STUDIES ON THE EXPLORATORY TRAWL FISHING AND SIGNIFICANCE OF SELECTIVITY IN TRAWL FISHING GEAR FOR CONSERVATION OF MARINE FISHERY RESOURCES WITH SPECIAL REFERENCE TO THE INSHORE WATERS OFF MANGALORE

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BY

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2009

CERTIFICATE

This is to certify that this thesis entitled "**Studies on the exploratory trawl fishing and significance of selectivity in trawl fishing gear for conservation of marine fishery resources with special reference to the inshore waters off Mangalore**" embodies the original work carried out by **Mr. B. Hanumanthappa (Reg. No. 2522),** under my guidance and supervision from July 2002 to April 2009. I further certify that no part of this thesis has previously been formed the basis of award of any degree, diploma, associateship, fellowship or any other similar titles of this or in any other university or institution. He has also passed the Ph.D qualifying examination of the Cochin University of Science and Technology, held in October 2005.

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Co-Supervising guide
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DECLARATION

I, B. Hanumanthappa, (CUSAT Ph.D Reg. No.2522) hereby declare that this Ph.D thesis entitled **"Studies on the exploratory trawl fishing and significance of selectivity in trawl fishing gear for conservation of marine fishery resources with special reference to the inshore waters off Mangalore"** is based on the original research work carried out by me under the guidance and supervision of Dr.C.Hridayanathan, Professor (Rtd.), School of Industrial Fisheries, CUSAT, Kochi and no part of this work has previously formed the award of any degree, associate ship and fellowship or any other similar title or recognition.

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CONTENTS

CHAPTER I

INTRODUCTION

The harvesting of the marine sector for its seafood resources gained prominence in the wake of rapid dwindling of land resources. Rapid industrialization and urbanization coupled with ever-increasing population in the world make a very skewed ratio between food availability and the end users. In this context exploitation of alternative resource areas gained momentum and it is in this context that the marine sector forming 71% of the global area (Nathaniel, 1988) rose to prominence. Globally, harvesting the seas for their living resources has seen rapid strides in the development, in coastal as well as offshore sectors. Mainly exploitation of offshore / demersal resources along with commercialization of these resources is the mainstay in todays world fisheries scenario. According to FAO (Food and Agricultural Organization) statistics the total harvest has increased during the last half century from just over 20 million metric tons (mmt) in 1950 to 30 mmt by 1956 (Sainsbury, 1996). Since then, World fish production has gradually increased largely due to the introduction of larger fleets and mother ships in the fishing industry. At the same time fish farming had developed rapidly, especially in Asia. During 1980s the total production inched towards the 100 mmt mark, reaching it in 1989, before a decline in 1990 and again in 1991. This first fall in two decades was due largely to a sharp drop in the landings of Peruvian Anchovy fishery. The global production rose to 120 mmt. in 2005.

India can be said to be strategically located in world map with a peninsular portion with vast coastal line marked by Indian Ocean and adjacent seas. Many maritime states along this coastline made it exemplarily feasible for optimally exploiting the marine resources. However, the real picture is far from satisfactory as-far-as exploitation of capture fishes potentials of India is concerned. This is more so, in the offshore and demersal sectors. Of late the percentage share of exploitation of resources of different maritime states of India has significantly declined, making it mandatory to introspect and follow suitable optimal exploitable and conservation measures of otherwise plentifully available resources showing rich species diversities and habitats. The following data on marine capture fisheries of world nations and Indian subcontinent augurs well to arrive at a suitable inference with regard to future exploitation strategies of marine fisheries resources of India involving fishery scientists, managers and industrialists and policy makers.

Exploratory fishing forms an important prerequisite for rational exploitation of the harvestable stock on an economic basis. The term 'exploratory fishing' can assume different meanings depending on the context in which it is used. With reference to the immediate needs of the fishing industry, it is the process of locating commercial concentrations of fish and communicating such findings to the fishing fleet. On long-term basis, it is used to refer to the process of finding suitable fishing areas or grounds where commercial fishing can be carried out economically. Exploratory fishing, in a restricted sense, applies even to the process of experimenting with the most effective means of extracting the resources of any fishing ground.

For the scientists conducting exploratory fishing activities, the term may imply a more formal approach to resource assessment. As given by Alverson and Pereyra (1968), exploratory fishing "represents a study of the species complex inhabiting certain areas of the ocean and their relation to the environment, the areas and time distribution of the elements of the complex and the relative and absolute abundance of certain segments of the fauna inhabiting a particular region". A detailed knowledge of the availability of different faunal elements and their density in time and space is an important aspect in the scientific evaluation of the abundance of stocks with respect to an exploitable region. It also necessarily includes the cataloguing and describing, as completely as possible, all the faunal components available to certain sampling gear.

Laevastu (1965) defined exploratory fishing as the use of various types of fish-searching equipment and fishing gear to ascertain the kinds of fish present in an area and to obtain some idea of the magnitude of these stocks. In exploratory fishing, the fish populations are studied to assess their relative abundance and to establish the distribution limits of species, particularly of species of potential economic interest, using fishing gear as a standard testing device (Holt, 1956). The aims of an exploratory survey, as delineated by Alverson and Pereyra (1968), are as follows: examine the zoogeographic distribution pattern of the animals encountered, determine their relative abundance to each other and to major environmental features and where possible, establish some first approximations of the magnitude of important or potentially important commercial species, together with the possibly maximum sustainable yield that these resources might provide to mankind.

From a scientific standpoint, exploratory survey takes into consideration a method of sampling which will enable most effectively to determine the community or complex of animals inhabiting a particular area and at the same time derive a fundamental understanding of their spatial distribution, how the distribution patterns change with time, and to quantify as best as possible the various items that constitute the community or animal complex. The fishing industry necessarily needs to have knowledge of long-range forecasts on the magnitude of the fishery resource for investment planning. But more often, the industry is directly concerned with the short-term distributional aspects, such as the areas where the fish aggregate and the availability of the resource to fishing gear. Further, the producer is keen on knowing how much he catches in what period of time and where and how he should deploy his vessels so as to obtain the maximum catch. It is not the concern of the producer to understand the average densities or total bathymetric or geographic range of the species. On the other hand, he is concerned about the bathymetric zone in which fish tend to concentrate and the seasonal distribution pattern of the stock.

When a processor plans to set up his industry he would find information on geographic and seasonal distribution of the stocks, including areas and times of the year of maximum landings, useful. In addition to an idea of the magnitude of potential harvest of the fishery, he would appreciate information on the sizes of individuals from these stocks, so that he can plan the technical aspects of his processing operation in greater detail. This sort of data would help him in the selection of a suitable site for locating his plant and also in deciding upon the magnitude of investment. Exploratory fishing in the Indian waters is of comparatively recent origin. The pioneering accounts of the various scattered attempts at exploratory surveys have been documented by Hornell (1915), Gravely (1929), Sundara Raj (1930), Sorely (1948), Hefford (1949), Chidambaram (1953), Kristensen (1953), Srivatsa (1953), Anon (1954), Gopinath (1954), Jayaraman *et al.* (1959) and others. However, the establishment of the Deep Sea Fishing Station (now known as Exploratory Fisheries Project) by the Government of India in 1946 at Bombay marked the beginning of extensive and elaborate investigations on the availability of commercially important fishes in deeper waters, normally not tapped by fishermen or the fishing industry employing only the indigenous non-mechanized craft or the smaller mechanized boats. Since exploitation in an organized way can be achieved only after the fishing grounds have been identified, the decision taken by the Government of India towards charting the exploitable grounds and determination of fishing seasons to delineate the various species of fishes available, marked the beginning of a venture which was till then largely ignored. Although considerable amount of information was available on the biology of a number of commercially important fishes, data on exploitable stock of fishes were generally lacking.

Organized exploratory operations were initiated in India in 1946 with a deep sea fishing station at Mumbai under the Government of India. Integrated Fishery project (IFP) in 1952, UNDP/FAO Pelagic Fishery project (1971), Indo-Polish Industrial exploratory survey (1977), the New India Fisheries (1956) and US Bureau of Commercial Fisheries were the other primary agencies, which were actively engaged in exploratory fishing on scientific lines. Besides, Central Marine Fisheries Research Institute (CMFRI), Central Institute of Fisheries Nautical and Engineering Training (CIFNET) and certain state Governments as well as fishing industries have also conducted offshore fishing operations.

The marine fisheries play a vital role in the India's socio-economics. It provides employment, livelihood support to the fisher-folk and, protein rich food security to the populations. India ranks second in Asia and rank 7th among the top ten countries of the world in marine fish production (FAO, 2005). India's coastline is ~8,129 km. with an Exclusive Economic Zone (EEZ) of 2.02 million km^2 and a continental shelf of 0.5 million km^2 (Srinath, 2004). This provides the nation a greater access to a rich marine living (microbial, floral and faunal) and non-living (minerals, petroleum reserves, natural gases and other physical energy means like tides and waves besides the advantages of vertical differences in temperature for ocean thermal energy conversion, etc.) resources. Fisheries research together including the harvesting and post-harvest technological advancements has resulted in an increased catch and better utilization of the catch.

Over the years, the fisheries sector has evolved from a subsistence fishery to a multi-crore industry. For instance, total marine fish landings has increased from 5,34,000 tons during 1951 to 1,69,8000 tons during 1985 to an all time high of 2,95,0000 tons in 1997 (Ayyappan, 2006). Since then the present catch however, has reached around 2,778,000 tons during 2005 (Ayyappan, 2006). This is indicative that either fishing activities in the present fished area with the available infrastructure have reached a saturation point or, there is pressure on harvestable stocks, beyond which they may have become unsustainable. The quantum leap observed in the marine landings is for the following reasons: viz. introduction of mechanized crafts over and above optimal level, use of mass harvesting gears like trawl nets and purse seines, motorization of crafts including fitting of outboard (OB) engines, use of stronger and more durable synthetic yarns for fabricating gears and practice of extended fishing periods (multi-day fishing). Coupled with the above, the increased numbers of fishing units and extension of fishing grounds have also helped in boosting fish production.

