2. REVIEW OF LITERATURE

2.1. Distribution of Eels along Parangipettai coastal waters

Leptocephalai biomass on Southwest Coast of India is constituted mainly by five families of Leptocephalai viz., Congridae, Opichthidae, Muraenidae, Nemichthyidae and Synaphobranchidae. Of the five families Congridae, Opichthidae and Muraenidae were distributed in Indian waters (Balu, 2004). The snake eel fauna of the western Indian Ocean is richly diverse and poorly known. Smith and Bohlke (1983) included 55 species in his monograph of the western Indian Ocean and Red Sea opichthids. Opichthids are predominant member of deep sea demersal fishes from the continental slope of abyssal plain. The earlier synopsis of Opichthidiformes in India reported 15 genera of the family opichthidae. Bande and Kartha (1972) recorded the longest Moray eel, Thyrsoidea macrura from the Indian waters.

Nair and Dorairaj (1975) studied the different species of eels of the genus Anguilla distributed throughout the world and reported three species namely the European eel Anguilla anguilla, the American eel A. rostrata and the Japanese eel A. japonica are of high economic importance. Wenner (1976) studied the biological and morphological characters of the snake eel opichthidae particularly on the species Pisonolphis crucentifer. Cohen and Nielsen (1978) subsequently included all opichthidiformes fishes of the world which describes 48 genera and 228 species of deep sea fishes under the family Opichthidae. Dorairaj et al. (1980) reported the importance of culture of Indian eels and their significance based on the results of the experiments conducted during the period 1974-1980. The first catalogue of
Opichthidiformes focused at the genus level and species classification didn’t reveal the detailed information’s up to the level.

Smith and Bohlke (1983) studied the key characteristics of ophichthidae and recorded a worm eel, *Neenchelys retropinna* from the Indian Ocean. Subramanian (1984) studied the burrowing behaviour and ecology of the crab-eating Indian snake eel *Pisodonophis boro*. Ogilby (1985) studied the description of new Australian moray eel and their distribution. Bohlke *et al.* (1989) interpreted the identification of small brown unpatented Indo-pacific Moray eels and described three new species belongs to the family Muraenidae. Machida and Ohta (1993) recorded a new species of snake eel *Neenchelys daedalus* (Ophichthidae) from Japan. McCosker and Rosenblatt (1993) documented a new species of snake eel genus *Myrichthys* with the description of new Eastern Pacific species. Most Opichthids occupy habitats shallower than 100m, ranging from coral reefs to sand and mud substrates, entering rivers and estuaries. Although most Opichthids are undesirable as a human protein, they are readily consumed by other fishes and their role in marine ecosystem is poorly understood.

Machida and ohta (1994) reported on the record of new finless ophichthid snake-eel, *Apterichtus orientalis*, and portrayed the specimen dredged from the Pacific coast of the Kii Peninsula, western Japan. Pillai *et al.* (1996) accounted that the need for exploitation on deep sea fishes is gradually gaining importance in the recent years as the production from the present fishing grounds alone isn’t sufficient to meet the future nutritional demand of the growing population. Lee *et al.* (1997) recorded a new opichthid eel, *Opichthus rotundus* from Korea. Castle and McCosker (1999) studied the description of a new genus and a new species.

Bohlke and McCosker (2001) studied a new species of deepwater worm eel *Muraenichthys* and about its distribution. McCosker and Robertson (2001) reported on the record of *Aplatophis zorro*, the first known eastern Pacific species of this new world genus to be described from a shallow water trawl-caught specimen from the Golfo de San Miguel, Pacific Panama. McCosker and Lavenberg (2001) affirmed a new species of Eastern Pacific Sand eel, *Gordiichthys combibus* (Anguilliformes: Opichthidae) and *Aplatophis zorro*, a new species of Eastern pacific snake eels with comments on new world Opichthidae distributions which is first known eastern Pacific species of Gordiichthys and is very similar to *G.randalli* from Puerto-rico. McCosker (2002) disclosed the description of Hawaiian snake eel *Opichthus bonaparti*, which belongs to the family opichthidae.

Prokofiev (2006) recorded eight species of Morays from the soft grounds in the Bay of Nha trang (Central Vietnam) namely *Echidna delicatula*, *Gymnothorax* sp., *G. minor*, *G. prolatus*, *Strophidon satthe*, *Echidna polyzona*, *G. punctatofasiatus* and *G. reevesii*. Schepper *et al.* (2007) displayed the detailed morphology of the head and tail of *P. boro* and examined the anatomical specializations among headfirst burrowing, tail-first burrowing, and rotational feeding.


