsiana* studied, 163 were females and 61 were males indicating a male: female sex ratio of 1:2.7 which was significantly different (l^2 = 23.22, $p < 0.001$).

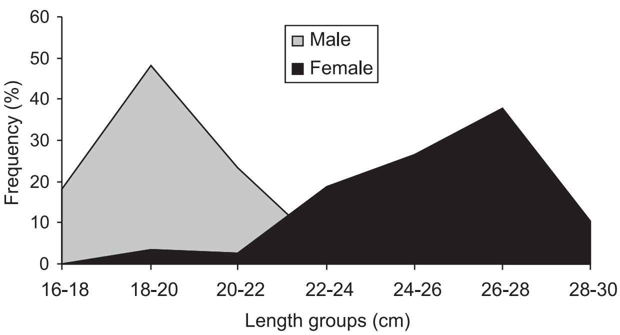

Fig. 1. Length frequency distribution of *A. edwardsiana*

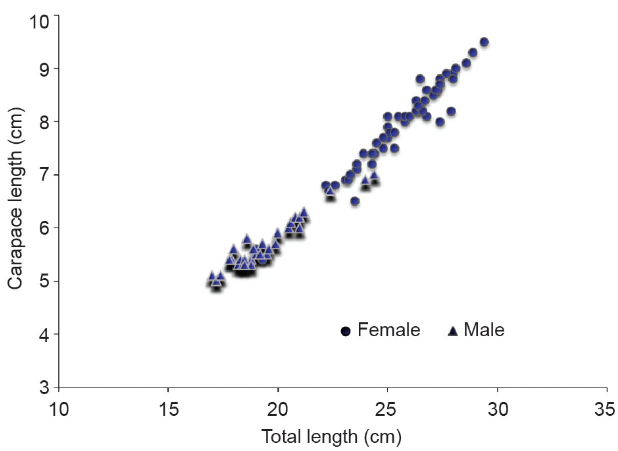

Fig. 2. Relationship between carapace length (CL) and total length (TL) for male and female *A. edwardsiana*

Sexual dimorphism

The species exhibits an additional sexually dimorphic characteristic in that the scaphocerite (antennal scale) has an elongate acuminate tip in the males as compared to females (Fig. 3). The rostrum was found to be moderately elongate in females and juvenile males, reaching beyond apex of scaphocerite and somewhat shorter in adult males.

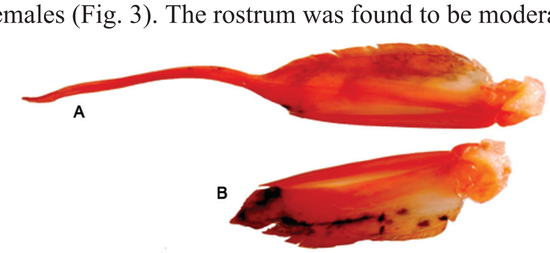

Fig. 3. Shape of scaphocerite in male (A) and female (B) *A. edwardsiana*

Discussion

The present study conducted in October 2010 which covered transects between 8^0- 21^0 N latitudes in the Arabian Sea observed occurrence of *A. edwardsiana* only at 8^0 N latitude at 900 m depth, indicating a very geographically and bathymetrically limited stock. Exploratory surveys in Brazil and French Guiana also report that the species is highly concentrated in the vicinity of the 800 m isobath (Gueguen, 1998; Pezzuto *et al*., 2006). While Suseelan and George (1990) reported four female specimens in length range of 20.7 - 24.5 cm TL, a relatively high CPUE of about 14 kg h^1 was observed in the present study which yielded information on length frequency distribution, sex ratio and morphometric relations. However, the present study was also limited by a pre-defined sampling programme wherein trawling operations at various depths in the same ground were not possible. Spatial (depth-wise, canyons, open slope) and temporal segregation of sizes and sexes have been widely reported in aristeid shrimps (Sarda *et al*., 1997; Guegen, 1998; Figueiredo *et al*., 2001 and Pezzuto *et al*., 2006) probably as a result of factors related to seasonal reproductive pattern (Sarda *et al*., 2003). This has important implications regarding the capacity of the species to withstand high or uncontrolled fishing pressure and therefore more detailed surveys are required in the fishing ground identified.

Among aristeid shrimp, this particular genus is distinguished by an additional sexually dimorphic character in the antennal scale (Farfante and Kensley, 1997; Poore and Ahyong, 2004) which is described in the present study. Females were found to dominate the catch and similar observations of females dominating the landings of aristeid shrimps irrespective of season and depth have been reported (Guegen, 1998). A thorough understanding of the reproductive potential of the species can be achieved only by dedicated surveys of the fishing ground identified at various depths to arrive at reasonable estimates of population structure including depth-wise abundance, length distribution, sex ratio and maturity stages.

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New distributional records of deep-sea sharks from Indian waters

*K. V. Akhilesh, M. Hashim, K. K. Bineesh, C. P. R. Shanis and U. Ganga

*Central Marine Fisheries Research Institute, PB No. 1603. Cochin-682 018, Kerala. India. *E-mail: akhikv@gmail.com*

Abstract

This paper reports the first documented record of three deepwater sharks from Indian waters *i.e.*, *Hexanchus griseus* (Hexanchidae), *Deania profundorum* (Centrophoridae), pygmy false catshark (undescribed) (Pseudotriakidae) and presents a taxonomic account of smooth lanternshark, *Etmopterus pusillus* (Etmopteridae) and leafscale gulper shark, *Centrophorus squamosus* (Centrophoridae), caught by hooks & line units operated in the Arabian Sea, west coast of India and landed at Cochin Fisheries Harbour (Kerala), southwest coast of India.

Keywords: Deep-sea sharks, new reports, Arabian Sea, Indian EEZ

Introduction

The Arabian Sea with its unique ecological features such as position between two land masses, presence of islands, features like oxygen minimum zone (OMZ), circulation pattern, currents, influence of monsoon and high saline water intrusion from Persian Gulf and Red Sea etc. supports a very diverse ichthyofauna. Reports on the diversity of deep-sea fish fauna especially that on deep-sea chondrichthyans from Indian waters are very few. Raje *et al.* (2007) listed 47 species of sharks in commercial landings along the Indian coast mainly from catches made within 100 m depths. However elasmobranchs are also known from deeper waters and probably many species, which are not yet recorded, occur in the unexploited/underexploited deep waters of the Indian EEZ.