The fishery of India is typical of any other tropical country with a large variety of species coexisting in the same ground. There are nearly 1,570 species of finfishes and about 1,000 species of shellfishes known from our seas (Pillai and Katiha, 2004). The important species belonging to the pelagic groups are tunas, mackerels, carangids, sardines, anchovies, Bombay-duck, ribbon fishes, seer fishes; demersal finfish stocks which includes perches, silver bellies, lizard fishes, catfish, croakers (sciaenids) and rays. The crustaceans like penaeid and non-penaeid shrimps, crabs and lobsters, and cephalopods like squids and cuttlefishes are also of common occurrence (Pillai, 2006). The abundance of these stocks differs from region to region and from season to season. Tunas, the large-sized pelagics, are more abundant around Island territories. Along the southwest and southeast coasts, small pelagics like sardines and mackerels support the fishery of considerable magnitude (Pillai, 2006). The Bombay duck and non-penaeid shrimps form a good fishery along the northwest coast, while perches in the southwest coast and southeast coasts, especially in the Gulf of Mannar, Palk Bay and Wedge Bank (Anon. 2006). Among this, species/groups contributing to more than 1 lakh ton per year are oil sardine, mackerel, Bombay-duck, ribbon fishes, carangids, perches, croakers, shrimps and cephalopods (Anon, 2006). The estimated sustainable fish resource potential in

India's EEZ is 3.9 mmt per annum. Of this, 58% is distributed in the in-shore waters, 34.9% in the offshore areas and the remaining 7% in the deep-sea region (Ayyappan, 2006). The major share of this resource is demersal in nature, accounting for 2.09 mmt. followed by 1.67 mmt pelagic and 0.24 mmt oceanic resources (Dehadrai, 2006). These resources are exploited by about 2.08 lakh traditional, non-motorised craft, 55,000 small scale beach landing craft fitted with out-board motors and 51,250 mechanized craft mainly bottom trawlers and purse seiners. About 80 deep-sea fishing vessels are also in operation with the size of more than 20 meters long (Anon., 2005).

Trawling is the most important method of commercial fishing contributing to more than 45% of the total marine landings the in the country (Vivekanandan, 2006). The methods of trawling have been revolutionized in the wake of scientific knowledge and technological developments. This technique is aimed at harvesting chiefly the demersal fish and shrimp resources. As a result of intensive and indiscriminative trawling, most of the demersal fishery resources have started showing over-exploitation. Further, some of individual fish stocks appear to be presently fished intensively or over-fished. This is particularly so, as there are no controls as to the type of fishing gear, size of fishing vessels and the quantum of fishing efforts to be employed for a given resource. Recent survey showed that commercial trawlers, which are using small mesh in their codend, resulted in landing of large quantity of by-catch along the Karnataka coast (Jayanaik, 2002). An increase level of by-catch and juveniles has attracted the attention of all those concerned for evolving effective methods to stop this dangerous onslaught.

The joint study conducted by the International Development Research Centre (IDRC), Canada, and Food and Agriculture Organization (FAO) has revealed that globally as much as 3.5 mmt. of edible marine fish is thrown back to the sea annually by the trawlers. This quantity is so significant that it is almost equal to the quantity consumed by the people of developing countries (Labon, 1982). Efforts in reducing the amount of unwanted by-catch in trawl fisheries are being made throughout the world (Brewer *at al*, 1997). This is being done from the view points of resource conservation, to maintain bottom fauna for sustainable fisheries and to avoid fishing the juvenile stages. Behavioral studies have been conducted to understand the interaction between the fish and the fishing gear (Wardle, 1986). Results from such studies were used in the successful design and development of several by-catch reduction devices as well as selective fishing gears (Wardle, 1988). The trawl by-catch in India is estimated to be 3.15 lakh tones (George *et al.*, 1981), which mainly consisted of juveniles. Therefore, it should be our national concern to minimize their catch in order to conserve the resources.

The property of any fishing gear or the method employed causes the probability of capture to vary with characteristics of each fish species is termed as selectivity (Fridman, 1986). Selectivity mainly depends on the principles of captures and other intrinsic design features of fishing gear itself. Information on fishing gear selectivity is important in biological investigations, fish stock assessments, fisheries management and fishing gear design and development. Selectivity characteristics of three important widely used fishing gears like trawls, gill-nets and hook-and-line is considered in the context of their relevance in the conservation of resources and development of selective fishing gear and fisheries management (Fridman, 1986). In trawl, netting is used in the capture process and in retention of the catch, wherein mesh-size has the greatest influence on the selectivity (Hameed and Boopendra, 2000). Among the intrinsic design features which influence the selectivity of trawls are mesh configuration (in shapes of diamond, square or hexagonal), load on twine, material and thickness of twine, hanging ratio, towing speed, towing duration and type of ground rig. Most of the selection occurs in the cod-end and hence its selection has received greater attention.

It is evident that little or no regard is being given to conservation measures by the government or fishermen themselves. The uses of small mesh-sized trawl gear are causing mass destruction of juveniles as evidenced in the present day trawl catch (Jayanaik, 2002). The prevalent multi-species composition in coastal waters of Karnataka, suffers the consequence of small mesh-sized gears. Such nets strain out juvenile and immature stages of many species causing recruitment and sustainability problems to many commercially valuable as well as keystone species. When finfish are dominant in the fishing ground, it becomes rather difficult to avoid the same from the targeted species i.e. shrimps. With the knowledge of fish behavior and their habitats coupled with the performance of the gear, selective trawl gears are now being developed to avoid the by-catch to the possible extent. In the face of emerging challenge confronting the capture fisheries development the world over, there is need for a better understanding of fish harvesting systems in relation to the fish habitats and behavior and also a reorganization of their strengths and weaknesses in terms of the objectives of responsible fishing, by all those who are concerned with the development, utilization and conservation of aquatic resources. In view of the above, the present study was planned with the following objectives.

1. The main aim was to fabricate high opening bottom trawl (HOBT) and to conduct experimental trawl fishing. The rationale for the need of gear modification is explained above. While not loosing sight on protecting the juvenile stages of marine fauna, the other important criterion essential for any modification in the gear is that it should become acceptable for commercially viable operations. The central objective of this study therefore was to experiment with many HOBTs codend with different mesh sizes and shapes. This study thus was aimed at studying the exploratory trawl fishing and selectivity of trawls with reference to alterations in codend mesh size and shape so as to evolve a most suitable mesh size and shape to be adopted for sustainable fishing and the conservation of resources.
2. Experimental trawl fishing using commercial trawl gear off Mangalore coast to obtain the catch data. The rational for collecting catch data by the regular trawl net was to know the quantum of juveniles caught and compare it with the data obtained. The rationale for collecting catch data by the regular trawl net was also to compare it with the data obtained using the HOBT used during this study.
3. The catch data obtained from both commercial trawl gear and HOBT with square and diamond meshes codends is analyzed by applying the appropriate statistical tests to eststablish the significance of modifications tried out during this study.

The data gathered during the course of this study would constitute a significant step towards a better inputs into the problem of dwindling catches and towards providing useful inputs for more elaborate and organized interdisciplinary investigations leading to better management of the marine fisheries resources.

CHAPTER II

2. Fisheries Development in Karnataka

Karnataka became a maritime State in 1956 when reorganization of states took place in the country. The three marine districts, South Kanara, Udupi and North Kanara, were then integrated into the present Karnataka State from the former Madras and Bombay states. Consequent upon the formation of the new State with added fisheries potentialities, an independent department of Fisheries with its Directorate at Bangalore, the capital of the State, was set up in the year 1957-58. A planned programme for the integrated development of fisheries in the State, therefore, could only be initiated from the second year of the Second National Five Year Plan and hence the First Five Year Plan and also a part of the second Five Year Plan could not at all benefit the fisheries development in the State. However, the story of fisheries development in Karnataka thenceforth was one of spectacular achievements. The matured and farsighted vision of the pioneers of fisheries development in the State had paved the way for the development of fisheries on a sound foundation. The State today produces more than 8% of the marine landings of the country though bestowed with only 5% of the Indian coast, the shortest stretch among the maritime states barring the Goa state (Anon., 2004).

Karnataka has the highest concentration of small-mechanized boats per Km. length of coast in the country and has the largest fleet of purse seiners in the country. The production of marine fish is not only steeply rising on account of this, but the purse seiners have also given stability to the annual catches normally subject to violent fluctuations which used to be a regular feature in so far as our pelagic fishery is concerned. With the boost to production by purse seiners, the contribution of mechanized sector of fishing is now more than 50% of the total catch and is higher than production from traditional sector. Even among active fishermen more than 50% are being engaged in mechanized sector of production. This indicates a high degree of mechanization and production by mechanized sector in marine fisheries.
On the inland fisheries side, the State has 5.20-lakh hector of inland water resources and annual estimated fish potential of these resources is about 2.75 lakh metric tonnes. During the period between 1956 and 1966, the important activity in the

inland sector was to import fish seed, mostly riverine major carp fry collection, from West Bengal. Fish seed production and rearing farms have been set up in the Government sector with view to develop the much needed infrastructures for producing fish seed for stocking in tank, ponds and rivers in the state. At present there are are 55 fish seed production and rearing farms under the control of the state department, Zill Panchayath and Fish Farmers Development Agencies. The State requires about 46 crore fish seed to develop all water resources suitable for fish culture. The present annual fish seed production capacity of the state is about 24 crore fry per annum. . Inland the fish farms being established and expanded, is progressively growing. The fish produced by them provides a livelihood or additional income to them.

2.1. Mechanization programmes

Introduction of mechanization in fishing was successfully achieved by training fishermen in mechanized fishing and then distributing mechanized boats on loan cum subsidy basis to groups of 5 fishermen who have completed training in the state fishermen training centres. Thus initially the fishermen were able to own mechanized boats without any capital investment. The mechanization of fishing operation was initiated with the introduction of programmes were started by the state from 1957-58 only. Starting with 2 small-mechanized boats the state had a fishing fleet of 1,500 coastal trawlers of size ranging from 30 – 43½ feet trawlers in 1977 for exploiting inshore demersal fishery including shrimp. Subsequently, the fishermen extended the fishing area beyond 50 meter depth using bigger vessels with endurance of 7-8 days. In recent years majority of fishing vessels of 50 ft and above are the common, which have effectively increased the range and fishing effort s of fishing operation.

Starting with 2 demonstration purse seine units by the Government in the year 1975-76, the fishermen were induced by financial incentives by way of subsidy and necessary technical know-how to venture into purse seining in the state. This as well as the successful operation of some purse seines units in neighboring Goa helped in the introduction of two purse seine units under private sector for the first time in the year 1975-76. The successful results of these pioneering units have evoked an all round interest among fishermen as well as financial institutions in the state to consider purse seiners as commercially viable. By 1976-77 the number of purse seine units rose to 20, which again shot up to 52 by 1977-78 and at present 338 purse seinrs are operating in the coastal Karnataka waters. Primarily the purse seine nets used in the state were about 450 meters long and 36 meters deep operated from a 43.5 feet boat. Later, improvements were made in the gear and tackles to enhance the operational efficiency. At present, boats which are slightly large than 45 feet length, an improved version of the same basic design of 43.5 feet, are preferred in the state for purse seining.

Centrally sponsored scheme for motorization of traditional fishing crafts was introduced in the state during the year 1887-88. Under the scheme, 33.3 % of the unit cost for the purchase of an out-board engine was provided as subsidy to a maximum of Rs. 20,000/-, which is equally shared by the state and centre. The rest of the amount is borne by the beneficiaries with assistance from financial institutions. Further, financial institutions have extended the required loan facilities for acquiring fishing boats, which have helped in enhancing the fleet strength. The growth of the number of small mechanized boats for inshore trawling has been spectacular, increasing from 2 boats to 1,500 during 1980s (Anon., 1986). Today, with 2777 trawlers, 338 purse seiners, 5127 gill netters, 138 long liners and 50 other mechanized boats, and 20,985 traditional boats are operating along 300 km. coast line. In recent years, Fishermen are being trained in operation of sophisticated electronic equipments both for fishing and navigation as a result majority of fishing vessels are fitted with fish finders, Global Position System (GPS) and VHF.