Cubelio *et al.* (2009) re-described *Dicrolene nigricaudis* a rare species of deep sea cusk eel which belongs to family opichthidae from Andaman sea and Arabian Sea and to compare the morphometric and meristic characters with the closely related species *Ditr里斯is*. Loh *et al.* (2010) examined the length weight relationships of 39 muraenid species belonging to seven genera from the Taiwan waters. Reece *et al.* (2010) revealed the distribution of moray eel along the coast of central Indian Ocean to central pacific and described two new moray eel. Miller *et al.* (2011) calculated the distribution, diversity, and abundance of Garden eel larvae off West Sumatra, Indonesia.
McCosker and Stewart (2012) studied the distribution of moray eels from New Zealand and Australia and recorded two new species which belong to the family Muraenidae. Loh et al. (2012) narrated three rare Moray species by including diagnostic characters and the fresh coloration on whole body, head, dorsal and ventral sides and the key to the relative species. Ho et al. (2012) described snake eel Neenchelys guitendjiki as a new species and provided the detailed sketch about the species from Malaysia. Jawad and Mamry (2012) reported on the record of snake eel which belongs to order Ophichidae from Oman. McCosker et al. (2012) reported on the record of Pylorobranchus hoi, a new genus and species of myrophine worm-eel from Taiwan (Anguilliformes: Ophichthidae). The moray eel Gymnothorax reticulari was reported for the first time from the Mediterranean Sea, with a note on its taxonomy and distribution by Stern and Goren (2013).

2.2. Molecular Taxonomy (DNA Barcoding)


Ma et al. (2008) examined the genetic differences and speciation mechanisms within the genus Uroconger in the Indo-Pacific. Yue et al. (2009) observed the
genetic diversity and population structure of sea bass (*Lates calcarifer*) in the Asia-Pacific region. Rosalee *et al.* (2009) investigated and identified the seven commercially important salmon and trout species by DNA bar-coding which belong to genera (*Oncorhynchus* and *Salmo*) in North America. Steinke and Tyler (2009) created the DNA barcode database for marine fishes that are commonly imported by the pet trade to Canada. Ardura *et al.* (2010) developed the genetic tools for rapid and accurate identification of commercial Amazonian fish species by applying a set of methodologies of different ease, cost and equipment requirement: FINS, RFLP and PCR-agarose gel visualization of 5S rDNA.

Alam and Islam (2010) assessed the genetic structure of the fresh water mud eel that could be used as a baseline study for taking any program on conservation and stock improvement of *Monopterus cuchia*. Reece *et al.* (2010) depicted the molecular phylogenetics of moray eels (Muraenidae) that demonstrates multiple origins of a shell-crushing jaw (*Gymnomuraena, Echidna*) and multiple colonizations of the Atlantic Ocean. Zhang (2011) exposed the species identification of marine fishes in China and also studied the high efficiency of species identification by DNA ‘barcoding. Zhang and Hanner (2011) evaluated 229 DNA sequences of cytochrome oxidase subunit I gene (COI) from 158 marine fishes of Japan and also tested the efficacy of species identification by DNA barcoding. Donburg *et al.* (2012) constructed the molecular phylogenetics of squirrel fishes and soldier fishes which belongs to the family Holocentridae and reconciling the taxonomy confusion.

Pathak and Serajuddin (2012) investigated and analyzed the genetic variation in the populations of barred spiny eel, *Macrognathus pancalus* collected from two rivers (Gomti and Ghagra) in Gangatic basin of Uttar Pradesh, India.
Cawthorn et al. (2012) unrevealed the fact that the development of DNA-based methods for the identification of fish species is essential for fisheries research. Cheng et al. (2012) evaluated the mitochondrial genome sequence of bighead Croaker *Collichthys niveatus* and explained the observed divergence between the two *C. niveatus* mitogenomes. Tzeng et al. (2012) studied the DNA barcode-based identification of commercially caught cutlass fishes (Family: Trichiuridae) with a phylogenetic assessment. Chiu et al. (2012) evaluated the usefulness of molecular marker methods, including PARD, ISSR, and cytochrome oxidase subunit I (CoxI) gene sequences, for development of a simple and reliable PCR-based ISSR-SCAR method for rapid identification of cultivated and wild giant grouper.