The targeted deep-sea shark fishery in Indian waters, especially along the southwest and southeast coasts of India started lately after 2002 by the multiday shark fishermen of Thoothoor (Tamilnadu). The fishery targets gulper sharks (Centrophoridae) but many other deep-sea chondrichthyans occur as by catch, which were dominated by bramble shark, *Echinorhinus brucus* and chimaera, *Neoharriotta pinnata* besides several small sized deep-sea sharks, skates and rays which are often discarded. Cochin Fisheries Harbour (Kerala), is a major fishing base where chondrichthyans which are caught along the entire west coast of India by multiday deep-sea trawlers, longlines and hooks & line units are landed throughout the year. The species described in this communication were captured by hooks & line units specifically targeting for deep-sea sharks operated off southwest coast of India at depths beyond 250 m. Deep-sea sharks, *Hexanchus griseus* (Hexanchidae), *Deania profundorum* (Centrophoridae) and pygmy false catshark (undescribed) (Pseudotriakidae) represent new species records from the Indian EEZ. In this paper these species are described and the occurrence of *Etmopterus pusillus* and *Centrophorus squamosus* off southwest coast of India is confirmed.

Material and Methods

During weekly observations of fish landings at Cochin Fisheries Harbour (CFH), Cochin, southwest coast of India, specimens of *Hexanchus griseus, Centrophorus squamosus, Deania profundorum, Etmopterus pusillus* and pygmy false catshark (undescribed) were collected from the deep-sea hooks & line landings operated in the Arabian Sea during April 2008. Species identification was based on Compagno (1984), Smith and Heemstra (1986), Shirai and Tachikawa (1993) and Compagno *et al.*

(2005). Morphometric measurements (direct) of formalin (5%) preserved specimens were taken following Compagno (1984) for all the specimens except those of *Etmopterus pusillus* which was followed by Compagno (2001). Unless otherwise stated all proportional measurements are expressed as percentage of total length (TL).

Results and Discussion

Order: Hexanchiformes

Family: Hexanchidae

***Hexanchus griseus* (Bonnaterre, 1788)** (Fig. 1)

Materials examined: immature (female), 870 mm TL.

Diagnosis: A heavily bodied, broad headed six gill shark with very long gill slits. Snout very short and blunt, mouth with 6 rows of lower, bladelike, comb shaped teeth on each side. Anal fin smaller than dorsal fin. Single dorsal fin placed well posterior of body. Dorsal fin base separated from upper caudal fin origin by a distance equal to, or slightly greater than its length. Brown above, paler below and fins white edged.

Fig. 1. *Hexanchus griseus*, 870 mm TL

Morphometry: Fork length 76.4; predorsal length 67; dorsal base 6.7; dorsal caudal space 7.9; anal caudal space 4.9; anal base 5.3; head length 21.6; pre gill length 17.1; intergill length 4.7; pre orbital length (not direct) 5.2; pre oral length 5.3; first gill slit height 9.2; sixth gill slit height 5.7; mouth width 14.9; inter narial length 5.2; inter orbital length 9.8; head width at 1st gill slit 17.6.

Remarks: Bluntnose sixgill shark, *H. griseus* has a circumglobal distribution in marine tropical and temperate waters, continental and insular shelves and slopes of Atlantic, Indian and Pacific Oceans (Nelson, 2006). Within Indian Ocean *H. griseus* has been reported from Madagascar, Mozambique, South Africa and Maldives. Depth of occurrence ranges from surface and 2500 m (Carey and Clark, 1995). Size at birth for this species is 650-740 mm TL and the maximum reported size is at least 482 cm TL (Compagno *et al.,* 2005). IUCN Red List status: Near Threatened (IUCN, 2009).

Order: Squaliformes

Family: Centrophoridae

***Centrophorus* Müller & Henle, 1837**

Seven *Centrophorus* species are reported/listed to be occurring in Indian waters: *Centrophorus moluccensis* Bleeker, 1860; *C. uyato* Rafinesque, 1810; *C. granulosus* (Bloch and Schneider, 1801); *C. lusitanicus* Bocage and Capello, 1864; *C. acus* Garman, 1906; *C. squamosus* (Bonnaterre, 1788) and *C. atromarginatus* Garman 1913 (Nair and Mohan. 1970; Appukuttan and Nair, 1988; Raje *et al.,* 2002; Venu and Kurup, 2002; Soundararajan and Roy, 2004; Titto D'Cruz, 2004; Jayaprakash *et al.,* 2006; Raje *et al.,* 2007; CMFRI, 2007; Joshi *et al.,* 2008; Vivekanandan and Sivaraj, 2008). This is a taxonomically problematic genus due to poor species descriptions, absence of type material for several nominal species and ontogenetic changes in some important morphological characters such as denticle morphology. Consequently the occurrence of several species in Indian waters requires confirmation.

***Centrophorus squamosus* (Bonnaterre, 1788)** (Fig. 2)

Materials examined: Several specimens in commercial fishery landings, total length 580-1070 mm TL.

Diagnosis: *Centrophorus squamosus* is easily identified by its denticle pattern (leaf like flattened crowns on elevated pedicels extending above the denticle bases (Fig. 3)), shape of the pectoral fins (broadly angular without extended rear tips) and tooth morphology (Fig.4).

Fig. 2. *Centrophorus squamosus,* female (mature), 720 mm TL

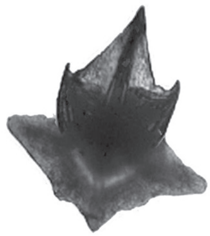

Fig. 3. Lateral dermal denticle of *Centrophorus squamosus*

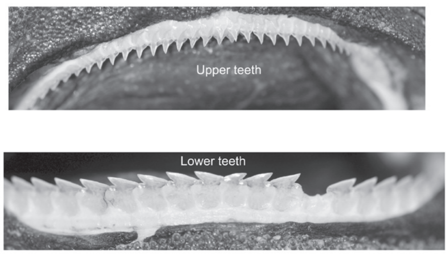

Fig. 4. Teeth of *Centrophorus squamosus*

Remarks: Titto D'Cruz's (2004) report of *C. squamosus* from Indian waters is confirmed here. Furthermore, we observed bulk landings of this species at Cochin Fisheries Harbour during 2008. This species is reported to live at depths between 229 and 2,359 m (Compagno, 1984) and has a very wide but patchy reported distribution in the world's oceans. In the Indian Ocean it has been previously reported from South Africa, Aldabra Islands and Maldives (Compagno, 1984; Adam *et al.,* 1998).

Order: Squaliformes

Family: Centrophoridae

***Deania* Jordan & Snyder, 1902**

***Deania profundorum* (Smith & Radcliffe, 1912)** (Fig. 5)

Materials examined: Three females, total length 580-602 mm.