2.2. Marine Fishery Scenario in Karnataka

Karnataka's coastline is 300 km long and it shared among Dakshina Kannada, Udupi and Uttara Kannada, the three coastal districts. Its EEZ is 87,000 sq. km and the continental shelf area is 27,000 sq. km. (Table 1). The coast is endowed with rich fishery resources and is exploited by a variety of crafts and gears (Chandrasekhar, 2004). This part of the Arabian Sea is popularly historically known as 'mackerel coast' due to the dominating status/role of the Indian mackerel in the socio-economics of the coastal population, as fishing is one of the prime avocations of the area. The state has the largest purse seine fleet in the country and its dual trawl fleets, single-day fleet (SDF) and multi-day fleet (MDF) are modern and dynamic. The state's contribution to the total marine fish production of the country varied from 6 % to 13 % annually during 1980 and 2004 respectively. Besides mackerel, other pelagics such as sardines, carangids, anchovies, and demersal finishes such as threadfin breams, perches and flatfishes, prawns and cephalopods are the mainstay of the state's marine fisheries.

Till the 1950s, marine resources were harvested by artisanal gears such as '*rampani*' (large shore seine) and a variety of gillnets operated from country crafts. From 1960 onwards, fishing was augmented with the introduction of mechanized boats (trawlers) and improved gears like purse seine. With further technological advancements, industrialization and mechanization of fishing crafts and innovative gears like purse seine, the fishery witnessed unprecedented growth both in landing and infrastructure facilities during mid-1970 onwards. The total marine fish landing which was around 0.87 lakh tons in 1975 increased to 1.5 lakh tons in 1978 soon after the introduction of purse-seiners and again to more than 2.5 lakh tons in 1989 (Chandrasekaraiah, 2004). However, marine fish production from Karnataka coast is showing considerable variation. During 1996-97 it had reached the peak of 2.23 lakh metric tons and the production during 2001-02 was 1.28 lakh metric tons. During 2002-03 the total production fell to 1.80 lakh metric tons (Anon., 2003). Subsequently the catch and catch rates decreased which have led to lower profits for fishers and less revenue for the State. The detais of the marine resources of Karnataka (Anon., 2005) is presented in Table 1.

2.2.1. Status of Marine fishery

Marine fish production in Karnataka in general, shows an increasing trend with year to year fluctuations from an average annual production of 57,000 tons during 1950s, which progressively increased to 1.65 lakh tons in 1980s and 1.63 lakh tons in 1990s and again the mechani increased to 1.9 lakh tons during 2000-04. The landing crossed 2 lakh tons during 1987, 1988, and 1989 and again in 2002. As compared to the decade annual average landings during 1980s and 1990s stood at ~1.6 lakh tons (Anon., 2003). But the average annual landings during 2000-04 witnessed a growth rate of about 19%. The State's current average marine fish yield per km coastal line (638 tons) has almost doubled the national average production (344 tons) since the 1950s (Anon., 2003). The marine production in continental shelf

Table: 1 Marine fishery resources in Karnataka

Sl. No.	Particulars	Number/area
1.	Exclusive Economic Zone	87000 sq.km.
2.	Continental shelf	27000 sq.km.
3.	Coastal length	300 km.
4.	Fishermen population	233624
5.	Active fishermen population	96853
6.	Fishermen village	217
7.	Major Harbours	5
8.	Fish landing centere.	25
9.	Mechanised boats	8430
10.	Non-Mechanised boats	20985
11.	Fishing nets	40035
12	Ice plants	163
13.	Cold storages	29
14.	Freezing plants	14
15.	Frozen storages	12
16.	Canning plants	8
17.	Fish meal plant	15
18.	Boat building yards	29
19.	Net making plant	3
20.	Fisheries co-operative socities	109
20.	Fishery marketing Federations	2
22.	Fish Markets	198

area in different bathymetric division of Karnataka (Anon., 2004) is presented in the Table 2. Mechanised sector comprising the trawlers and the purse-seiners contribute 84.4%, while the motorized crafts operating gillnets, ring seines and hand trawls, and the non-motorized sector 12.4 % and 3.2 % of the landings respectively

2.2.2. Major composition in the landings

It is observed that landing of the pelagics is the dominant feature of Karnataka's marine fisheries. As apparent from the data in Table 3 (Anon., 2005) during 2000-04, the finfishes accounted for 80% (pelagics 53% and demersals 27%), crustaceans 14%, molluscs 5% and other groups 1% of the landings. Among pelagics, oil-sardine (40.9%), mackerel (19%) and carangids (11.8%) have dominated the catches. Among demersals, threadfin breams (38.4%), flatfishes (19.3%) and perches (16.5%) have been the major contributors. Crustacean catches were constituted predominantly by stomatopods (53%) and penaeid shrimps (39.1%) while molluscan catches were dominated by cephalopods (97%). The catchable potential resources of Karnaqtaka is presented in Table 3 (Anon., 2000).

Table: 2 Continental shelf area in different bathymetric Division of Karnataka

Depth range	Divisional of continental shelf based on depth range (Area in km2			
Division	0-10 fathom	10-40 fathom	40-100 fathom	0-100 fathom
12/74	172	858	429	1459
13/74	1200	6689	258	8147
14/74	1200	2830	0	4030
13/73	0	1715	3945	5660
14/73	0	3259	4459	7718
Total	2572	15351	9091	27014

Table: 3 Annual catchable potential of important species/groups of fishes off Karnataka at 0 – 50 fathoms depth

Sl. No.	Species/groups	Potential catch (metric tons)	
		Estimated	% to the total
1	Elasmobranches	2704	1.0
2	Oil sardine	50902	18.90
3.	Other sardines	6331	2.35
4.	Other Clupeids	8255	3.07
5.	White Baits	53445	19.84
6.	Mackerel	53445	19.84
7.	Seer fish	4012	1.49
8.	Tuna	5700	2.12
9.	Carangids	27824	10.35
10.	Pomfrets	2511	0.93
11.	Silver Bellies	5854	2.17
12	Sciaenids	4156	1.54
13.	Ribbon fish	6506	2.42
14.	Cat fish	6600	2.42
15.	Flat fish	5984	2.22
16.	Shrimps	9908	3.68
17.	Cephalopods	26250	0.97
18.	Lzard fish	2508	0.93
19.	Perches	8358	3.10
20.	Others	40413	15.01
	TOTAL	269312	100.00

2.2.3. Trawl fishery in Karnataka

There are two types of trawl fleets in Karnataka – single-day fishing fleet (SDF) with boat size of 9-10 m (30-32 feet) over-all-length (OAL) in the inshore waters and the other multi-day fishing fleet (MDF) with larger boat of above 32 feet in the distant waters of up to 300 m water depth. The main catch composition of SDF is the stomatopods, soles, penaeid shrimps and croakers. In MDF fishing, the major components of the catch are threadfin breams, cephalopods, ribbonfish, other perches, carangids, penaeid prawns and lizard fishes. Studies have revealed that multi-day trawling is profitable and has greatly improved the catch of perches, cephalopods and deep-sea prawns. The catch-per-hour of around 40 kg in 2000-01 has come down to about 33 kg during 2003 and 2004. The catch as well as catch rate by the trawlers have recorded a gradual decline over the years. The increase in landings initially was due to several technological improvements brought about in the gears and crafts. These developments enhanced the vessel endurance to several days in the deep seas. Besides, expansions of fishing grounds, better methods of fish-detection and harvesting and utilization of some unconventional resources have also been proved effective. Furthermore, the bumper landings of threadfin breams, rock-cods, cephalopods, and deep-sea shrimps greatly contributed to the increased trawl catch in the recent years. However, since 2002 the catch as well as catch rate has registered a declining trend.

2.2.4. Purse seine fishery in Karnataka

Against the estimated average resource potential of about 3 lakh tons of Mackerel and 4 lakh tones of oil sardine on the West coast of India. Karnataka alone could yield an annual additional catch of 1.0 lakh tones of Mackerels and another 1.5 lakhs tones of oil sardine per year. Since the fishery of mackerel and oil sardine are annual crops predominantly based on "O" Year class, larger efforts for its exploitation by purse seining can only save this valuable resource form going waste. The mackerel and sardine schools are mainly observed extended over a belt along the coast between 20-50 kms. off- shore almost thought the year and only a fraction of it seems to move close to the shore after monsoon. This untapped zone of pelagic resources is now made available and accessible to Karnataka fishermen by the introduction of purse sciners. Before the introduction of purse seines, the pelagic fishing season in the state used to last only 3-4 months. It could now be extended over a period of about 8 months in a year by purse seine operation in addition to the advantage of its massive catching capacity and extended area of operation compared to the conventional operational range of traditional fishing methods. Starting with 2 demonstration purse seine units by the Government in the year 1975-76, the fishermen were induced by financial incentives by way of subsidy and necessary technical know how to venture into purse seining in the state. This as well as the successful operation of some purse seins units in neighboring Goa helped in the introduction of two purse seine units under private sector for the first time in the year 1975-76. The successful results of these pioneering units have evoked an all round interest among fishermen as well as financial institutions in the state to consider purse seiners as commercially viable. By 1976-77 the number of purse seine units rose to 20, which again went, shot upto 52 by 1977-78 and 180 by 1978-79. Presently, there are about 338 purse seine units operating in the Karnataka coast. Primarily the purse seines used in the state were about 450 meters long and 36 meters deep operated from a 43.5 feet boat. At present purse seine nets of over 600 meters long are being used with slightly larger than 45 feet length purse seiners.

The major catches of purse seines in the state are mackerels and sardines at an average of 800 tons per unit per year. The bulk of the catch is landed in the first four months of the season starting from September when a daily catch of 3 to 7 tons per purse seiner is common. There was an instance of a record mackerel catch by a purse seiner fetching Rs. 40,000. (Anon., 1976). There was also a record catch of other species by purse seines in Karnataka, during 1976-77 when there was a rare and interesting harvest of about 18 tons of large sciaenid weighing 20 kg each near Mangalore. In 1978-79 another single large catch of 1,200 pieces of sciaenid each weighing about 20 Kg (total catch about 24 tons), was recorded, which was valued at about Rs.72, 000. There was also a record purse seine catch of catfish during a previous year. The secret of success in commercial purse seining in Karnataka is the local fishermen themselves with their quality of adaptability, caliber, professional skill and their spirit of entrepreneurship.

