INTRODUCTION

Cephalopods consist of bilaterally symmetrical molluscs belonging to the class Cephalopoda with a well developed head that contains a circum-oral crown of mobile appendages that bear suckers and/or hooks except in Nautilus. Cephalopods first evolved 450 million years ago in the upper Cambrian period and represented by a single subclass, Nautiloidea. However, most of the species of this subclass became extinct during the Jurassic period. The subclass Coleoidea, comprising of present day cuttlefishes, squids, octopuses and vampire squids arose in the late Paleozoic era, about 330 to 400 million years ago. Most of its forms too became extinct by the end of the Mesozoic, about 150 million years ago. The living forms today have evolved in the upper Triassic and lower Jurassic periods Roper et al 1984. Around 1000 living species belonging to 43 families are distributed in all marine habitats of the world like benthic, epibenthic, pelagic and epipelagic in bays, seas, and the open ocean. They are distributed from surface to over 5000 m depths.

Cephalopods are soft-bodied animals with a cranium and mantle/fin support such as cuttlebone or gladius. An external shell occurs only in the primitive form Nautilus which is found restricted to the Indo-Pacific region. The mouth has chitinous beak-like jaws and a chitinous tongue-like radula. The eyes are well organized. Coloration with chromatophores and
iridocytes, is variable depending on group and habitat. Locomotion is achieved by drawing water into the mantle cavity followed by its jet-like expulsion through the funnel and by crawling along the bottom on the arms. Fins on the mantle provide stability, steering, and secondary locomotion. Cephalopods except Nautilus are provided with ink-sacs in the body cavity which darts ink as a defence mechanism. The life expectancy of cephalopods is about one to two years in most forms, but larger species of squids and octopus, live for several years. Many species are known to die after spawning.

All cephalopods are dioecious and many of them exhibit external sexual dimorphism, either in structural or size differences. Females generally are larger than males. Males of many forms possess 1 or 2 modified arms called the hectocotylized arms which transfer the sperm packets from the male’s mantle cavity to a locus of implantation on the female. Fertilization takes place in the female and the eggs are laid. The eggs are heavily yolked and development is direct, without metamorphic stages. At hatching, young animals often inhabit different habitats than the adults. Many species of oceanic cephalopods undergo diurnal vertical migrations, while shallow-living cephalopods are able to conceal themselves by chromatophore-produced colour patterns and chameleon-like colour changes, many deep-sea forms camouflage themselves by producing bioluminescent light from photophores. The role of cephalopods in the ecosystem seems to be that of subdominant predators. They are active predators on shrimps, crabs, fishes, other
cephalopods and bivalved molluscs. In turn, cephalopods are major food items in the diets of toothed whales, seals, pelagic birds and both benthic and pelagic fishes.

The four groups of cephalopods such as squids, cuttlefishes, octopuses, and chambered nautiluses are easily distinguished by external characteristics. The squids have an elongate, torpedo-like body with posteriolateral fins. They have eight circumoral arms which are not connected at bases with a web. The arms usually have two rows of stalked suckers bearing chitinous rings running the entire length. Besides they possess two longer tentacles with two or more rows of suckers at the distal end.

The cuttlefishes have broad sac-like bodies with lateral fins. The members of family Sepiidae have narrow lateral fins that extend the length of the mantle. On the contrary, the individuals of family Sepiolidae have short, round and flap-like lateral fins. In either case, the posterior lobes of the lateral fins are free and are separated by the posterior end of the mantle. They have ten circumoral appendages with fourth pair being the longest. These tentacles can be retracted into pockets at the ventro-lateral sides of the head. The remaining arms have four rows of stalked suckers with chitinous rings without hooks. The eyes have eye lids and are covered with a transparent membrane. The shell of sepiid is thick, chalky and calcareous while the same of sepiolid is chitinous.
The octopuses have a short, sac-like body. They lack tentacles and have eight circumoral arms with bases connected by a membraneous web. The arms possess unstalked suckers, without chitinous rings, along the length of the arms.

The chambered nautiluses are characterized by an external, smooth, coiled, chambered shell. Males have sixty three circumoral appendages while females have as many as ninety four. The circumoral appendages are without suckers. They have simple eyes without lenses. Nautiluses are characterized by the absence of an ink sac.