### 2.3. Seasonal Variation in Biochemical composition of Marine Eels

Venkataraman and Chari (1951) studied the seasonal variation in the chemical composition of mackerel (*Rastrelliger kanagurta*, Russel). Bano (1978) evaluated the seasonal variations in the biochemical composition of *Clarias batrachus* and changes in the biochemical constituents in different seasons also appear to coincide with the high and low feeding activities of the fish. Shreni (1980) studied the seasonal variations in the various biochemical constituents of muscle and liver of catfish.

compositions of the muscle and liver of bib (Trisopterus luscus) from the Cantabrian Sea. Narcisa et al. (2001) evaluated the Seasonal variation in the chemical composition of horse-mackerel (Trachurus trachurus). Shirai et al. (2002) analyzed the seasonal variation of fatty acid composition and free amino acid content in the Japanese sardine (Sardinops melanostictus) from the sea of Hyuga-Nada.

Munshi et al. (2005) observed the biochemical composition of sardine and mullet and compared the nutritional composition with relation to four different seasons. Nargis (2006) investigated the protein, carbohydrate, fat, ash and moisture contents in the body muscle of Anabas testudineus (Bloch) and found that there exists a seasonal variation of composition in relation to reproductive cycle of the fish. Zlatanos and Laskaridis (2007) analyzed the seasonal variation in the fatty acid composition of three Mediterranean fish viz., sardine (Sardina pilchardus), anchovy (Engraulis encrasicholus) and picarel (Spicara smaris) and found that they are the best source of \( n-3 \) fatty acids (35.35 g/100 g fatty acids). Kandemir and Polat (2007) investigated the seasonal and monthly variations in the amount of total lipid and fatty acid in muscle and liver of rainbow trout (Oncorhynchus mykiss) reared in Derbent Dam Lake.

Yıldız et al. (2008) evaluated the effects of dietary composition and seasonal variation on fillet composition and some morphological indices of wild and cultured sea bass. Effiong and Mohammed (2008) reported the variation in proximate composition of nutrients, mineral content and amino acid profile of freshwater fishes Citharinus citharus, Clarias anguillaris and Hemisynodontis membranaceus from Lake Kainji, Nigeria.
Shamsan and Ansari (2010) evaluated the seasonal variation in biochemical composition (moisture content, lipid, protein and carbohydrate) of an economically important fish *Sillago sihama* (Forsskal), from composition and stable isotopes of farmed and wild Brazilian freshwater fish. Marin *et al.* (2010) determined the Variations in the fatty acid composition and nutritional value of Adriatic sardine (*Sardina pilchardus*, Walb.) through the fishing season. Oksuz and Ozyılmaz (2010) depicted the monthly changes in proximate and fatty acid compositions of Black Sea anchovy and observed the changes in the fatty acid composition, particularly in DHA, during the fishing season. Ana *et al.* (2010) analyzed the chemical composition of farmed and wild Brazilian freshwater and recorded the seasonal changes.

Kalyoncu *et al.* (2011) evaluated the effects of seasonal variation on the fatty acid composition of carps *Cyprinus carpio* and found that carp contains highest level of polyunsaturated fatty acids. Rasheed (2011) evaluated the fat percentage and water content in fish tissue then relating them to the seasonal variation in addition to its health benefits to consumers in order to get best fish oils among seasons and among species. Hannachi *et al.* (2011) studied the biochemical composition of the edible part of the Moroccan Mediterranean cost anchovy (*Engraulis encrasicolus*). Mohamed (2011) examined the variations in lipid content and fatty acids composition in wild and cultured yellow fin Seabream, *Acanthopagrus latus* from the Persian Gulf. Nisa and Asadullah (2011) accounted the biochemical composition of Indian mackerel in relation to various season and found major changes in the fatty acids. Mathana *et al.* (2012) estimated the seasonal changes in biochemical composition of the *Lethrinus lentjan* and found that the lipid content was also low during the spawning season and high during pre-spawning season in all the four selected tissues.
Simat and Bogdanovic (2012) investigated the seasonal changes in proximate composition of the fillet of European anchovy caught in the Adriatic.

Jan et al. (2012) represented the seasonal variation in the protein content of muscle of Schizothorax esocinus from the Kashmir Valley. Deka et al. (2012) made a comparative analysis of total lipid components that states there exists a significant impact of habitat and seasonal variation on the nutritional quality of lipid in Labeo gonius.

Begum and Minar (2012) described and compared the biochemical composition like moisture, protein, ash and fat in six small indigenous species (SIS) (Ailiichthys punctata, Clupisoma psendeutropius atherinoides, Puntius sarana, Gudusia chapra, Corica soborna), One anadromous fish (Tenualosa ilisha) and two shell fishes (Macrobrachium and Penaeus sp.). Yeganeh et al. (2012) explored the chemical composition and fatty acid composition in wild and farmed carp and found out the changes in different seasons.