Diagnosis: First dorsal fin long, low and keel shaped. Second dorsal fin spine much larger than first. Pectoral fin free, rear tip not elongated. Snout greatly elongated and its length greater than distance from centre of mouth to pectoral fin origins. This species can be easily identified by the presence of a keel on the underside of the caudal peduncle (Compagno, 1984). Teeth of lower jaw broader than that in upper jaw. Dermal denticles on sides of body have stellate bases, high pedicels, tricuspidate and triridged erect crowns. Brownish grey or dark grey in color.

Fig. 5. *Deania profundorum*, female, 63 cm TL.

Morphometry: Pre-caudal length 81.6-82.2; pre-dorsal length 6.4-6.8; head length 26-26.2; pre-branchial length 21-22; pre-spiracular length 15.6-15.7; pre-orbital length 9.8-10; pre-pectoral length 24.7-24.9; pre-pelvic length 6-6.4; dorsal caudal space 3.3-3.9; interdorsal space 14.9-16.4; prenarial length 4.8-4.9; preoral length 12.7-13.1; inter gill length 5.4-5.6; pectoral fin-anterior margin 10.4-11.2, pectoral base 5-5.1; pectoral fin-inner margin 8.6-9.2; pectoral-posterior margin 7.5-8.2; dorsal caudal margin 18.7-19.5; preventral caudal margin 10-11.8; terminal caudal margin 6-6.6; first dorsal fin length 23.4-24.1; first dorsal anterior margin 11.2-11.9; first dorsal base 17.3-17.4; first dorsal height 4.9-5; first dorsal inner margin 6.3-7.2; 2nd dorsal base 12.5-13.5; 2nd dorsal height 6.4-6.5; 2nd dorsal length 16.6-16.9; 2nd inner margin 3.9-4.4; pelvic length 10.6-10.8; pelvic anterior margin 6.7-7.1; pelvic base 4.9-5.2; pelvic inner margin 5.8; caudal peduncle height 3.3; mouth width 7-7.2; nostril width 2-2.3; inter narial 3.8-3.9; inter orbital 6.4-6.7; head width 12.3-13.3.

Remarks: Arrowhead dogfish, *D. profundorum* is a little known deepwater shark species that lives at depths between 275 and 1785 m and has a very disjunct distribution in the world oceans. It's distributed on both sides of the Atlantic Ocean and Pacific Ocean (Compagno, 1984). Indian Ocean reports are only from South Africa (Compagno, 1998) and Gulf of Aden (Bonfil and Abdallah, 2004). Sousa *et al.* (2008) carried out pioneer work on the biology of the species.

Order: Squaliformes

Family: Etmopteridae

Three *Etmopterus* species are listed from the Indian EEZ: *E. granulosus* (Günther, 1880); *E. pusillus* (Lowe, 1839); and *E. lucifer* Jordan &

Snyder, 1902 (Jayaprakash *et al.,* 2006; Sreedhar *et al.,* 2007; CMFRI, 2007; Vivekanandan and Sivaraj, 2008). As detailed description of species found in Indian waters is not available, a note is presented here to confirm its presence in Indian waters following the listing by Sreedhar *et al.* (2007).

***Etmopterus pusillus* (Lowe, 1839)** (Fig. 6)

Materials examined: three females, 305 - 465 mm TL.

Diagnosis: Small shark with cylindrical or slightly compressed body, first dorsal fin usually smaller than second dorsal fin, second dorsal spine larger than first; colour blackish-brown above, with a broad black mark running above pelvic fins and ending just behind second dorsal and with truncated denticle.

***Morphometry*:** Fork length 87.87-89.03; pre caudal-fin length 80.66-81.72; head length 23.01-25.77; pre-orbital length 5.46-5.48; pre-oral length 8.7- 10.7; eye length 3.3-3.7; inter-gill length 5.38-6.76; dorsal caudal-fin margin 16.73-20.65; pre-ventral caudal-fin margin 10.58-10.67; caudal-fin fork length 10.23-10.72; first dorsal-fin anterior margin 5.02-5.44; 2nd dorsal-fin anterior margin 7.48-9.36; inter-dorsal space 22.74-26.65; pectoral-fin anterior margin 8.66-9.77; pelvic-fin anterior margin 5.10-5.80; head height 8.24-8.89; trunk height 9.08-10.10; tail height 5.53-5.81; caudal-fin peduncle height 2.20-2.30; head width 10.59-10.65; trunk width 9.15-10.77; tail width 4.13-5.55; caudal-fin peduncle width 1.63-1.81 and intestinal spiral valve turns 12-13.

Remarks: There are two species, *E. pusillus* and *E. bigelowi*, in the "*pusillus*" complex (Shirai and Tachikawa, 1993). They are separated from other *Etmopterus* species by their truncated dermal denticles. The characters distinguishing these two species are described by Shirai and Tachikawa (1993) and Last *et al.* (2002). There can be variations in some morphological characters due to growth and sexual dimorphism but certain characters are consistent and one of these is the number of spiral valve turns. *E. pusillus* has a spiral valve count of 10-14 and *E. bigelowi* 16. Another distinguishing character is the distance from snout tip to first gill slit which is shorter than distance from first gill slit to first dorsal fin origin (Shirai and Tachikawa, 1993; Last *et al.,* 2002; Gianeti and Vooren, 2008).

The smooth lanternshark, *E. pusillus* is a small circumglobally distributed shark found on or near the bottom over continental and insular slopes at depths from 274 to 1000 m, and possibly to 2000 m (Compagno *et al.,* 2005). In the western Indian Ocean this species has been reported from South Africa (Compagno, 1984).

Fig. 6. *Etmopterus pusillus*, female, 305 mm TL.

Order: Carcharhiniformes

Family: Pseudotriakidae

Pygmy False catshark Genus and species nov. **(**Compagno, Stehmann & Anderson), (Fig. 7)

Material examined: female, 630 mm TL.

Diagnosis: Second dorsal fin larger than the first with its origin over the pelvic inner margin. Last two gill slits over pectoral fin. 5th gill slit smallest.

Morphometry: Precaudal length 81.5; pre-first dorsal length 35.6; pre-second dorsal length 6.3; head length 24.3; prebranchial length 20.8; pre spiracular length 13.7; spiracle length 1.3; spiracle width 0.7; preorbital length 7.8; pre pectoral length 23.3; pre pelvic length 5.3; dorsal caudal space 4.8; snout vent length 5.7; inter dorsal space 13.7; pre narial length 6.2; pre oral length 7.1; inter gill length 4.6; first gill slit height 2.9; fifth gill slit height 1.8; pectoral anterior margin 10.4; pectoral base 4.6; pectoral inner margin 5.0; pectoral posterior margin 9.7; dorsal caudal margin 21.1; preventral caudal margin 9.1; terminal caudal margin 5.1; first dorsal length 16.1; dorsal anterior margin 9.7; first dorsal base 13.6; first dorsal height 5.9; first dorsal inner margin 2.6; 2nd dorsal base 13.5; 2nd dorsal height 6.6; 2nd dorsal length 16.0; 2nd inner margin 2.4; pelvic length 11.0; pelvic anterior margin 8.4; pelvic base 7.4; pelvic inner margin 3.9; caudal peduncle height 2.7; mouth width 13.4; nostril width 2.6; inter narial 4.0; inter orbital 7.2; inter spiracle 10.2 and head width 17.4.