Catches of cephalopods have been steadily increasing in most parts of the world. The world cephalopod landings during 1950 was a mere 0.58 million tonnes which rose to 3.77 million tonnes during 2004 (FAO, 2004). The world catches of squids and cuttlefishes registered a phenomenal increase by 57% and 84% respectively during the seventies. However, a similar increase in the landings of octopuses could not be encountered during the same period. Cephalopod fisheries are unevenly distributed in the world’s oceans. Cuttlefishes are taken mainly as a bycatch in trawl fisheries. The coastal squids are caught mainly with otter trawls, pair trawls, purse seines and by night-lightfishing methods. Oceanic squids are captured primarily by jigs and gillnets. Octopuses are taken by bottom trawls, pots, dragnets, hooks and spears. More than half of the total catch is taken in
the northwest Pacific, the northeast and northwest Atlantic and the northeast
Pacific, but a number of small scale fishing activities also exist in other areas.

Cephalopods comprising mainly squids and cuttlefishes form an
important resource of world oceans and are of increasing economic
importance. Of the 786 species of cephalopods in the world, large sized
cuttlefish and squids belonging to families Sepiidae, Loliginidae and
Ommastrephidae and a few octopods are commercially exploited presently
(Hamabe et al., 1976; FAO, 1976).

The world cephalopod production has grown from 1.55 million t in
formed 67.01% of the landings, followed by cuttlefishes (15.93%), Octopi
(9.48%) and other cephalopods (7.58%). India occupies nineth rank in
cephalopod production in the world with a production of 0.11 million tonnes.
Japan is the leading cephalopod producing country with an average annual
landing of 0.57 million tonnes (2001), followed by China (0.50 million t),
Korean Rep. (0.41 million t), Argentina (0.23 million t), Thailand (0.17
million t), Morocco (0.14 million t) and Vietnam (0.13 million t). The other
important contributors to cephalopod landings are USA, Mexico, Peru, Spain,
Malaysia, Indonesia, Philippines, Russian Fed., Falkland Islands, New
Zealand, Italy, France, Mauritania, Portugal and Uruguay (FAO/GLOBEFISH,
2003). The rapid increase in the landings of cephalopods was mainly due to
increase in demand for this group in Japanese market and simultaneous
increase in fishing effort to exploit this group all over the world using sophisticated methods, especially jigging for squids.

The fishing techniques for common squid in Japan has been greatly developed during the last 30 years through biological knowledge, the improvement of the fishing technologies including boats, engines, equipment; and particularly in jigging technology with light attraction, as well as better preservation of the catch for utilization and processing (Hamabe et al., 1976). The Japanese common squid, Todarodes pacificus (Steenstrup) yields the largest catch of cephalopods in Japanese waters. Till the forties the Todarodes pacificus fishery had been only small-scale, exploited by non-powered boats of 1 to 2 GRT size and yielding less than 100,000 t per year. Powered boats of 10 to 30 GRT size, using more jigging lines and battery powered fishing lamps were introduced in the fifties for fishing in nearby waters. Later, in the sixties, 50-100 t boats equipped with motor-driven jigging machines, powerful lights run by generators, followed in the seventies by ocean going vessels of 100 to 300 GRT. Japanese squid jigging gear has been described by Yajima and Mitsugi (1976).

REVIEW OF LITERATURE

Earlier works on cephalopods of Indian waters are mainly confined to faunistic records and taxonomic studies. Silas (1968) has catalogued 201 species of cephalopods collected during the cruises of R. V. Varuna. The cephalopods collected by the research vessels which participated in the
International Indian Ocean Expeditions were reported by Filipova (1968). Several species of cephalopods were recorded by Oommen (1966, 1967, 1971, 1975, 1976) from the south west coast of India which included *Opisthoteuthis philippi*, is a new species from 275 – 365 m depths off Alleppey and three new species of octopodida viz. *Octopus varunae, Berrya keralensis* and *B.annae*. Sarvesan (1969) has listed 33 species of cephalopods from the Indian waters.

The occurrence of *S. trygonina* in Indian waters was reported by Sarvesan (1976) based on specimens of one male and one female collected from Gulf of Mannar off Tuticorin. The population structure and distribution of *Sepia pharaonis, S. aculeata, Sepiella inermis* and *Loligo duvauceli* of Visakhapatnam coast were described by Rayudu and Mohan (1982). The distribution of the cephalopods both in the coastal and oceanic waters of the Andaman-Nicobar Archipelago was reported by Sreenivasan and Sarvesan (1990). They described twenty-six species belonging to 22 genera and the most dominant species were found to be *Symplectoteuthis oualaniensis, Abralia andamanica, Onycoteuthis banksi, Sepia pharaonis, S. aculeata, S. prashadi, S. trigonina, Euprymna stenodactyla, Loligo duvauceli* and *Octopus sp*. A distinct pattern in the distribution of cephalopods according to the depth of the offshore areas off Gulf of Kutch was reported by Siraimeetan (1990). The cuttlefishes were mostly collected from the area 18 to 21°N and squids were common in the area 22 to 23°N. Nateewathana (1995) described two genera and 7 species of sepiids viz. *Sepia brevimana, S.aculeata, S.pharaonis,*
S. recurvirostra, S. prashadi, S. arabica and Sepiella inermis from the Indian Ocean. Among them, S. prashadi and S. arabica are new records from the Andaman Sea. Cephalopod resources in southeast and northeast coasts of India and Andaman-Nicobar waters were reported by Kripa et al. (1996). The distribution and relative abundance of various neritic and oceanic group of cephalopods by area and depth are described by them. An account of the availability, species composition of octopuses along the southwest coast of India is given by Kripa et al. (2000). According to them, the major species of octopus in Kerala is Octopus membranaceous (Quoy and Gianard).