2.3. Fishing holidays in Karnataka

The official monsoon fishing ban is in force from June 15th to August 10th while traditional boats can under take coastal fishing operation during the ban period. A number of problems arise due to lack of uniform fishing holidays across the state as well as the country. The fishing holidays are for 57 days in Dakshana Kannada and Udupi while it is 45 days in Utter Kannada. This is to keep up with the fishermen of Goa, who venture into Karwar seas as fishing holidays there are only for 45 days and same is the case with Kerala. Fishermen who defy the ban will be cut off their quota of subsidized diesel, hence they have to stay back from their territory while fishermen from Goa and Kerala encroach Karnataka waters. This is the reason why fishermen's organizations are demanding a uniform ban all over the western coast.

Following the ban order, fishermen have hauled trawlers, long liners and other mechanized fishing vessels to the shore and parked them in the fishing ports. During the ban period the men generally go for traditional fishing, where they will be able to fetch income for some 30 days. Country crafts of 10 HP engine are used for the purpose. They go about 4-5 nautical miles in the sea and catch fishes in traditional ways and some fishermen go for fishing in the rivers and lakes. They also involve in purse seine net resetting during this season based on daily wages of Rs. 120/-. They also take up engine works and required renovation works of the hull.

2.4. Exports of fish products

After the adoption of modern technology of fish handling and preservation in the state by the beginning of the fifties, technology of freezing prawns, lobsters etc. has been developed and reached the level of sophistication by the early sixties. This has led to overseas trade of these high priced delicacies of Karnataka. Today frozen prawns and lobsters of Karnataka reach the American and Japanese markets mainly based on export markets and today the state have 14 freezing plants provided by Co-operative, Private and Public sectors. The growth of fish processing and export industry of the state has been considerable and today the 50 registered exporters of the state export annually around 14946 tons (Anon., 2006) of fishery products to many foreign countries of which Japan and U.S.A. top the list. Those who do not own freezing plants of their own could hire out freezing facilities provided by the

State Fisheries Corporation and therefore entrepreneurs, among the educated fisher youth could substantially participate in this processing and export trade. Export growth achieved during the past 10 years is given in Table-4 (Anon., 2005). By the commissioning of a major commercial harbour at New Mangalore in South kanara District in 1974 - 75, export trade of the state received a fillip and a direct access to steamers with reefer capacity. In the near future, it is planned to develop frozen mackerel export in large quantities besides the commercial production of fish sausages, paste products and starting fish canteens in the major cities of the state. Today, the major items of export are frozen and canned prawns, frozen lobsters, frozen quality fish, fish maws, dried fish, shark fin and fish meal, of which almost 80% consists of frozen prawns.

Table: 4 Year-wise export of marine fish products, its value and growth rate

Year	Quantity (metric tons)	Value (Rs.in lakhs)	Growth %		Unit value per kg.
			Quantity	Value	
1997-98	10551	11731.87	+ 6	+18	111
1998-99	11747	11395.35	+11	- 3	97
1999-00	12897	12238.00	+10	+7	95
2000-01	11823	9446.00	- 8	-23	80
2001-02	9430	6338.00	- 20	-33	67
2002-03	9788	6270.00	+ 14	-1	64
2003-04	8474	6447.00	- 13	+3	76
2004-05	10349	7692.39	+ 22	+19	135
2005-06	15965	10327.00	+ 54	+34	65
2006-07	26723	14949.00	+ 67	+39	56

2.5. Infrastructure development

The State has given importance for the development of infrastructure facilities like fishing harbours, landing centres, auction halls, and to setting up ice plants, cold storage, freezing plants and frozen storages. There are five fishing harbours in the sate at Karwar, Tadri, Honnavar, Malpe and Mangalore and 25 fish landing centres at Kodibengre, Hejamadikodi which have been recently constructed. It is proposed to take up construction of fish landing centres at Belekeri, Alvekodi with central assistance and at Belambur and Koderi with NABARD's assistance. Extension works of wharfs at Mangalore and Karwar fishing harbours have been taken up in 'Sea Bird' naval project, Karwar. Construction of fishing harbour at Amdahalli at an estimated cost of Rs.1032.00 lakh has been initiated.

As on 31.03.2003, there are 182 ice plants with a capacity of 2270 metric tons of ice per day, 32 cold storages with a capacity of 2638 metric tons, 17 freezing plants with a capacity of 332 metric tons per day, 14 frozen storages with a capacity of 1920 metric tons, 7 canning plants with a capacity of 526 metric tons and 17 fish meal plants with a capacity of 174 metric toes in marine districts.

2.6. Fishermen Co-operatives

The first fishermen co-operative society was registered in 1915 at Karwar. By 1956, Karnataka had 39 marine and 9 inland co-operative societies with one district level fish marketing federation at Mangalore. However, at present there is one state level Co-operative Fisheries Federation at Mysore and two district level co-operative Fish Marketing Federations at Mangalore and Karwar. There are 404 Primary Fisheries Co-operative Societies in the state with 1,36,383 members and a total paid up share capital of Rs.15.04 crore. These societies are engaged in fish production, harvesting, marketing and allied activities.

2.6.1. Co-operative Marketing Federations

There are two District Co-operative Fish Marketing Federations, one in South kanara district and another in North kanara district. These Federations are engaged in fish marketing and ice production for supply to fishermen, sale of diesel and lubricants, besides sale of fishery requisites to the members. These federations are also implementing NCDC funded "Integrated marine Fisheries development project".

2.6.2. Fisheries Corporation

The Karnataka Fisheries Development Corporation was established during 1971 under the Indian Company's Act. 1956. The authorized share capital is Rs.6.00 crore. The Corporation is engaged in activities like ice production, cold storage, freezing plant, and frozen storages for fishermen and processors, besides marketing of frozen fish through its cold chain. The Corporation is actively engaged in marketing of fish through a cold Chain established for this purpose. There are about 20 retail centres run by the corporation, which are fed from the 5 production centres through insulated vans. Deep freezers and portable frozen storage units are provided at retail and intermediary storing centres. About 100 tonnes of frozen fish per year are sold to consumers at these centres. To popularize frozen fish consumption, a few fish canteens are operated in exhibitions and at the main outlet point at Bangalore. In the effort to diversify fish products, a fish bone separator of the capacity of 3 tons/day has been installed in one of the plants to produce minced meat, which is sold in frozen form in 400 grams packets. Another product now under production is fish wafers by utilizing minced meat of fish. Commercial production of fish pickles and sausages are also being planned.

CHAPTER-III

3. REVIEW OF LITERATURE

Trawling is an important technique of fishing methods, coming under the category of dragged gear. In this method a bag-shaped net is towed through water with its mouth kept open by a frame, a beam, otter boards, floats, sinkers, kites etc. Sometimes, it is kept opened by being towed by two vessels moving at a distance from each other in the same direction. Based on the position in the water column where the trawl is dragged, trawls can be categorized into bottom trawl or demersal trawl and mid-water or pelagic trawl (Brandt, 1972). Mid-water trawl, though can give very high catch in a short time, is an aimed trawling and needs a fish shoal to be detected first before operating the gear skillfully. However, this is not popular in India. On the other hand, bottom trawling is a blind trawling, which does not need much of instrumentation and thus, is the only widely accepted method of commercial fishing practiced in India. There have been continuous developments in demersal trawl nets and their accessories to reach the present status. A brief review of different studies done on demersal trawling with special reference to the effect on trawl net mouth opening is summarized below.

3.1. Trawl gear performance

The suitability and acceptability of any gear depends on its satisfactory performance in a specific location. Therefore, several studies have been conducted to find out the relative gear performance in different locations.

3.1. 1. Aspects of general trawl designs

Designing fishing gear is the process of preparing technical specifications and drawings for the fishing gear, which meets the operational benefits and satisfies gear (Fridman, 1986). The key to successful development of selective gear designs is the understanding of the behaviour of the individual species to various environmental stimuli (Watson, 1989). Buckingham (1972) stated that the factors to be considered while designing a gear include engine power of vessel, length of belly, head line height, mesh size and its shape, netting material used and the overall resistance. Lonnevik (1989) stated that the hanging ratio of netting affects its overall shape, vertical and horizontal openings and stability. Adoption of standard design and modern fabrication methods in anchored bag net results in better catchability (Kunjipalu *et al.,* 1993).

Some characteristics of netting and twine material have significant hydrodynamic, behavioral and mechanical effects on gear selectivity (Ferro and Neill, 1994). The major factors influencing on the fish catch is the vertical opening of the net (Takayama and Koyam, 1959 and Parrish 1959). In a known fishing ground the quantity of fish caught by trawl gear has direct bearing on the volume of water filtered during a certain period of operation and depends on the both the horizontal and vertical opening of the net while in operation (Deshpande, 1960). It has been mentioned by Hridayanathan and Hameed (1990) that the catch of stake net (bag net) is highly influenced by its design besides the lunar cycle and operation methods. Trawl design should be made in such away that it offers minimum resistance. The behavior of the fish to be caught, technical characteristics of the vessel and condition of the ground are some of the important factors to be considered while designing a trawl (Sreekrishna and Shenoy, 2000).

The braided polyester netting and the new generation spectra fiber ropes for trawls give superior strength and abrasion resistance with very low elongation (Stone, 1989). The use of monofilament netting in otter trawls would reduce the total drag significantly compared to multifilament one (Sumptron *et al.,* 1989). Kartha *et al.(1977* stated that trawl made up of tape twine has increased the catch compared to poly amide and polyehlene monofilament material. The substitution of netting in the fore parts of the trawl by ropes would reduce the drag (Rao *et al.*, 1994). Mounsey and Prado (1997) analysed three net designs for ecofriendly demersal fish trawling systems. Neethiselvan and Brucelee (2003) have analyzed the design features of fish trawl and shrimp trawls of Thoothukkudi coast with those of standard FAO fish cum shrimp trawls. Manikandan (2005) designed the big mesh trawl to reduce the by-catch in bottom trawling.

3.1.2. Design of efficient trawl gear

Fridman (1969) described the general principles involved in the theory and design of trawl gear and the several traditional and scientific methods of evaluating the efficiency of the gear. The efficiency of trawling operation can be improved by increasing fishing time using two trawls alternatively - hauling one and shooting one (Anon., 1969). Nair *et al.,* (1966) from their study to judge the most suitable size of trawl that can be economically operated in shallow waters, reported that towing two or more small trawls by a vessel is more advantageous than a single large trawl. Bigger trawl catches more, but at the cost of higher hydrodynamic drag and increased difficulty in gear handling (Dickson, 1959). Chandrapal (1975) opined that success of trawling operation depends on the proper matching between the gear and the trawler. Miyamoto (1959) studied the relationship between the size of trawl gear and the vessel towing power and formulated several equations for finding out the size of trawl net and otter board along with its weight in relation to the horsepower of the engine. Nair and George (1964) also came out with similar relationships between horsepower of the vessel and the size of the trawl gear and its accessories. Pradhan (1965) had given a preliminary account and review of the simple methods for determining the operational parameters of fishing gears.