Remarks: This species has previously been reported only from two localities in the northwest Indian Ocean: off Socotra Island in the Arabian Sea, and from the Maldives Islands. It is believed to occur upto depths of 1120 m (Compagno *et al.,* 2005).

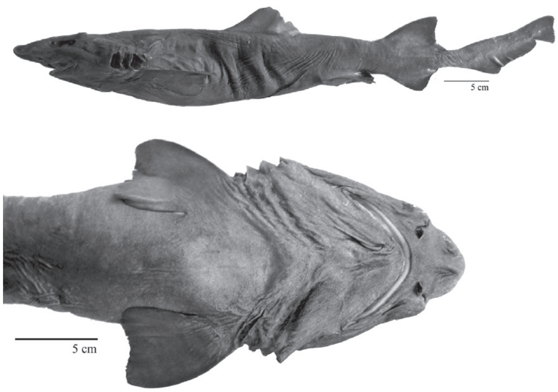

Fig. 7. Pygmy false catshark (genus and species nov.), female, 630 mm TL.

The diversity of deep-sea fauna of Indian EEZ still remains largely unknown/undescribed. Recent increase of distant water multiday fishing is resulting in landings of rare deep-sea species, which were not reported earlier from Indian waters. Deep-sea resources, especially chondrichthyans, are highly vulnerable to fishing pressure (Kyne and Simpfendorfer, 2007) and a knowledge base on their occurrence, distribution and abundance is a critical factor in formulating conservation and fisheries management strategies. The recent exploratory surveys for chondrichthyan resources in Indonesia and Australia have come up with fascinating results and emphasize the need to conduct similar exercise in Indian waters also.

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First record of the anthiine fish, *Meganthias filiferus* (Perciformes: Serranidae) from Indian waters

K.V. AKHILESH, N.G.K. PILLAI, U. GANGA, K.K. BINEESH, C.P. RAJOOL SHANIS AND HASHIM MANJEBRAYAKATH

Central Marine Fisheries Research Institute, PB No. 1603, Ernakulam North PO, Cochin–683 018, Kerala, India

The present paper reports the first record of occurrence in the Arabian Sea and extension of distribution of Meganthias filiferus *from the Thailand coast of the eastern Indian Ocean. A single specimen measuring 211 mm SL was collected from a commercial trawler operating in the Arabian Sea off the south-western coast of India during August 2008. The two known specimens of this rare species are compared.*

Keywords: *Meganthias*, Serranidae, Indian Ocean

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The subfamily Anthiinae (family: Serranidae) comprises some 24 genera and more than 100 species of beautifully coloured fish that inhabit coral and deep reef habitats in tropical and warm temperate seas. Anthiine fish are usually small in size, but a new genus, *Meganthias*, was described by Randall & Heemstra (2006) for two large (34 and 28 cm SL) anthiine fish previously known as *Holanthias* or *Odontanthias natalensis* (Fowler, 1925) from South Africa and *Holanthias kingyo* Kon, Yoshino & Sakurai, 2000 from Okinawa, Japan. Another large species, based on two fish of 24 and 30 cm SL discovered off the coast of Nigeria, Atlantic Ocean has also been added to the genus as *M. carpenteri* Anderson, 2006. Another species of *Meganthias* was collected from the Andaman Sea, off the south-western coast of Thailand and reported by Sirimontraporn & Bussarawit (1993) as *Holanthias chrystosticus* (Günther, 1872). This 29 cm SL fish was later described as a new species *M. filiferus* by Randall & Heemstra (2007) due to its marked variations from other congeneric species in coloration, larger head proportion (head length 2.5 in SL), corner of preopercle strongly angular and dorsal filament morphology.

On 26 August 2008 a single specimen of *M. filiferus*, 211 mm SL was collected from a commercial trawler operated in the Arabian Sea, off the south-western coast of India (Figure 1). This is the first report of the species from Indian waters. The specimen was deposited in the National Marine Biodiversity Referral Museum at Central Marine Fisheries Research Institute, Cochin India. The morphometric and meristic characters of the specimen agree well with data from the holotype given by Randall & Heemstra (2007) (Table 1). This second report of *M. filiferus* is the first record from the west coast of India and indicates a marked extension of the distribution from its type locality.

Corresponding author:
K.V. Akhilesh
Email: akhikv@gmail.com

DIAGNOSIS

Dorsal rays X18; anal rays III.8; pectoral rays 17; pelvic rays I.5; lateral line scales 43–44. Scales above lateral line to 5th dorsal spine 4; gill rakers; 12 + 25. Upper jaw with canine teeth on anterior portion. Vomer and palatines with villiform teeth. Similarities between the Thai and Indian fish include the elongated 2nd and 3rd dorsal-fin rays and the acutely elongated caudal fin lobes.

The colour patterns are identical with similarities as follows: head and body pink with several yellow markings that include a broad, slightly greenish yellow area on top of head from upper edge of eye (interorbital area) to below first 4 dorsal-fin spines and extending out over the first four inter-spinous dorsal fin membranes. Rear part of spinous dorsal fin pink, the posterior 6 spines with a scarlet spot at tip of each spine; the first 4 dorsal-fin rays elongated, pinkish proximally and yellow distally, the second and third dorsal rays greatly elongated and merging to form a slender filament about equal to head length, with a small oval red spot on the lower edge of yellow part of these two rays; rest of soft dorsal fin pinkish with a row of 6 small oval red

Fig. 1. *Meganthias filiferus*, 211 mm SL, Arabian Sea, off the south-western coast of India.

Table 1. Morphometric comparison of *Meganthias filiferus* (%SL in mm) from India with the holotype (Randall & Heemstra, 2007).