Tulgar and Berik (2012) determined the effects of seasonal changes on water, protein, lipid and ash contents of commercial fish species of red mullet (Mullus barbatus) and hake (Merluccius merluccius) from Saroz Bay, Turkey. Sreevalli and Sudha (2012) disclosed the seasonal variation and effect of salinity on the total protein, glycogen and cholesterol content of Mystus vittatus. Cengiz et al. (2012) revealed the seasonal effects on the fatty acid composition of total lipid, triacylglicerol and phospholipids in the dorsal muscle of cat fish, Silurus triostegus via gas chromatographic (GC) method. Satar et al. (2012) evaluated the seasonal variation on the fatty acid composition of total lipid, triacylglycerol, and phospholipids in the dorsal muscle of Capoeta trutta by gas chromatographic method.
Bhaware and Mane (2012) evaluated the protein content in the muscles, liver and gonad of *Rastrelliger kanagurta* from Sakhri-Natyte fish landing centre at Ratnagiri district coast.

Som and Radhakrishnan (2012) inspected the fatty acid composition of *Sardinella longiceps* and *S. fimbriata* and found the changes in EPA and DHA composition with relation to the various seasons. Simoes et al. (2013) analyzed the seasonal variation in proximate composition and fatty acid profile of Grey Triggerfish (*Balistes capriscus*) captured along the coast of Portugal. Karina et al. (2013) studied the seasonal changes in condition, biochemical composition and energy density during an annual cycle in order to establish the pattern of energy distribution and storage in relation to sexual development of *P. brasiliensis*.

### 2.4. Isolation of Collagen from Marine Eels

Collagen, an excellent biomaterial is prepared from mammalian tissues, including bovine and porcine sources. However mammalian tissues have recently been suspected as posing a large risk of pathogens such as bovine spongiform encephalopathy (BSE). Although fish skin is thought to be safe and potentially a major source of collagen, it has not yet been widely used. In addition, large quantities of fish skin are discarded as waste in the food industry. Collagens are easily extracted from wasted fish skins with high yield. Fries (1998) studied the chemistry of collagen, processing characteristic of dosage forms and application of collagen products in medicine and discussed the recent development with a special focus on drug delivery. Rose et al. (1998) characterized collagen from the swim bladder of catfish which is rich source of type I collagen.
Guille et al. (2000) calculated and compared the different structural properties of bovine and fish collagen. Nagai and Suzuki (2000) extracted acid soluble collagen and pepsin soluble collagen from underutilized resources of fish which included skin, bone and fin respectively. The report indicated that the fish waste materials have potential in replacing the skin of land vertebrate as the source of collagen. Nagai et al. (2001) extracted and characterized collagen from the outer skin of the cuttle fish Sepia lycidas. Mizuta et al. (2002) recorded the distribution of type I and V collagen from several parts of tiger Puffer Takifugu rubripes with respect to their biochemical and immunochemical properties. Muyonga et al. (2004) carried out the extraction of gelatins derived from the skin and bones of young and adult Nile perch (Lates niloticus) and compared them to those of acid soluble collagen from the young Nile Perch in a effect to elucidate the changes in secondary structure that occur during the conservation of collagen to gelatin. Ogawa et al. (2004) isolated acid soluble collagen and pepsin soluble collagen from bones and scales of black drum (Pogonia cromis) Sheephead sea bream (Archosargus probatocephalus). Nagai (2004) typified collagen from Japanese sea bass caudal fin waste material. The results suggested that caudal fin collagen could be used as an alternative source of mammalian collagen in various fields such as food, medicine and cosmetics.

Nagai et al. (2004) isolated and partially characterized fish scale collagen. Nishimoto et al. (2004) prepared pepsin solubilized collagen from the muscle tissues of Japanese amberjack (SerioLoa quinqueradiata) and characterized into type I and V collagens. The result suggested that this collagen might relate to textural changes of each muscle during chilled storage and subsequent processing such as heating. Nishimoto et al. (2005) studied on the characterization of molecular species of