3.1.3. Fish behaviour with respect to gears

Knowledge of fish behavior and its reaction to fishing gear forms the basis for the development of the efficient gears and the energy efficient fishing methods with good selectivity (Anon 1980). Mous *et al., (*2002) have reported that fish that are encountered by the net tend to keep a constant position relative to the net, even if the net tend to be towed at a speed of lower than its maximum swimming speed and, the fish that gets exhausted end up in the codend. The need to understand the fish reaction to gear for the development of efficient gear has been stressed by Parrish and Blaxter (1963) and Fridman (1969). Fish arriving at the trawl mouth may enter it and continue swimming towards the codend but it turns in the trawl mouth and continues swimming in the towing direction. Depending on the towing speed and the size of the gear the fish become exhausted after some period of time and drop back towards codend (Main and Sangster, 1981)

Chikimasa (1964) and Garner (1967) stated that pressure build up inside a tapering gear could have a frightening effect on fish. Arimoto *et al.,* (1989) have observed with the help of underwater cameras, more fish reach near the net mouth and throat part of the net. Fridman (1986) noticed that the swimming speed of fish, to large extent, determines the required operation speed and gear size. Dickson

(1959) had stated that the most commonly observed reaction of fish is to swim perpendicular to moving wire rope. Suueronen (1989) observed that avoidance and escapement of herring (*Clupea harengus*) is dependent on the swimming patterns of this fish during trawl operation. Bottom trawl efficiency is function of horizontal herding ability of the gear so as to enable the fish towards the centre of the path in response to stimuli provided by sand cloud and bridles (Engas and Godo, 1989a; Ramm & Xaio, 1995; Dahm, 2000 and Somerton & Munro, 2001).

Sreekrishna (1995) reported that mullets are known to have the habits of jumping out of water when encountered with obstacles and when disturbed. The flying fish, pomfrets and sardines are known to take shelter around the bundles of vegetation for breeding. Main and Sangster (1983) compared heavy rigged trawl with light rigged trawl and observed the reaction of fish to the trawls. Haddock, sardine and mackerel were found to swim straight to light rigged trawl while they turned away from the path much ahead of heavily rigged trawl. Goeden *et al.*, (1990) observed in large low tanks through video and formed that 65% of shrimps escaped under net because of the insufficiency of the foot rope in containing their escape jumps. Variation in footrope contact with the bottom could impact the capture efficiency of the trawl (Weinberg *et al.*, 2002).

Main and Sangster (1981) stated that behavioral studies can be best observed by divers directly than the photographic or video cameras due to their limited vision. Amos (1984b) had communicated on the use of vertical echo sounders and sector scanning to monitor the action acoustically tagged fish. Ona *et al* (1999) reported that high frequency scanning sonar could be used to study the fish behaviour to trawls. Turbidity of water and the visibility have great effect on fish behaviour to the gear and its selectivity (Wardle, 1989). Farmer *et al.* (1998) analysed the behaviour of the fishes and noticed that prawn escaping through 45mm codend have minimum damage. The size of the trawl depends on the towing speed of the vessel and towing speed should be proportional to the swimming speed of the fish (Srikrishna and Shenoy, 2000). Glass *et al.,* (1993) observed that the fish reacts more in small mesh narrowing funnel netting when compared to large mesh netting panels. Walsh (1992) and Ona (1999) have observed the behavior of fish in small codend and noticed that most escapements occurs by fish passing underneath the footrope, especially near its centre where fish are concentrate by herding.

3.1.4. Selection of trawl depending on the ground

The selection of trawl type for a particular region has profound influence on the trawl efficiency. Nakamura (1971) is of the view that the type of trawl net to be used should depend upon the fishing ground and the fish to be caught. Prado (1977) opined that muddy bottom allows the trawl to slide more freely than the one, which is hard or uneven. Buckingham (1972) suggested the use of a four-panel trawl without wings for fishing on hard grounds. Foster (1976) reported that a four-panel trawl developed at the Aberdeen Laboratory had improved fishing performance on rough grounds than a two seam trawl. The fishing grounds off Mangalore are an important trawling ground along the Western coast of India. Several workers have studied the efficiency of different typpes of trawls on this fishing ground (Mathew, 1978; Puthran, 1981; Mohankrishna, 1985; Ashok, 1989; Nayak, 1991; Talwar, 1997; Girish, 1999; Jayanaik, 2002 and Manikandan, 2005).

3.1.5. On species depending trawl selection

Botha and Payne (1980) found beam trawl to be more efficient in catching soles in comparison to the otter trawls in their study off south West coast of Africa. Kurian (1965) in his comparative study found that bottom burrowing or resting species including shrimps prawns were more in the catches of beam trawl, while bottom swimmers dominated the catches of otter trawl. The author further reported a 50 per cent increase in shrimp catches in shrimp trawls by using long wings. Deshpande and George (1965) suggested that, in order to increase the effectiveness of shrimp otter trawls, heavy ground rope and less buoyancy on the head rope are necessary. Satyanarayana *et al.* (1970) developed shrimp trawls of wider horizontal spread at low towing speeds. Nair and George (1964) and Panicker *et al.* (1978) also worked on similar aspects.

Besides exploring the demersal resources, attempts were made for exploring off-bottom fishes. Kunjipalu *et al.* (1979) carried out comparative study of fishing efficiency of a bulged belly, a long wing and a four panel trawl and found that the bulged belly trawl had superiority over others in catching bottom and column fishes while the long wing trawl was found to be the best for catching shrimps. Similar results have also been reported by Pillai *et al.* (1979). Nair *et al.* (1971) have reported on the effect of over hang on increasing catch in a bulged belly trawl. The efficiency of a platform panel as a forward extension of lower belly in semi-pelagic trawls have been evaluated by Mathai *et al.* (1993). Mahalathkar *et al.* (1983) found that over hang trawl to be more efficient for the capture of off-bottom and column fishes than the non-over hang trawl. Nakamura (1971) found two-seam trawl to have greater vertical height than four-seam trawl. Contrary to this Deshpande *et al.*, (1972 a) have reported that four-seam trawl had better catch efficiency when compared to a High Opening Bottom Trawl (HOBT) gear with bridles and a sweep line on each side with a greater efficiency in catching off-bottom fishes. Miyata (1977) has mentioned on the rapid increase in the use of HOBT in Malaysia over conventional bottom trawls. Pajot *et al.* (1982), Pandurangan and Ramamurthy (1983), Kunjipalu *et al.* (1984), Mohankrishna (1985), Pajot and Mohapatro (1986) and Raja (1987) found the HOBT to be superior to orthodox shrimps trawls in catching valuable pelagic and semi pelagic species. Brabant and Nedelec (1983) have reported on several HOBT for inshore waters and large lakes. Kunjipalu (1994) has given a brief account of the development of high opening trawls.

3.2. Mouth opening of the trawl

Mouth opening of the trawl refers to the trawl mouth geometry while towing. This is an important parameter of any dragged gear, which is directly related to the amount of water filtered and thus the fishing ability.

3.2.1. Importance of mouth opening of the trawl

There is an old and often quoted saying in trawling, "It all comes out of the codend". Thus, it is the amount of fish in the codend that matters much to a fisherman. And so, what is more important is to discover how best to fill the cod-end in the shortest possible time with greater economy. Among the various factors concerning to this, trawl mouth opening, which depends on the spreading force and the lifting force of the gear commands immense importance. There exists certain definite inverse relationship between these two forces and for proper trawling operation, there should be a balance between them (Takayama and Koyama, 1959). The authors further stated that the major factors influencing the catch of trawl gear are the horizontal spread of the net for bottom fish and its vertical opening for off-bottom fishes. Philips (1959) and Hamuro (1964) were of the same opinion. Deshpande (1960) stated that the quantity of fish caught by a trawl net has direct bearing on the volume of water filtered through it during a certain period of towing and inturn depends on both the vertical and horizontal opening of the net while in action. The area of net mouth is one of the factors that influence the drag of the net (Kwalski and Giannolti, 1974). Jayanaik, (2002) had reported that bridles and sweeps also influence the mouth opening of the trawl.

3.2.2. Horizontal mouth opening of the trawl

The horizontal mouth opening of a trawl usually refers to the door spread, though the wingspread is taken for consideration many a time. Importance of this for catching of fish has been widely studied.

3.2.2.1. Otter boards

3.2.2.2. History of the otter boards

Otter board was employed initially in line fishing at Ireland to keep the main line tight and is not an innovation of trawl fishery (Davis, 1958 and Brandt, 1972). Davis (1958) was of the opinion that the actual invention of otter boards must be credited to Hearder or Musgrave. He further stated that, though Danes were using a modern type of otter boards on their seine net way back in 1888; it was on 1892, the first successful otter board was made at Shields on the North East Coast of England. The otter board reached Germany through Holland in 1895. During the same year France completed successful experiments with the doors. After this, the otter boards became popular all over the world.

Before the introduction of otter boards, the trawl gear was kept open by a rigid self-supporting frame called 'beam'. Introduction of otter boards coupled with the introduction of radical changes to trawl fishery as it has many advantages of easy handling, use of bigger nets, operation in deeper waters and larger coverage for the given net (FAO, 1974 and Baranov, 1976). The flat wooden plate was the type of otter board initially introduced, which has undergone many changes in size and shape to evolve into the present forms namely rectangular, oval, polyvalent, vee form, hydrofoil, suberkrub and saucer shaped, flat and cambered (horizontally or vertically), with or without slot(s) and foil(s), at various aspect ratios, fabricated out of varied materials and rigged to provide various angles of attack.

3.2.2.3. Design and selection of otter boards

Design of more efficient otter boards is one important way to reduce net drag (Wray, 1986). FAO (1974) emphasized on the correct choice of otter board angle to reduce net drag. Pillai *et al.* (1973) have studied the effect of weight of otter boards on the horizontal opening of trawl net. Ben-Yami (1975) explained about how optimum size and setting can be calculated to avoid wastage of towing power and improve trawl performance. McLaughlin (1986) and Gabriel (1987) have emphasized on the selection of a correct trawl board shape and size to get best results. Mukundan (1970) has reviewed the design and construction of flat rectangular otter boards for bottom trawling. FAO (1974) has compiled the otter board types, their design and performance. Ashworth (1989) and Cheesley and Gates (1989) have described the history of developments of trawl doors. Anon (1995) has written a book on characteristics and functioning of otter boards.