	Cochin 2008	Randall & Heemstra (2007)
Standard length	211	293
Body depth	49.3	48.8
Body width	19.8	19.6
Head length	41.6	40.3
Snout length	10.1	10.9
Orbit diameter	9.5	9
Interorbital width	13.3	13.4
Upper-jaw length	19.3	20.4
Caudal-peduncle depth	13.5	13
Caudal-peduncle length	18.3	17.8
Predorsal length	35.3	34.9
Preanal length	62.8	66.9
Prepelvic length	33.9	39
Dorsal-fin base	67.5	65.7
First dorsal spine	5.8	5.5
Second dorsal spine	9.3	8.2
Third dorsal spine	11.9	10.9
Fourth dorsal spine	12.6	11.2
Tenth dorsal spine	13.1	12.6
First dorsal ray	25.1	28.5
Longest ray	62.8	66
Last dorsal ray	7.0	8.9
Anal-fin base	20.9	20.8
First anal spine	6.8	6.9
Second anal spine	12.1	11.8
Third anal spine length	13.7	13.7
Longest anal ray	22.5	21.8
Caudal fin length	74.9	89.7
Pectoral-fin length	30.4	29.1
Pelvic spine length	18.2	14.7
Pelvic- fin length	29.0	30.4

spots near the fin margin, perhaps 2 or 3 red spots on 5th ray (fin membrane slightly damaged here); caudal fin pink, with dull yellow sub-marginal band along each lobe; upper margin of opercle yellow; a dull yellow band along vertical edge of preopercle, suborbital area, cheek above and behind maxilla and extending onto lower lip; maxilla pink, the upper edge yellow, upper lip and front of lower lip pink; pectoral and pelvic fins dusky yellow; anal fin pink proximally, the outer third and interspinous membranes bright yellow. The oval red spots on the soft dorsal fin of the holotype are more numerous (12) and scattered irregularly over the distal part of the fin; and this difference may be ontogenetic or sexually dimorphic.

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Correspondence should be addressed to:
K.V. Akhilesh
Central Marine Fisheries Research Institute
PB No. 1603, Ernakulam North PO
Cochin–683 018
Kerala, India
email: akhikv@gmail.com

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Short Communication

Morphometric characteristics of deepwater stingray *Plesiobatis daviesi* (Wallace, 1967) collected from the Andaman Sea

*K. V. Akhilesh, Hashim Manjebrayakath, U. Ganga, N. G. K. Pillai and Manju Sebastine

*Central Marine Fisheries Research Institute, P. B. No. 1603, Ernakulam North P.O., Cochin - 682 018, Kerala, India.*E-mail: akhikv@gmail.com*

Abstract

The present paper reports on the morphometric characteristics of two specimens of *Plesiobatis daviesi* collected during the deep-sea fishery resource survey of FORV *Sagar Sampada* in the northeastern Andaman Sea off Diglipur (13^0 14' N lat; 93^0 09' E long.) at 320 m depth and off Mayabandar (12^0 48' N lat; 93^0 07' E long.) at 369 m depth.

Keywords: Andaman Sea, deepwater stingray, *Plesiobatis daviesi*

Introduction

Plesiobatis daviesi (Wallace, 1967) belongs to monotypic family Plesiobatidae (Rajiformes) which was established by Nishida (1990). The species was formerly included under the genus *Urotrygon* (Nelson, 2006). *P. daviesi* is well distributed in the Indo-West and Central Pacific Oceans from South Africa to Hawaii (Froese and Pauly, 2009). Nair and Soundararajan (1973) reported *P. daviesi* (female; 534 mm TL) for the first time from Indian waters off Mandapam in the Gulf of Mannar (08^0 58' N lat. 79^0 16' E long.), southeast coast of India. Like most of the deep-sea organisms, studies on deepwater stingray *P. daviesi* are limited. This communication presents the morphometric characteristics of two female *P. daviesi* specimens collected from the northeastern Andaman Sea.

Material and Methods

An exploratory deep-sea fishery survey (cruise: No. 252) was carried out by FORV *Sagar Sampada* in the Andaman Sea (Fig. 1) of the Indian EEZ during 2007. Trawling was carried out during daytime using EXPO and HSDT nets at depths ranging from 300 to 700 m. A female *P. daviesi* measuring 156 cm total length (TL) with two spines, disc width 78 cm and weighing 15 kg (Fig. 2 and 3) was collected from the northeastern Andaman waters off Diglipur (13^0 14' N lat; 93^0 09'E long.) at 320 m depth and another one with a single spine measuring 92.5 cm TL and weighing 3 kg was collected off Mayabandar (12^0 48' N lat; 93^0 07' E long.) from 369 m depth. The specimens were identified following Wallace (1967) and Compagno (1986). Morphometric measurements were taken from formalin preserved (5%) specimens and comparisons (as % of TL) with earlier reports were made. Specimens were deposited in the National Biodiversity Referral Museum, CMFRI, Cochin, India (GA.7.6.1.1).

Results and Discussion

P. daviesi is mainly found on continental and insular slopes at a depth of about 275-680 m and is reported to attain at least 270 cm TL (Compagno, 1986; Nelson, 2006; White *et al.,* 2006). *P. daviesi* can be identified from the following characters: snout pointed, broadly angular and markedly produced; snout length > 6 times orbit diameter, tail with a lobe-like caudal fin, upper and lower caudal present. No dorsal fin or skin folds on side or undersurface of tail. Upper surface of the disc covered with prickles. The morphometric characteristics of the present specimens match with the representative described from South African waters even though slight variations were observed in certain characteristics (Table 1). This includes the inter-orbital length, which was higher (7.0-7.4% TL in the present study) compared to 4.2-5.9% of TL reported by Wallace (1967); slightly smaller eyes, eye length 1.68-1.73% TL compared to 2.06% TL observed by Nair and Soundararajan (1973). Snout length (pre-orbital) 10.7-11.2% in eye length and 18-19.5% TL. Nair and Soundararajan (1973) reported similar variations in the morphometric characters of *P. daviesi* collected from Gulf of Mannar. However most of the morphometric characteristics showed variations within the limit described by Wallace (1967).

Stingrays usually have single spine in the tail but the presence of two spines is relatively common in certain rays. Occurrence of multiple spines in *Dasyatis sabina, D. pastinaca*, *Ateobatus narinari* and *Urolophus halleri* are reported (Russel, 1955; Halstead, 1970; Teaf and Lewis, 1987). *P. daviesi* normally has a single sting/spine on dorsal side of the tail and can inflict a painful wound if handled (White *et al.,* 2006). One of the specimens collected from the Andaman Sea had two stings and there are no morphometry reports of *P. daviesi* with multiple spines for comparison. However certain species of

Table 1. Morphometric comparison (% of total length) of *Plesiobatis daviesi* (Wallace, 1967) captured from Andaman Sea with that of earlier reports