A new cuttlefish species Sepia ramani. collected from Tuticorin Bay is described by Neethiselvan (2001). Similarly, another new cuttlefish Sepia prabahari. collected from Tuticorin Bay is also described by Neethiselvan and Venkataramani (2002). Morphometric study on the squid, Loligo duvauceli from Mumbai waters was presented by Karnik and Chakraborty (2001).

Rao (1988) studied the length-weight relationship between males and females of Loligo duvauceli collected from Mangalore coast. The largest recorded male and female of this species recorded so far from Indian waters were 355 mm and 228 mm in length respectively. The length-weight relationship of Sepia aculeata collected from Mangalore was reported by Rao (1997), who observed significant difference in length-weight relationship between immature and mature male and female.
Food and feeding habit of the squid *L. duvauceli* obtained in trawl nets operated during the night were studied by Oommen (1976) and reported a carnivorous habit and cannibalistic behaviour in this species. Similarly, the food and feeding habits, morphology and histology of the gut as well as the physiology of digestion of *Loligo duvauceli, Sepia aculeata* and *Sepiella inermis* from west coast of India were also described by Oommen, (1977).

Sexual maturity, spawning seasons, sex ratio and fecundity of *Loligo duvauceli* of Mangalore coast were studied by Rao (1988). Morphometric measurements carried out in *Loligo duvauceli* indicated the degree of reproductive maturation along with the size at first maturity (Rahim and Chandran, 1988). They also reported the differentiation of the hectocotyliised arm as an indicator of sexual maturity in *L. duvauceli*. Functional morphology and histology of the testis of the same species was reported by Rahim and Chandran (1984a, b). They also have reported the formation of spermatophore in *L. duvauceli* (Rahim and Chandran, 1994). Mohamed (1993) reported a non-semelparous reproduction in *L. duvauceli* as evidenced from low gonadosomatic index and tangible growth after reaching sexual maturity. According to him, two successive spawning congregations occurred along the southern Karnataka Coast during 1990 and 1991 which took place during the postmonsoon months (Sep-Oct). Spawning, sex ratio and fecundity of *Sepia aculeata* from Mangalore coast was reported by Rao
(1977). This study revealed that the major spawning season of this species is October to March. It attains first maturity at a dorsal mantle length of 86 mm and the fecundity ranges from 206 to 1,568 ova. Breeding biology of the spineless cuttlefish Sepiella inermis collected from Tuticorin waters was reported by Neethiselvan et.al (2002). This species is a prolonged breeder as mature and spent specimens were recorded almost round the year. However, two peak spawning periods, one in November and another in March were observed.