3.2.2.4. Comparative studies between otter board types

Wide range of literature is available on the feasibility study of various types of otter boards. Mukundan *et al.* (1967) studied the relative efficiency of three different shaped otter boards on the basis of horizontal opening and towing tension. Narayanappa (1968) described different types of otter boards namely, flat rectangular, horizontally curved and oval single slotted rigged to a two seam trawl off Kakinada and found that the horizontally curved otter boards gave greater horizontal spread with high catch rate. Comparative fishing trials with flat rectangular and curved rectangular otter boards rigged to a four seam trawl showed higher catch rate with 13 % more horizontal spread but with 10 % higher towing resistance in the case of rectangular curved boards (Deshpande *et al.*, 1970). Sreekrishna (1970) in his study off Kakinada found that a 12.96 m two seam trawl with rectangular curved doors and a 11.98 m two seam trawl door with oval boards were equally efficient. Deshpande *et al.* (1972) recorded better catch of fish and shrimp when trawls were rigged with rectangular otter boards than when rigged with oval doors. Lange and Steinberg (1989) studied the influence of size and form of otter boards on the opening area of a bottom trawl. Anon (1995a) evaluated six different designs of cambered otter boards available in Australia in shrimp trawling. They also studied its effect on the performance such as total system drag, spreading capability, stability characteristics while on tow, shooting away characteristics, ease of handling etc. Anon (1991) developed a more fuel efficient environment friendly otter board. Jong and Marlen (1991) did model studies on use of single trawl door on the port side and Dan-leno on the star board side to catch pelagic fish closer to sea surface.

High aspect ratio otter boards for pelagic trawling called "Suberkrub" was first developed in Germany and later used in Japan with little modification for catching demersal fishes (Brandt, 1972). The author also reported on the use of "Tendem boards", which consists of two smaller high aspect ratio boards instead of single suberkrub doors so as to overcome the problems of handling onboard while giving the same result. Development of spherical otter boards, called "Saucer boards or O- boards" by Russian was found suitable for rough fishing grounds as well as column water fishing by trawls (Brandt, 1972). Garner (1988) opined that the conventional boards with a flat surface present a high ratio of resistance and consequently good spreading force. Besides, the ground shear or friction along the seabed may be quite severe. On the other hand, in the case of oval boards the ground shear is much less and so also the spreading force and the board can easily clear obstacles on seabed. Further, oval boards with one slot, show a greater spreading force besides ease of riding over obstacles. Brandt (1972) reported that flat doors, Vee doors and spherical doors are associated with added advantages of interchangeability between starboard side and port side to avoid uneven wear of keel. Nair *et al.* (1973) reported that, though the Russian type oval boards are favourable on East Coast of India for the uneven rocky grounds and the superiority of the horizontal curved boards for bottom trawling has been proved, they were not popular due to the difficulty of manufacture and the cost compared to the flat rectangular type.

Brandt (1972) pointed out that, the simple flat rectangular wooden boards are less influenced by the hydrodynamic and hydrokinetic rules compared to the curved boards, thereby resulting in lesser efficiency of the conventional flat boards. Catasta (1959) designed two new otter boards of the shape of aeroplane wing section and reported that, when compared to flat doors they offered lesser resistance, not falling flat, less liable to dig into the bottom and expected better durability. Mukundan (1970) reported that flat rectangular boards offered high resistance and spread force was not satisfactory. The new types of boards having good engineering/hydrodynamic performance are expensive to manufacture and difficult to handle as compared to conventional flat rectangular otter boards (FAO, 1974 and Ben-Yami, 1975). Garner (1988) substantiated that any trawl development must begin at otter board as it affects the rest of the gear in its performance.

Mukundan (1970) and Brandt (1972) gave an account of the different materials used for otter board construction. Originally the flat boards were made up of wooden planks or marine plywood strengthened by steel frame and iron struts. Catasta (1959) used iron and plastic material for his new aeroplane wing section type otter boards. However, nowadays steel is replacing the wood in the construction of most of the otter board types, especially used in deeper waters.

3.2.2.5. Vee otter boards

Many workers have studied the feasibility of vee boards in demersal trawling. Brandt (1972) reported that vee – shaped trawl doors (butterfly otter boards) became very popular in small scale inshore trawling and were designed by the Chinese captain Loo-Chi Hu in 1956/57. The author further adds that these boards claim a good performance on rough grounds. Although the vee doors are associated with low shearing power, successful fishermen prefer them Wray (1986) studied the performance of the varying type of vee doors such as standard vee doors, cambered and square vee doors and vee doors with or without slots. Satyanarayana *et al.* (1978) investigated the relative efficiency of different shaped otter boards under identical fishing conditions and found the gear fitted with vee shaped otter board performed well when compared to the gear fitted with horizontally curved and vertically curved boards. Main and Sangster (1979) found superior spreading force with rectangular cambered boards, whereas, vee doors were superior in terms of stability and clearing rough grounds. Kunjipalu *et al.* (1984a), in their comparative study found that 'V' shaped all-steel doors, with their inherent stability to ride over obstacles and mud and interchangeability of starboard side and port side boards, were superior to conventional flat rectangular otter boards for bottom trawling.

Matsuda *et al.* (1990) studied the hydrodynamic characteristics of a vertical V shaped otter board in model tank to determine the lift, drag and moment. Loverich and West (1989) designed high aspect ratio otter boards, called "fishbusters", which was found successful for bottom trawling by increasing the catch rate significantly over those with conventional flat rectangular vee doors. Lange (1987) used 13 % camber ratio in his new type of V door to get 70 % higher lift coefficient. Le *et al.* (1987), in their model experiments observed that the simple cambered otter boards performed better than super V otter boards, even though same camber ratio was used. Lange (1989) conducted wind tunnel tests to develop vee form boards. Lange (1991, 1991a) did model tests to study the hydrodynamic characteristics of cambered V doors of high aspect ratio (1.0) and found that when compared to cambered vee doors of traditional aspect ratio (0.5) the new boards reduced the drag coefficient. Greening (1989) reported that, for deep sea fishing beyond 200 nautical mile high aspect ratio cambered vee doors were found suitable.

It has been mentioned that, poly ice vee doors had better spreading ability while shooting the gear (Anon 1996). Kunjipalu *et al.* (1984a) reported that flat rectangular otter boards of wood and steel construction are extensively used in commercial trawling along Sourastra coast but steel V boards were superior in terms of construction, durability, inherent stability and higher hydrodynamic efficiency. Sahu (1997) studied the efficiency of vee otter door in comparision to the conventional flat rectangular otter board for demersal trawling and concluded that vee type is better.

3.2.2.6. Otter board characteristics

The otter board attitudes such as angle of attack, heel, tilt, aspect ratio and hydrodynamic characteristics such as lift, drag, sheer, camber, slot etc. play an important role in the engineering performance of otter board (Mukundan, 1970). Effect of angle of attack on the performance of different types and shapes of boards have been reported by Blestikina (1962), Dale and Moller (1963), Mukundan (1970), FAO (1974), Lin *et al.* (1989, 1989a), Ko *et al.* (1990), Matsuda *et al.* (1990) and Mukundan and Hameed (1994). With his studies on flat rectangular otter boards, Crewe (1964) got maximum sheer at 30^0. Angle of attack ranging from 30^0 to 39^0 has been suggested for trawling with flat rectangular boards (Ben-Yami,

1963) The effect of heel of boards has been reported by Crewe (1964), Ben-Yami (1963), Mukundan (1970), Lin *et al.* (1989, 1989a) and Mukundan and Hameed (1994). Mukundan (1970) discussed the effect of tilt of otter board on the ground performance. The ratio lift to drag, which is an important characteristic of an otter board has been studied (FAO, 1974 and Mukundan, 1970).

Gabriel (1987) compiled the general criteria and various hydrodynamic coefficients for most common type of otter boards to help selecting otter board type. Kim and Ko (1987) studied the sheering characteristics of simple cambered and super V otter board attached with a flat plate at the trailing edge. Daartz *et al.* (1987) investigated the dynamic behaviour of otter boards. Ibrahim (1988) and Park *et al.* (1993) studied the effect of ground touching on the hydrodynamic efficiency of otter boards. Ben-Yami (1995) has reviewed the hydrodynamic behaviour of otter boards, the influence of ground touch and speed and other aspects that influence the performance of otter boards in action.

Lin *et al.* (1988, 1989, 1989a) studied the hydrodynamic characteristics of lift and drag of saucer shaped otter boards of different camber ratios. Matuda *et al.* (1989) reported on the hydrodynamic characteristics of wing parakite, a net mouth-opening device made of canvas and found its performance to be comparable to an ordinary cambered upright otter board. Jo *et al.* (1991) studied the sheering ability of a newly designed canvas net sheering device.

3.3. Importance of horizontal mouth opening of trawl

Horizontal opening of the trawl net mouth is a key factor in the efficient operation of all the demersal trawls (Okonski, 1972). Narayanappa (1972) and Satyanarayana *et al.* (1978) found that catch per trawling hour increased with increase in lateral spread of the net upto a certain range beyond which the rate declined. Levi *et al.* (1989) measured the horizontal distance between otter boards to study the biomass abundance in the Sicillian channel. Kunjipalu *et al.* (1992) established relationship between the size and type of net and its optimum horizontal opening, which is suitable to catch a particular fish resource. Rose and Walters (1990 and 1991) reported that variation in the horizontal opening of bottom trawls at different depths gave varied and biased results in the catch of ground fish fishery in USA due to the changes in the length of warp required at different depths.

3.3.1. Factors influencing horizontal mouth opening of trawl

Mukundan (1970) summarized that the lateral opening of trawl depends on the type of gear used, nature of bottom, length of warp released during operation and towing speed and more particularly the type of board and the position of the door assumes during fishing. Kotsyunin and Nikonorov (1971) is of the opinion that the horizontal spread between the otter boards depends on the size of trawl, quality of trawl board (i.e. the ratio of spread to resistance), length of sweep line or bridles, warp scope etc. Pillai *et al.* (1979) recorded significant increase of otter boards horizontal opening in the large mesh trawl. Kunjipalu *et al.* (1989) recorded 7.9% more horizontal opening between the otter boards of a 25 m large mesh two seam demersal trawl than that of a 25.6 m two seam trawl developed by BOBP (Bay of Bengal Programme). Several authors have reported a higher horizontal opening in large mesh trawls (Anon., 1973 and Naidu *et al.*, 1987). Nair *et al.* (1973) suggested that horizontal opening can be improved with long sweep lines and extension wings, which in combination with tickler chain yields better prawn landings. Satyanarayana and Nair (1964) had stated that shrimp trawls with 35-60 ft head rope had a horizontal spread of 50-60% of the total length of the head rope including sweeps. Satyanaryana *et al.* (1972) related a relationship of horizontal spread of the otter boards to the total length of head rope. The methods for theoretical calculation of wing and door spreads for bottom trawls have been given by Ben-Yami (1959), Deshpande (1960) and Dalmendray and Valdes (1984). Hagstroem (1987) described the method of measuring the door spread and headline height of trawl net. Marteinsson (1992) measured the wingspread, door spread and trawl height by acoustic instruments.

Otter boards trawl doors or doors as they are frequently called are the devices to keep trawl net horizontally open while towing. They account for approximately one fourth to one fifth of the total drag of trawl gear, and also directly influence the geometry of a trawl and consequently the overall drag of the gear (Anon, 1974). Each door is connected with towing brackets for attachment of warp on one side and the bridles of the net on the other side, so that the boards keep obliquely to the direction of motion due to the forces from flow of water (Hodson, 1942 and Brandt, 1972). The two doors on either side in a trawl net are working on the same principle as that of a kite, causing the shearing effect in the water (Mukundan, 1970). The most recently developed methods of keeping the horizontal opening of the net are canvas mouth opening devices and wing parakites (Jo, 1985; Matuda *et al.* 1989; Ko *et al.* 1988 and Jo *et al.* 1991).