Characteristics	Wallace (1967)	Nair and Soundararajan (1973)	Present specimen (double spine)	Present specimen (single spine)
Total length (cm)	*	53.4	156	92.5
Disc width	53.7-59	56.93	50.32	54.05
Disc length	54.2-58.5	57.12	53.00	52.97
Pre-caudal length	*	*	75.48	75.13
Pre-narial length	*	*	15.61	15.78
Pre-oral length	18.6-19.5	20.97	18.39	19.46
Pre-orbital length	17.4-19.8	19.1	17.95	19.46
Pre-spiracle length	*	*	19.23	20.54
Pre-gill length (from 1st gill)	*	26.4	24.84	25.41
Pre-gill length (from 5th gill)	*	*	29.29	31.89
Eye length	*	2.06	1.68	1.73
Eye height	*	*	0.46	0.73
Interorbital width	4.2-5.9	6.93	7.38	7.03
Internarial width	7.8-9.8		7.55	7.68
Spiracle length	*	4.12	3.23	3.78
Interspiracle width	8.3-9.2	9.55	8.47	8.76
Mouth width	5.8-7.1	5.99	6.45	6.05
First gill slit length	*	*	2.04	1.76
Second gill slit length	*	*	2.03	1.76
Fifth gill slit length	*	*	1.32	1.43
Distance between first pair of gill slits	12.4-14.1	12.73	13.50	12.76
Distance between fifth pair of gill slits	8.1-9.3	7.86	7.70	8.65
Lower caudal fold length	*	*	24.84	24.86
I sting length	*	*	10.84	11.89
II sting length	*	*	10.84	0.00
I sting width	*	*	0.59	0.65
II sting width	*	*	0.87	0.00
Anterior pelvic length	*	*	6.77	6.49
Pelvic width	*	*	4.65	4.32
Pelvic inner margin	*	*	5.29	4.22
Snout to spine origin	72.3-73.7	72.28	71.80	74.05
Tail length	*	49.62	51.53	50.59

*indicates NA

Urolophids, which are the closest group to *Plesiobatis* are reported to have two spines and in some rare instances, some species from Indonesian waters have 3 spines (White, 2009, personal communication). All the variations in comparison with Wallace (1967) were within the limit range and not enough to describe as a new species (Table 1) and two specimens collected from Andaman Sea did not differ much in their morphometric characteristics. Perhaps genetic studies and DNA sequence comparison with similar species from other parts of world may confirm whether the two specimens of *P. daviesi* have morphometric variation due to zoogeographical factors. More specimens are needed for a detailed study on the species.

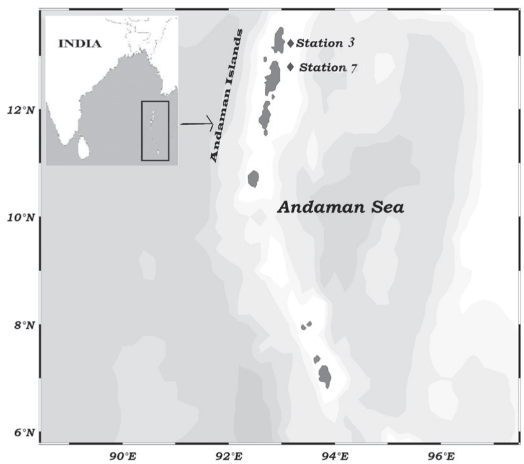

Fig. 1. Map of northeastern Andaman Sea showing sampling sites of *Plesiobatis daviesi* by FORV *Sagar Sampada* (St. 3 and St. 7)

Fig. 2. *Plesiobatis daviesi* female with two spines (156 cm TL)

Fig. 3. Enlarged spine image

The gut content analysis of the two *P.daviesi* specimens collected showed semi-digested teleosts and shrimps. White *et al*. (2006) reported that the fish feeds primarily on small fishes, crustace-ans, cephalopods and numerous mesopelagics suggesting a possible feeding migration into water column. There is no targeted fishery for *P. daviesi*, though incidental occurrences in deepwater trawls and longlines have been reported from Taiwan and Indonesia. The IUCN Red List status has classified the species as least concern (IUCN, 2009).

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covering the southwest coast, northeast coast and the Andaman waters; 8-16^0 latitude in the west and 8 to 21^0 latitude in the east. A comparison of the results shows that during the period 2005 – 2007, more number of species was recorded. During 1998-2002, the investigation was mainly focused in the depth range of 200-500 m, whereas during 2005-2007 the survey was conducted at depths above 500 m. In terms of depthwise distribution, 200-700 m depth range harbored most of the fish groups. Analysis revealed that lat 9° -10° and 10° -11° N along the west coast are rich in species diversity, whereas 14 -15° N latitude showed the lowest diversity. Along the east coast, 11^0-12^0, 12^0-13^0, and 14^0-15^0 latitude showed rich species diversity when compared to 19^0-20^0 latitude with the lowest diversity. Distributional pattern of deepsea fishes along east and west coast of India are discussed. *Saurenchelys taeniola* dominated the catches in the west coast and *Lamprogrammus exutus* in the east coast. Selected species were analyzed for biological parameters such as food and feeding, maturity stages, sex ratio, length-weight relationship etc. Majority of the species were in the maturing stage. Ideal sex ratio was observed in a few species though the sheerness of male population was observed in respect of very few other species. All the fishes analyzed were carnivores with a predatory food habits. Most of the species showed an ideal b value of around 3 which is an indication of isometric growth. The exponential value "b" for different species varied from 0.007 to 4.56. The paper also stresses the need for more scientific and exploratory strategies to exploit the least explored deepsea resources for future use.

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DIVERSITY OF THE DEEPSEA FINFISH RESOURCES OF THE INDIAN CONTINENTAL SLOPE

Hashim Manjebrayakath*, Divya Thankappan, A.A. Jayaprakash and U. Ganga
Central Marine Fisheries Research Institute, P. Box No. 1603,
Cochin- 682 018
*hashimaqua@yahoo.com

During the period 2005-2007, four exploratory deep sea cruises were carried out by FORV *Sagar Sampada* in the Arabian Sea (9^{0}N-12^{0}N), Bay of Bengal (8 -20^0 N) and Andaman Seas (11-13 ^{0} N) of the Indian EEZ. Trawling was carried out during the daytime using EXPO trawls and HSDT nets. Catch per hour (CPH) as well as depth-wise (200-400, 400-600, 600-800, 800-1000 and >1000 m) distribution and abundance of deepsea finfish resources in the three regions were assessed.