Population dynamics of the squid Loligo duvauceli in Saurashtra waters based on catch, effort and length frequency data collected from trawl net operations at Veraval, from 1979 to 1983 was reported by Kasim (1985). Menon (1988) studied the population dynamics of Sepia aculeata, along the Bombay coast. Similarly, the population dynamics and stock assessment of the cuttle fish, Sepia pharaonis (Ehrenberg) in Wadge Bank was studied by Philip and Ali (1989). They reported that a total biomass of 2060 tonnes from Wadge Bank and 74% of this biomass is supported by 20-50 m depth zone in the area. Stock assessment of Loligo duvauceli in Bombay waters was attempted by Vidyasagar and Deshmukh (1992). They reported further scope for the exploitation of L. duvauceli by the trawlers in Bombay waters. Rao et al. (1993) worked out the stock of the needle cuttlefish Sepia aculeata of both the coasts of India and opined that the present catches are optimal on the east coast but on the west coast there is considerable scope for
increasing production. Similarly, stock assessment of the pharaoh cuttlefish *Sepia pharaonis* was attempted by Nair *et al.* (1993) and suggested that west coast has scope for increase in production. Stock assessment of the Indian squid *Loligo duvauceli* based on the data collected at different centres on both the coasts of India worked by Meiyappan *et al.* (1993) and reported that the present level of exploitation was at the optimum level on both the coasts. Population dynamics of the cuttlefish *Sepia elliptica* in Saurashtra waters was studied by Kasim (1993). Estimates of growth, mortality and stock of the Indian squid *Loligo duvauceli*, exploited off Mangalore was reported by Mohamed (1996). According to him, the maximum sustainable yield (MSY) of this species along Mangalore coast is 877.3 tons which could be achieved only by a 35% decrease in fishing effort. Similarly, the seasonal growth, stock-recruitment relationship and predictive yield of the same species exploited off Karnataka coast were studied by Mohamed and Rao (1997), which revealed that this species reaches a length of 181 mm at the end of first year. Stock assessment of *Loligo duvauceli*, *Doryteuthis sibogae*, *Sepioteuthis lessoniana*, *Sepia pharaonis*, *S. aculeata* and *Sepiella inermis* from Tuticorin coast was attempted by Neethiselvan *et al.* (2002). They reported overexploitation of four species viz. *Loligo duvauceli*, *Doryteuthis sibogae* *Sepioteuthis lessoniana* and *Sepiella inermis* off Thoothukkudi waters. The study recommended a reduction of 10% effort from the present level to sustain the stock of squids and cuttlefishes of this area. Growth and mortality of
Indian squid, *Loligo duvauceli* from Mumbai waters were studied by Karnik *et al.* (2003). They opined that a reduction in fishing effort is required to maximize the yield per recruit of *Loligo duvauceli* from Mumbai waters.

Details of catching methods of *Sepioteuthis, Loligo, Sepia* and *Sepiella* species are described by Sarvesan (1974). The cephalopod fishery of the Indian Ocean with respect to the Visakhapatnam coast was described by Rayudu and Mohan (1982). Of the 9 species of squid and cuttlefish encountered in trawl catches off the coast, *Sepia pharaonis, S. aculeata, Sepiella inermis* and *Loligo duvauceli* contribute 90% of the total catch. A brief account of the fishery aspects of squids off Mangalore coast is reported by Rao (1988). Sreenivasan and Sarvesan (1990) reported a wide distribution of the cephalopods both in the coastal and oceanic waters of the Andaman-Nicobar Archipelago and suggested adoption of suitable techniques such as light fishing with lift net. Area wise and depth wise cephalopod catches of the chartered fishing vessel off Gulf of Kutch was reported by Siraimeetan (1990). Catch statistics and status of exploitation of squids and cuttlefish in India was reviewed by Nair *et al.* (1992). According to them, *Loligo duvauceli* is the single species that constitutes the squid fishery on the west coast while *Sepia pharaonis* and *S. aculeata* mainly form the cuttlefish fishery. On the west coast of India, the post-monsoon season (September-February) is the best period for cephalopod landings accounting for an average of 63% of the annual production. According to Kripa *et al.* (2000) the total landing of
octopus during 1994 was 630 tonnes. Details of fishery of cuttlefish and squid resources off Tuticorin coast are well described by (Neethisvelan et al, 2002a). Cuttlefishes are also reported to contribute substantially to the cephalopod fishery of Tuticorin (Neethisvelan et al., 2002b).

In India, about 2,80,491 fishing crafts of various sizes and classes are under operation, consisting of 53,684 mechanized boats, 44,578 motorized crafts, 181,284 non-mechanised crafts. About 50 deep sea fishing vessels of more than 20 m LOA are operating along east coast, based at Visakhapatnam, particularly targeting shrimp resources in the north-east coast.

Both traditional and mechanized fishing crafts of medium and large size are operated in the country for exploitation of cephalopods. Fishing gears like hooks and line, jigging, surrounding nets, seines and traps are operated from traditional and small mechanized crafts, and bottom and pelagic trawls from medium and larger trawlers. Hand jigging methods adopted at Vizhinjam south west coast for cuttle fish is described by Nair (1986) with a brief description of the modern squid jigging method. An account of the experimental trawling and light fishing conducted at Vizhinjam is given by Nair and Omana (1986). The results of exploratory squid jigging with automatic squid jigging machines conducted from the vessel Matsya Sugandhi of Fishery Survey of India are discussed by Nair et al (1992). They have described the arrangements of jigging machines on the deck, the specifications of the jigging gear, lights and fishing operations. High opening trawl, high
speed demersal trawl, bobbin trawl and hybrid trawl developed for deep sea operations are found very effective for exploitation of cephalopods and they are described by Panicker (1990), Kunjipalu et al (1994), and Kunjipalu (2003). About 85% of the cephalopods landed in India are caught as by-catch of trawl nets operated upto 100m depth (Meiyappan and Mohammed, 2003) The introduction of high opening bottom trawls resulted in rapid increase in cephalopod production. The semi pelagic trawl system developed by Central Institute of fisheries Technology has shown better catch rate for squids (CIFT,2006)