Wooa et al. (2008) extracted and optimized collagen from the dorsal skin obtained from Yellow fin Tuna (Thunnus albacares) by using a central composite design of response surface methodology. Motowidlo et al. (2008) reported on the isolation and characterization of a thermally stable collagen from the outer skin of the silver carp (Hypophthalmichthys molitrix). Khan et al. (2009) isolated Acid soluble collagen and pepsin solubilized collagen from the seaweed pipefish (Syngnathus schlegeli) and characterized as type I collagen. Duan et al. (2009) isolated acid soluble collagen from skin, scale and bone of carp (Cyprinus carpio). Potaros et al. (2009) extracted acid soluble and pepsin soluble collagen from Nile Tilapia skin using 2 different methods. Zeng et al. (2009) characterized acid soluble collagen from the skin of Nile Tilapia (Oreochromis niloticus). Zhang et al. (2009) extracted acid soluble and pepsin soluble collagen from the large fin long barbed catfish (Mystus macropterus). Zelechowska et al. (2009) studied on the isolation and properties of collagen from the backbone of Baltic cod (Gadus morhua).

Nagai et al. (2010) depicted the isolation and physicochemical properties of acid-soluble collagen from the skins of surf smelt for use as an alternative to mammalian collagen in the food, cosmetic, and biomedical materials. Kittiphatthanbawan et al. (2010) isolated 2 forms of collagen, acid soluble and pepsin soluble collagen form the skin of brown banded bamboo shark. Pati et al. (2010) segregated collagen from the scales of Labeo rohita (Rohu) and Catla catla (Catla) and confirmed the presence of collagen by different physiochemical techniques. Hue et al. (2010) isolated acid soluble and pepsin soluble collagen from the skin of flatfish Paralichthys olivaceus) and characterized their electrophoretic pattern.
Bama et al. (2010) accounted on the extraction of collagen from catfish (*Tachysurus maculatus*) and characterization of collagen chitosan sheet. Singh et al. (2011) extracted and distinguished acid soluble and pepsin soluble collagen from the skin of striped catfish (*Pangasianodon hypophthalmus*). Liu et al. (2012) extracted and characterized the pepsin-solubilised collagens (PSC) from the fins, scales, skins, bones and swim bladders of bighead carp and suggested that pepsin-solubilised collagens can be used as a potential substitute for mammalian collagen. Veeruraj et al. (2012) isolated and characterized ASC and pepsin-soluble collagen (PSC) from the outer skin waste of marine eel fish (*Evenchelys macrura*).

**2.5. Isolation of Serum Protein from Marine Eel Blood**


Gisladottir et al. (2009) witnessed two C-reactive protein homologues from cod serum (*Gadus morhua* L.). Kim and Wijesekara (2010) reported on the development of Marine derived bioactive peptides and its biological activity. Wang et al. (2010) portrayed the isolation of novel protein from the serum of rabbit fish and suggest that protein may contribute considerably to the innate host defence mechanism to combat microbes of the rabbit fish. Shamsuddin et al. (2011) compared the serum protein of man and four teleosts using polyacrylamide gel electrophoresis. Lee et al. (2011) revealed the radical scavenging activity of enzymatically prepared sand eel protein hydrolysate and isolated a potent antioxidant
peptide. Akinwande et al. (2012) recorded the biochemical characterization of *H. longifilis*, *C. gariepinus C.anguillaris* and their hybrids using SDS–PAGE based on their protein profile. Diyaware et al. (2012) examined the protein profiles of the *C. anguillaris, H. bidorsalis*, and their hybrids by SDS-PAGE from the semi-arid zone of Nigeria with the view to providing base line information for further genetic studies.

### 2.6. Antibacterial activity


### 2.7. Anticancer activity

Fouda (2005) described the antitumor activity of tetraodotoxins extracted from the Masked Puffer Fish of the Red Sea against EAC cells. Picot et al. (2006) carried out the characterization of fish protein hydrosylate and to determine whether FPH exert an antiproliferative activity on cancer cells grown under in vitro conditions. Sevilla et al. (2007) studied on the identification of the antitumor drug emodin binding sites in bovine serum albumin by spectroscopic methods. Hoskin and Ramamoorthy (2008) examined the anticancer activities of antimicrobial peptides. Gromov et al. (2010) witnessed the up-regulated proteins which are present in the fluid bathing the tumour cell microenvironment as potential serological markers for
early detection of breast cancer. Riedl et al. (2011) carried out the optimization of host defence peptides using various strategies to enhance further selectivity and serum stability is expected to yield novel anticancer drugs with improved properties in respect of cancer cell toxicity as well as reduced development of drug resistance. Wang et al. (2012) characterized the antitumor protein in *S. acus* as well as purified the novel protein Syngnathusin and found to possess the potent antitumor *in vivo* and *in vitro.*