In the Arabian Sea, the catch varied from 1793.7 kg (CPH:53.4kg) to 3013.9 kg (CPH: 231.8 kg). The finfish component of the catch varied from 55 to 60%. A total of 126 species belonging to 29 families were recorded. In the Arabian Sea the maximum number of families occurred in the depth range 600 -800 m with 29 families followed by 400 m with 21 families, and 400 -600 m depth with 20 families. Families

which showed the highest abundance in terms of catch were Chloropthalmidae, Ophiididae, Muraenidae, Stromateidae and Macrouridae. The most abundant species were *Chloropthalmus bicornis, C. punctatus, Uranoscopus archionema, Eridacnis radcliffei, Lampogrammus* exutus, *Gavialiceps taeniola* and *Bembrops caudimaculata.*

In the Bay of Bengal (including the Andaman Sea), 17 trawl operations were carried out at 11 stations between 50 and 770 m depth and 91 species belonging to 28 families were recorded. Regionwise diversity of fishes including elasmobranchs was studied using the presence/absence of families as well as the number of species within each family and their biomass. While 22 families were represented in the catches at 200 - 400 m depths, 28 families were observed at 400 -600 m depths. Compared to this, only nine families were recorded in 600 - 800 m depth and six families in the depth beyond 1000 m. The most common family in the 200 - 400 m depth was Priacanthidae represented by *Priacanthus hamrur* and Rhinochimaeridae in the 400 -600 m depth represented by *Neoharriotta pinnata*. The eel *Bathyuroconger brauei* (Congridae) was recorded in the 600 -800 m depth.

Table 1. Number of deepsea fish species recorded

Order/Family	Arabian Sea	Bay of Bengal
Order - Anguilliformes		
Family – Congridae	1	1
Muraenidae	2	1
Nemichthyidae	1	1
Synaphobranchidae	1	1
Order – Aulopiformes		
Family – Evermannellidae		1
Chlorophthalmidae	3	3
Paralepididae	1	
Order - Beryciformes		
Family – Berycidae	1	
Holocentridae	1	
Trachichthyidae	1	
Order – Carcharhiniformes		
Family – Proscyliidae	1	1
Scyliorhinidae	2	2
Order – Chimaeriformes		
Family – Chimaeridae		1
Rhinochimaeridae	1	1
Order – Gadiformes		
Family – Macrouridae	3	3
Moridae	1	
Order – Lophiiformes		
Family – Ceratiidae	1	1
Chaunacidae	1	1
Diceratiidae	1	1
Lophiidae	1	1
Melanocetidae	1	1
Ogcocephalidae	1	1
Oneirodidae	1	

Order - Myctophiformes		
Family – Myctophidae	2	1
Neoscopelidae	2	1
Order – Ophidiiformes		
Family – Carapidae	1	1
Ophidiidae	9	4
Order – Perciformes		
Family – Acropomatidae	2	
Apogonidae		1
Bathyclupeidae	1	1
Cepolidae		1
Gempylidae	2	2
Gobiidae		1
Nemipteridae	1	1
Nomeidae	1	1
Percophidae	1	1
Priacanthidae	1	1
Serranidae	1	
Stromateidae	1	1
Uranoscopidae	1	
Order – Pleuronectiformes		
Family – Bothidae	2	1
Cynoglossidae	1	
Order – Rajiformes		
Family – Rajidae	2	1
Plesiobatidae		1
Order – Salmoniformes		
Family – Alepocephalidae	6	2
Platytroctidae	2	
Order – Scorpaeniformes		
Family – Peristiediidae	1	3
Scorpaenidae	1	1
Triglidae	1	1
Order – Squaliformes		
Family – Echinorhinidae	1	
Squalidae	6	2
Order – Stomiiformes		
Family – Astronesthidae	1	2
Chauliodontidae	1	1
Gonostomatidae	1	1
Idiacanthidae		1
Malacosteidae		1
Sternoptychidae		1

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Short Communication

Morphometric characteristics of the pelagic stingray *Pteroplatytrygon violacea* (Bonaparte, 1832) caught off Cochin, southwest coast of India

*K. V. Akhilesh, Hashim Manjebrayakath, U. Ganga, K. K. Bineesh and C. P. Rajool Shanis

*Central Marine Fisheries Research Institute, P. B. No. 1603, Ernakulam North P.O., Cochin - 683 018, Kerala, India.*E-mail:akhikv@gmail.com*

Abstract

The morphometric characteristics of the pelagic stingray *Pteroplatytrygon violacea* (Bonaparte, 1832) are described for the first time from the Indian waters. The specimen was collected at Cochin in August, 2008. The mature male specimen measured 102 cm in total length, 47 cm in disc width, 35 cm in disc length and weighed 2.5 kg. The morphometric characteristics of the specimen were very similar to that described from the North Sea.

Keywords: Dasyatidae, stingray, *Pteroplatytrygon violacea,* Indian Ocean

Introduction

Pteroplatytrygon is a monotypic genus (Compagno, 1999; Nelson, 2006) and one of the six genera of family Dasyatidae (Myliobatiformes), which is the largest stingray family comprising about 68 species. In the Indian waters, 32 rays including 18 species of Dasyatidae have been reported (Raje *et al.,* 2002, 2007) and the presently described species *Pteroplatytrygon violacea* is a new addition. It was earlier considered as a rare species occurring only in the Mediterranean Sea (Tortonese, 1956), but later its distribution in the Indian, Pacific and Atlantic Oceans has been reported (McEachran and Capape, 1984; Mollet, 2002; Domingo *et al.,* 2005; Ellis, 2007; Froese and Pauly, 2008). However, reports from the Indian Ocean are very rare and restricted to the waters off South Africa and eastern Indonesia (White and Dharmadi, 2007). *P. violacea* has been reported in the exploratory survey of FORV *Sagar Sampada* along the southwest coast of India (Jayaprakash *et al.,* 2006) and in the fishery survey of *Matsya Vrusti* (Anon, 2007). This communication gives the first report on the morphometric characteristics of *P. violacea* from the Arabian Sea.

Material and methods

The pelagic stingray *Pteroplatytrygon violacea* (Bonaparte, 1832) was collected from the Cochin Fisheries Harbour, Kerala in August 2008. The mature male specimen was obtained as by-catch from a tuna gillnetter, which operated at a depth of about 150 m. It measured 102 cm in total length (TL), 47 cm in disc width (DW) and 35 cm in disc length (DL) and weighed 2.5 kg. The morphometric measurements of the specimen were measured with a Mitutoyo digital vernier caliper with an accuracy of 0.5 mm. Morphometric characteristics were compared with the specimen from North Sea (BMNH 2007.7.3.1), which is deposited in the British Museum of Natural History (Ellis, 2007). The present specimen has been deposited in the National Marine Biodiversity Referral Museum at CMFRI, Cochin.