3.3.2. Vertical mouth opening of the trawl

Vertical mouth opening of a trawl refers to the maximum height to which the head rope is lifted while towing. This is considered important for catching certain fish resources by trawls.

3.3.2.1. Kites and gussets

Takayama and Koyama (1959) suggested the use of kites and gussets. Burgess (1967) reported that a kite attached to the float line gave a higher headline height in a trawl. Cerdic (1978) had commented on the use of a canvas sail kite to double the mouth opening of a trawl net. Ben-Yami (1979a) did flume tank tests and confirmed the benefits of using sail kites. Ben-Yami (1979) stated that sail kite gave 120% increase in fishing height while fishing spread was reduced by about 10%. He also reported that increasing the fishing height affects the bottom contact of the footrope. Successful use of sail kite by Russian, Polish and Burmese fishermen were mentioned by Ben-Yam (1979). Lange (1989) has discussed the simple method of designing and rigging flexible sail kite to a trawl mouth. A strip of canvas was fixed to the trawl mouth to attain higher headline height by Day (1978). Ben-Yami (1979) studied the feasibility of using a sail kite to achieve more vertical opening.

3.3.2.2. Floats

Floats are widely used devices for lifting the headline. Catasta (1959) used plastic floats with a hydrodynamic section and an elevating hood to lift headline. Satyanarayana *et al.* (1970) employed different methods to increase the vertical height in an otter trawl and found that the trawl with additional float line gave better catch when compared to the nets with triangular gussets or with rectangular kite. Studies at Aberdeen Laboratory showed that the floats of squashed sphere were efficient to spherical floats (Anon., 1973). Chen (1989) got encouraging results with the use of flexible hydrofoil wing float for lifting the headline of a trawl. Kunjipalu and Boopendranath (1993) developed a flexible float made of canvas and their investigation resulted in a significant improvement in the yield of finfish and total catch besides many other advantages.

3.3.2.3. Sinkers and tickler chain

Use of sinkers is of prime requisite to pull the lower lip of the net mouth down. Many references are available on the use of tickler chain for the dual job of sinker and tickling the ground to catch burrowing variety of fish and crustaceans (Deshpande and George, 1965 and Beardsley, 1973). At the same time many workers have discussed the adverse impact of using heavy tickler chain in damaging the bottom fauna as well as the echosystem (Anon, 1971 and Manoharados *et al.*, 1993). The use of heavy chain had been mentioned (Anon,1971).

3.3.3. Importance of vertical mouth opening of trawl

Takayama and Koyama (1959) stressed the importance of vertical opening of the net for catching demersal fishes. Philips (1959) has indicated the effect of increase in headline height on the catching power of the net. He has emphasized the importance of headline height over the horizontal spread by otter boards in catching high swimming fish. Hamuro and Ishii (1959) found that, by increasing the headline height by 1.5m the catch could be increased by 50% in a two-boat trawl. Verghese *et al.* (1968) reported that a high opening bulged belly trawl gave higher catch rate of 31.8% than an identical conventional bottom trawl. George (1978) examined the superiority of a 4 – 4.5 m high opening trawl over that of a Mediterranean trawl of Tunissian design with a vertical opening of only 0.9 – 1.2 m. Lan (1980) had reported that with large mesh in the trawl could get higher net mouth and more catch besides less resistance. Boopendranath *et al.* (1986) had mentioned that a 25 m high opening bottom trawl with sail kite landed 54.4% more catch with 13.2% reduction in by-catch than a trawl without sail kite.

3.4. Factors influencing the mouth opening of the trawl

Factor affecting the successful spreading of the trawl should be controlled properly so as to produce an effective fishing gear (Binns, 1959). Okonski (1972) stated that the type of net construction, the speed of towing, current speed, rigging of ground rope and sea bed condition influence the mouth opening of a trawl net.

3.4.1. Towing speed

Carrothers and Foulkers (1972) studied the effect of towing speed on the net mouth opening and found that, at higher towing speeds the head line height and wing spread were reduced while its drag increased. On the contrary, Perumal *et al.* (1973) reported that both during the model and full-scale experiments, the trawl showed increased horizontal spread and warp tension and reduced vertical opening due to the increase in towing speed. Further increase in towing speed causes the net spread and start flying finally foul net on other hand speed is too slow boards welcome together and entangled (Koyama, 1984).

3.4.2. Gear design

The designs of trawl gear do have influence on the trawl mouth opening. The design of a new large bottom trawl by increasing the headline length was found to be to give greater spread and lift to the trawl mouth (Anon., 1974). Satyanarayana *et al.* (1972) designed a four-seam trawl net and compared its performance with conventional two seam net. The new gear had lesser horizontal spread and more vertical height, but both had almost the same warp tension. It has been suggested that greater spread and higher headline height could be obtained by increasing the number of meshes in the square piece and top wing of the trawl (Anon., 1974). Wray (1990) is of the opinion that Y-type trawl design seems to give better horizontal and vertical spread. Panicker *et al.* (1978) did comparative studies on parallel twin body trawl with bulged belly trawl off Cochin. They found that twin body trawl had 28% higher fishing efficiency and about 9% less resistance due to 26.6% extra wide mouth opening than the other. San and Fuwa (1975), in their model experiment found that the height of the trawl mouth of six-seam trawl was much higher than shrimp trawl under normal towing speed. Okonski (1972) from his long experience reported that different type of fishing and nets need different proportions of horizontal opening in the trawl. Experiments on the modifications in the gear design to achieve greater trawl height have been tried by many scientists (Verghese *et al.*, 1968; Satyanarayana and Narayanappa, 1976; Pajot *et al.*, 1982).

3.4.3. Others

Okonski and Sadowski (1959) studied the effect of length of headline and footrope on the vertical mouth opening of the trawl gear. Fujushi and Taniguchi (1976) tried using bottom curtain to increase the trawl net height. Fuwa (1979) described a method to decide the height of a trawl net mouth directly from the net plan. He also noted the relationship between the height of net mouth corresponding to the length of warp released and the distance between the two trawls. Wan and Hou (1992) changed the wing tip into double shallow tailed construction to give better vertical mouth opening and better trawl geometry under normal towing speed. Kotsyunin and Nikonorov (1971) described a method to measure fishing height of a trawl net. Mouri *et al.* (1976) elaborated on a theoretical equation to measure the central height of net mouth of a four-panel bottom trawl.

Narayanapa and Satyanarayana (1973) studied the optimum buoyancy-weight relationship for bottom trawl. Dickson (1959) suggested for a critical balance of sinkers and floats in order to reduce fish escape below the ground rope without sacrificing headline height.

3.4.4. Other factors influencing trawl performance

Besides the above, so many other factors influence the performance of trawl gear in their own way. A few of such factors have been described below.

3.4.4.1. Warp – depth relationship (scope ratio)

The fishing spread of the gear and the behaviour of otter board depends on the length of warp payout for that depth (Mukundan, 1970). Miyamoto (1959) proposed a formula and Johntson (1950) prepared graph to decide the length of warp to be released. Nair *et al.* (1966) summarized the factors influencing the minimum length of warp paid out for bottom trawling. The authors have studied on the scope ratio based on the net size and water depth for small shrimp trawls. Mukundan (1970) had discussed in detail the effect of different warp scope ratios at the same depth and same warp scope ratio for different depths on horizontal mouth opening. Nair *et al.* (1966), Chandrapal (1975) and Ercoli (1986) studied the effect of scope ratio on gear efficiency.

3.4.4.2. Effect of bridle/sweep line on mouth opening

The importance of bridles and sweeps to improve the performance of trawl system herding fish in the direction of trawl has been reported (Chapman, 1964, Crewe, 1964, Blaxter *et al.*, 1964 and Narayanappa 1968). Scharfe (1959), from his study with Mediterranean type of trawl, observed that the sweep lines, particularly the mud ropes used for herding fish into the net, play an important role in its catching ability though the resistance due to this part of the net is only 8 % of the total gear resistance. Kuriyan (1965) and Gabriel (1978) reported that the method of rigging of a trawl net also influences its functioning. Kuriyan (1965) got more catch when he used single sweep line in between the net and the otter boards than the otter boards were attached directly with the net. Satyanarayana and Mukundan (1963) stated that the angle of attachment of bridles with otter boards influence it's functioning. Use of longer bridles to catch more fish in bottom trawls has been reported by several authors (Deshpande *et al.*, 1972 and Roberts, 1964). It has been that the size distribution of fish caught in a trawl is affected by sweep lines (Anon., 1974). Dickson (1959) said that the gap between spreading wires or sweep lines is a potential place for fish escape. Narayanappa (1972) studied on optimizing the length of single sweep wire for an otter trawl. Rajendran (1982) could adjust the headline height and wing spread of a butterfly trawl by changing the bridle length. Mathai *et al.* (1984) and Rajan *et al.* (1990) undertook studies on optimization of bridle lengths for demersal trawls. Rajan *et al.* (1990) reported that several demersal species excluding crustaceans are known to respond to herding by sweeps and bridles crossing the seabed. Fish also respond to the noise and vibration of the otter board and to the clouds of mud and sand generated by them. The herding effect is maximized when the trail of sand and the cloud is positioned in alignment along the bridles and sweeps (Main and Sangster, 1981). According to Sainsbury (1996) the otter boards are usually separated from the forward end of each wing by a length of wire and the sweep line. Hanumanthappa and Radcliffe (1998) have conducted model testing two bridle and three bridles rigs arrangements in wing trawl and recorded the vertical height and wingspread. Paine and Gruver (1996) have found that the design of trawl bridle rigging and foot rope attachment technique enable the net to fish slightly above the bottom. Hameed and Boopendranath (2000) have reported the rigging of two bridle and three bridles arrangement in bottom trawling based on the bottom conditions where trawl is to be operated. Jayanaik *et al.* (2004) have conducted the bottom trawl with variation in bridle length and found that 19-20 meter bridle length had an optimum mouth opening during bottom trawling. Further, they also reported the highest catch in the above bridles arrangement when compared to other combinations.