The distribution and abundance of squid and cuttle fishes along the east and west coast of India based on the exploratory surveys conducted by the Government of India Vessels are given by various authors.(Joseph et al 1976, Joseph et al 1987, Oommen 1980,1985; Sudarsan et al 1987 , 1988 ; Philip and Somvanshi 1991; Sulochanan and John 1982). The potential yield of squid and cuttle fishes were estimated by (Joseph 1985, Sudarsan et al 1990, Philip and Ali 1989) based on the catch rates obtained during the surveys. Potential yield of one lakh eighty thousand tonnes of cephalopods from the Indian continental shelf was estimated by George et al (1977), Gullan (1970) and Voss (1973) estimated the cephalopod resources of Indian Ocean as several hundred thousand tones. All these estimates indicate the scope for increasing the fishing effort for enhancing the production.
The prospects of developing cephalopods into products for internal and foreign markets have been discussed by Padmanabhan (1970) along with methods of processing and storage. The changes in nitrogen, proteins, non-protein nitrogen and total free amino acids of Sepia aculeata preserved in ice were studied by Sastry and Srikar (1982). The method for processing dried squid according to the quality requirements of the Japanese market is given by Shenoy (1985). The mantle is the main edible portion of cephalopods, which are comparable in composition with low fat fish, and white meat of fish. Water, lipids and ash form the basic constituents in the proximate analysis (Love, 1970). Various biochemical properties of squid and cuttle fishes were studied by Lakhmanan and Balachandran (2000) and Lakshmanan et al. (1993) dealt with the quality of commercially frozen cephalopods products from India. Several studies have been reported on the storage characteristics of iced and frozen squid and cuttle fish. (Joseph et al. 1977; Dananjaya et al. 1987; Joseph and Perigreen 1988). Nazeem Beevi (2002) has found that temperature abused contaminated fish could act as a potent vehicle of food borne infections.

No specific literature is available on the export and marketing of Indian cephalopods except the periodic publications containing export statistics and reviews published by the Marine Products Export Development Authority Ministry of Commerce, Govt. of India and other International bodies.
OBJECTIVES OF THE STUDY

Though some information is available on the taxonomic, faunistic features and biological aspects of some of the commercially important species of Indian waters, very little is known about the handling and processing of cephalopods followed by the processing industry, trends in export and domestic markets and various factors influencing the cephalopod export. As such the present study is proposed with the following main objectives:

To get a clear picture of the cephalopod landing in India at different centers, the species composition, commercially important species and their share in the landings.

To assess the status of various mechanized and non-mechanized fishing crafts employed in the country for the exploitation of the squids cuttle fishes and octopuses and the fishing gears especially those developed targeting the cephalopods and to suggest suitable gears for the harvest.

To study various biological aspects like growth, mortality, maturation and spawning, food and feeding habit and stock of commercially important squid and cuttle fish of the south west coast and their influence on the fishery.

To evaluate various handling and processing techniques for cephalopods being followed by the fish processing industry and to suggest suitable methods to improve the quality of products and product diversification.
To study the present status of export of cephalopods from India, the shares of the top countries importing cephalopod products, the price offered by different countries, the total foreign exchange earnings and to formulate suitable ways to increase the export by expanding the international markets and diversifying the products.

**Plan of study**

In the present study two aspects of cephalopod fishery such as (i) landings and (ii) utilization including export of cephalopods from Indian are dealt with. Under the topic landings, craft, both traditional and mechanized and fishing techniques employed for capturing cephalopods are discussed. General trend in cephalopod landing in India and particularly south west coast, species composition, description and geographic distribution of important species of cuttle fishes, squids and octopus and the distribution and abundance of cephalopods along the continental shelf of the south west coast are also discussed. Some biological aspects like population parameters, maturation and spawning, food and feeding of the two representative species of cuttle fishes and squid viz, *Sepia pharaonis* and *Loligo duvauceli* are studied.

Under utilization, general handling and processing of various frozen cephalopods products for exports and commercial operation in a typical plant are studied. The export of cephalopod products since its commencement is studied in detail and market strategy for enhancing the export are suggested.