Results and Discussion

The pelagic stingray *P. violacea* (Bonaparte, 1832) is found in the open oceans and inshore bays. It is the only whiptail stingray known to inhabit epipelagic waters of oceans (Wilson and

Beckett, 1970; Menni and Stehmann, 2000; Mollet, 2002; Neer, 2008). *P. violacea* is identified by its symmetry and dark coloration on the dorsal and ventral surfaces of the characteristically broad wedge-shaped disc. The snout is very small and the tail has a membranous fold on the ventral surface underneath the spine (Fig. 1). The morphometric characteristics of the present specimen matches with the representative described from the North Sea by Ellis (2007) (Table 1). A slight variation was observed in the interorbital distance, which may be due to geographical

Fig. 1. Dorsal view of *Pteroplatytrygon violacea* (Bonaparte, 1832)

variation and size difference. There are a few reports on the biology of *P. violacea* Mollet *et al.,* 2002; Hemida *et al.,* 2003; (Neer, 2008). The diet of the ray has been reported to consist of coelenterates, decapods, squids, crustaceans and pelagic fishes (Mollet *et al.,* 2002). Analysis of stomach content of the specimen collected at Cochin showed that crustacean biomass was

Table 1. Morphometric comparison (% of total length in mm) of *Pteroplatytrygon violacea* (Bonaparte, 1832) captured off Cochin with specimen from North Sea (Ellis, 2007)

Dimension	Arabian Sea (off Cochin)	North Sea
Total length (cm)	102.00	99.5
Disc width	46.08	42.20
Disc length	34.31	33.70
Pre-orbital length	5.49	5.30
Length of the eye	1.57	1.60
Inter-orbital distance	6.57	4.10
Pre-spiracular distance	7.35	6.90
Length of the spiracle	2.55	2.20
Inter-spiracular distance	7.65	7.70
Pre-narial length	5.10	4.80
Inter-narial distance	4.41	4.20
Pre-oral distance	6.27	6.30
Mouth width	5.39	4.90
Interspace first gill slits	8.82	8.50
Interspace fifth gill slits	6.47	6.00
Snout to first gill opening	11.37	10.80
Snout to fifth gill opening	16.57	15.70
Snout to cloaca (anterior) distance	29.90	29.60
Cloaca (anterior) to end of the tail	70.10	71.40
External clasper length	6.18	5.50

dominant (60%) followed by digested fish and squid.

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two similar areas in natural ecosystem (coral reef and sand- muddy bed). At each site 3 transects and at each transect 3 quadrates were selected for sampling of benthic epifauna, which commenced 1 year after deployment of the Artificial reefs. Quantitative samples were collected seasonally using quadrate and SCUBA diving methods. The result of quantitative analysis of samples provided valuable information on species composition, abundance and distribution. The benthic groups in the order of abundance were: Crustacea (*Balanus* sp., Decapoda, Amphipoda), Mollusca (Bivalvia, Gastropoda), Corallinaceae, Worms, and many coral reef fish fauna such as *Epinephelus* sp., Sea bream, Angel fish; Ascidicea, and Ophiuroidea (brittle stars).

Seasonal variations in occurrence and abundance of the fauna are explained in detail in this paper. Comparison between the artificial reefs and the control sites clearly indicated that ARs could be productive habitats for benthic epifauna, which in turn attract predator species such as fish. This indicates that in the long run, these ARs would lead to replenishment of fishery resources of the area, thus contributing to the fishery production of Salakh coast.

BDP 023

HARMFUL MICRO ALGAE OF THE INDIAN EEZ

K. B. Padmakumar, *M. G. Sanilkumar, A. V. Saramma and N. R. Menon, Department of Marine Biology, Microbiology and Biochemistry, School of Ocean Science and Technology, Cochin University of Science and Technology, Kochi 682 016, Kerala, India; *sanil@cusat.ac.in

The International Council for the Exploration of Seas has defined the phytoplankton blooms as, those, which are noticeable, particularly to general public, directly or indirectly through their effects such as visible discolouration of the water, foam production, fish or invertebrate mortality or toxicity to humans. These are natural phenomenon that occurs in the seas under special hydrological conditions, when the combined effects of grazing factors are less than the biomass production, due to the growth of phytoplankton via advective processes. The accumulation of phytoplankton may also be so dense that the water appeared to be coloured red, green, brown, orange etc. The frequency of appearance of algal blooms is increasing in the recent past. The expansion of harmful algal blooms during the past 25 years is responsible for economic losses approximating $100 million per year world wide due to the loss of production in fisheries, declines in fisheries-related businesses, severe reductions in local/regional tourism and its associated service industries and public illness and its medical treatments.

Since 1998, as a part of regular monitoring of algal blooms in the Indian EEZ, Ministry of Earth Sciences has been conducting regular oceanic cruises for the surveillance, identification, enumeration and ecology of HABs in territorial waters and contiguous seas in the Indian EEZ. Altogether 414 species of micro algae (phytoplankters) have been reported from the EEZ of India. Around 34 species of harmful micro algae have been recognized during a study period extending nine years. Among these, during favourable conditions only a few species form blooms. Commonly occurring blooms in the Indian EEZ are due to species belonging to the genera of *Trichodesmium*, *Noctiluca*, *Gymnodinium* , *Gonyaulax*, *Cochlodinium* and *Hornelia*.

BDP 024

DEEP-SEA FINFISH DIVERSITY IN NORTH ANDAMAN SEAS

***Hashim Manjebrayakath, Divya Thankappan and A. A. Jayaprakash**, Central Marine Fisheries Research Institute, Kochi 682 018, Kerala, India; *hashimaqua@yahoo.com

The deep-sea demersal finfishes in the shelf edge off North Andaman were studied based on trawl survey at nine stations by FORV Sagar Sampada (Cruise No.252) during January - February 2007. HSDT-CV and EXPO demersal trawl net were employed in continental shelf edge at depths ranging from 300 to 700m.

A total of 63 species of finfishes belonging to 53 genera, 42 families and 19 orders was recorded. The highest abundance was recorded at Station No. 8 with 25 species and lowest at Station No. 9 with 3 species.

The data were further analyzed using PRIMER software for species indices, cluster analysis and taxonomic distinctness. It was found that Shannon Weiver indices were high at Station 8 with a value of 2.51 but low at station 1 with a value of 0.6. Simpson indices were high in Station 7 but low in Station 1. Margalef Species Richness showed a maximum at Station 8 with a value of 3.88 and a minimum at station 9 with a value of 1.11. Species evenness indicated that they were evenly distributed at Stations 2 to 9 but unevenly distributed at Station 1.

Dendrogram plotted showed similarity between Stations 1&2, 3&6 and 5&7. The 95% confidence funnel generated for the variation in taxonomic distinctness and average in taxonomic distinctness was also plotted separately. All the stations fell within the confidence funnel showing no deviation from the normal in variation of taxonomic distinctness. Average taxonomic distinctness calculated and plotted indicated that all the stations fell within the confidence level except Station 1 and 6, which deviated outside the funnel.