3.5. Gear resistance and economy in fishing

The water through which the trawl is dragged offers a great resistance to the forward movement of the gear, which necessitates greater power requirement, more fuel consumption and ultimately greater cost. Therefore, many a study in trawl gear also focused on reducing gear resistance and obtaining the economy in fishing operation. Buckingham (1972) found that a HOBT with large mesh netting not only had reduced water resistance but also had greater mouth area. Naidu *et al.* (1987) studied the effect of variation in mesh size and found that trawls with bigger sized mesh gave better horizontal spread at low resistance and thus saving fuel. Prado (1977) reported that a long narrow net has a lower drag than a broad barrel like net. Two small trawls joined side by side with a shared head rope and foot rope and fished between a single pair of doors resulted in reduced towing resistance for the same catch as obtained by the trawl towed separately (Charles, 1986). Panicker *et al.* (1977) on their comparative study between parallel twin body trawl and bulged belly trawl of identical size, conduced off Cochin, found the former to have better catching efficiency than the latter. The parallel twin body trawl had about 28% higher catch rate with 20% increase in horizontal spread and about 9% reduction in resistance than the bulged belly trawl. Yang (1988) discussed the energy saving measures of bottom otter trawls in consideration to the drag from the net, trawl door, foot rope, warp, lazy line and floats. Hanumanthappa and Radcliffe (1998) have conducted flume tank experiments and recorded the resistance at various towing speed. Nayak (1991) and Manikandan (2005) have reported the resistance of big mesh trawl, considerably lower than that of HOBT.

3.6. Exploratory fishing

According to Baragi and James (1984) who studied the fishery and bionomics of *sciaenids* off South Kanara coast, it is reported that fourteen species of *sciaenids* contribute to the fishery along the coast, of which *Johnius aneus*, *Otolithus* *ruber* and *O. Cuvieri* were abundant. Two survey vessels conducted survey in the area between latitude 14° N and 18° N using demersal trawl up to 300 m depth to study the distribution and abundance of the demersal fishery resources of the Karnataka-Konkan coast and found high concentration of Nemipterids and Priacanthids in this region throughout the year except in July. About 46% of the total landings were contributed by these two species alone. The next dominant species were catfish and ribbonfish, constituting about one fourth of the catch. Other important verities recorded in this region were perches, elasmobranchs, decapterids, cephalopods, carangids and lizardfish. Abundance of Serrainds was observed in the depth up to 100 m in this region (Anon., 1986a). Sivaprakasam (1986) elaborated the results of the intensive survey conducted by the vessel Matsya Shakthi and Matsya Vishwa along the Karnataka coast upto a depth of 500 m. He stated that the catch rates in the three latitudes, 12° N, 13° N and 14° N were comparatively low ranging from 89 to 134 kg/hr The catch composition in various depths ranges indicated that coastal waters up to 70 m were dominated by cat fish followed by *Nemipterus, Decapterus* and *Priacanthus*. However considerable concentration of squids and cuttlefish at 70m to 150 m depth, Priacanthus at 150 m to 200 m depth, centrolophus and deep shrimp at 200 m to 500 m depth range were recorded, while the lizard fish was distributed widely at all depths. Sukumaran *et al.* (1986) recorded the decrease in the catch of *Portunus sanguinolentus* from 102.30 ton to 27.0 ton during 1979-78 to 1981-82 along the Mangalore coast and from 65.9 ton to 44.1 ton during 1980-81 to 1981-82 along the Malpe Coast.

According to the survey conducted to study, the distribution and abundance pattern of demersal fishery resources in the area between 14° N and 18° N, high concentration of bull's eyes was observed in 100-300 m depth range with peak abundance during September. Threadfin breams were more concentrated in the depth range of 100-200 m with higher catch rates during December-May contributing up to 40% of catch during February. During this survey, squids were also reported in significant quantities all along North Karnataka-Konkan coast (Anon., 1987). Studies conducted on Macrobenthos in the Arabian sea, off Manjeshwar up to 50 m depth for a period of one year revealed that molluscs, echiruids, polychaetes, brittle star and starfish were the main components of benthic fauna and also revealed that higher trawl catches were directly correlated to higher standing crop of macro benthos (Nathaniel et al.1988). Syda Rao (1988) had stated that *Loligo duvaucelli* was emerging as one of the important by-catch of trawl landings at Mangalore operated up to 50 m depth. The largest size of male and female of this species were 355mm and 228mm respectively, which were the largest so far caught from the Indian coast.

According to the demersal resource survey conducted along Karnataka and South Maharashtra coasts between latitude 11° N and 18° N, the maximum catch rate of 1153.5kg/hr was registered from the depth between 200-300 m at 11 ° N off Kerala coast followed by lat 12 ° N off South Kanara coast (847.6kg/hr). Thread fin bream dominated the catches in 50-100 m and 100-200 m depth range as well as in the shallow regions of 30-50 m depth followed by catfish and ribbon fish. There was a progressive increase in catch rates obtained in depth range below 50 m from lat. 13° N towards North and highest catch rates was recorded from lat. 17° N. Bulls eye contributed to about 62% of the total catch recorded from above 100 m depth. *Priacanthus* species was observed between September -October in the Northern latitude, highest being at 16° N in zone 0-50 m depth in the month of September but size of which was small being 120-160mm. Squids and cuttle fish formed 8% and 12% of the catch in the depth below 50 M and 50-100 m depth respectively (Anon,, 1990a; 1991 and 1992).

According to the preliminary survey conducted for neretic and oceanic squid resources along the west coast, large quantities of squids captured by jigging were from the shallow areas (Anon., 1992). Demersal resources survey and monitoring along Karnataka -Goa-South Maharashtra coast between latitude 11 N° and 18 N ° Anon., (1994) showed that the highest catch rate was recorded in the deeper section and the important resources being bulls eye, scads, squids and mackerel. Similar results were obtained by the survey conducted for demersal resources and monitoring along Karnataka coast between latitude 10° N and 15° N. Experimental squid jigging along the southwest coast (Anon., 1995) showed that a high yield of squids was recorded during the month of September.

Biological data on the mackerel, based on its heavy landings in trawler at Mangalore have been documented (Prathiba and Kemparaju, 1995). Based on the exploration of juveniles of the spiny cheek grouper, by multi-day trawlers along

Dakshina Kannada coast. Zacharia *et al.* (1995) gave details stating that the size range of 9 to 24 mm were in sizeable quantities during Oct-May at Mangalore and Malpe landing centres. Prathiba Rohit *et al.* (1996) have given information regarding Mackerel fishery during the monsoon period by indigenous gears along the South Kanara coast.

According to the demersal resource survey (Anon., 1997a) along the south west coast between latitude 11° N and 18° N, deeper zones of latitude 15° N and latitude 12° N were found to be more productive. It has also been suggested that the months of July, August and September to be more productive for squid jigging (Anon., 1997a). Zacharia *at al.* (1997) have provided information on the abundance of large size rock cods off Karnataka coast during the post monsoon months of September based on the survey conducted by R.V. Varuna. Premalatha (1997) has provided information on the availability and biological characteristics of *Priacanthus hamrur* based on trawling operations of F.V. Samudrika and F.V. Sagarika of the Integrated Fishery Project, Government of India. Biological characteristics, length -weight relationship and occurrence of *Sepia aculeata* along the Mangalore coast have been studied (Syda Rao, 1997). Sukumaran *et.al.* (1998) has studied the potential new resources of penaeid shrimps off Manglalore coast. A fishery and population characteristic of mackerel landed by trawlers along the Dakshina Kannada coast has been extensively studied by Prathiba Rohith *et al.* (1998). Nandakumar *et al.* (2001) have reported the deep sea shrimp fishery first along the Kerala and Karnataka coast with 505 kg. per boat off Mangalore coast.

Kaikini (1974) studied the regional and seasonal abundance of white fish (*Lactarius*) in the trawling grounds off Bombay -Saurashtra coasts and found that the fish was concentrated in the depth range of 20-45 m. The biology and distribution of *Nemipterus* caught from Bombay waters was reported by Muthiah and Pillai (1979). Sivakumaran (1984) recorded the landing of oil Sardine (*Sardinella longiceps*) along Parangipettai (Porto Novo), South east coast of India. The catch and size composition of Carrangid fishery, the fishing ground, the craft and gears used and its economic importance in Porto Nova were discussed by Venkataramaji (1983). He recorded 29 different species of Carrangid in the inshore waters of Porto Nova. Kurup and Surendranath (1985) observed decline in the catch of *Penaeus indicus* from 29% to 6% against an unusual increase in *Metapenaeus dobsoni* from 52% to 72%. Khan and Zafar (1985) reported that the fishing season for Bombay duck (*Harpodon neherus)* fishery along the Saurashtra coast varied from September to January.

Rajyalakshmi and Reddy (1985) observed the dispersal and recruitment of fry and juveniles of *Chanos chanos* in Kakinada Bay area. Studies conducted by Rao *et al.* (1985) on the commercial trawl fishery off Veraval during 1979-82 showed the demersal fishery resources off Veraval, particularly shrimps were under a strain of over fishing due to the year-to-year increase in shrimp trawlers and the fishery was becoming increasingly uneconomical. Vivekanandan and James (1986) reported that the maturity size of *Nemipterus japonicus* off Madras was 145 mm length and the spawning period ranged from June to March. Observation of the fish landings at Sassoond dock during the year 1971 and 1981 showed that there was a continuous decline in the landings of pelagic fishes from 31.4% to 18.1% (Pillai and Krishna, 1986). Studies were made on the growth, maturity, seasonal abundance and distribution of *Decapterus dayi* along west coast of India by Premalatha (1986a). She observed that larval abundance was more from May to November with a peak in July and September in the Capecomorin region. The fishery of *Alepes kalla* and its distribution in relation to environmental parameters were discussed by Premalatha (1986b). Sivaprakasam (1986b) has documented on the various deep-sea fishery resources of the Indian waters beyond 70 m to 500 m zone. The threadfin bream fishery off Cochin was studied by Nair *et al.* (1986) who observed that their migration during Southwest monsoon from 75-100 m depth to 35-40 m depth coincided with upwelling due to the change in hydrographic conditions. The demersal fishery resource of Wedge Bank up to a depth of 73 m was discussed by Joseph *et al.* (1987). Premalatha (1988) studied on the carrangid fishery (*Megalaspis cardyla*) along the south west coast of India and found out that the contribution of this fish larvae to the total Carrangid landings was about 20 %.

Fishery resources of the Exclusive Economic Zone (E.E.Z.) of North-West cost of India was estimated by Bapat *et al.* (1982). He has estimated the potential yield of standing stock of pelagic and demersal fishes to be 2,47,000 ton in the depth zone of 55-360 m. Silas (1985) studied the cephalopod resources of the E.E.Z. off

Mangalore and found that 70% of *Loligo duvaucelii* landed at Mangalore were from the inshore region. *Lolignid* squid (*Doryteuthis sibogae*) was described for the first time by Silas *et al.* (1985) from Indian seas. He reported the occurrence of this species in commercial quantities along South-West coast of India. The occurrence of oil sardine (*Sardinella longiceps*) along the Orissa coast was confirmed by Ramasomayajula and Dhana Raju (1985). Occurrence of large shoals of *Elagatis bipinpulata* (Carrangidae) at 50-60 m depth off Cape Comorin was reported by Sivaprakasam and Nagarajan (1986). Shivaprakasam (1986b) has studied the fishery resources of Cape Comorin and has given the composition of catch and their depth-wise and month th- wise distribution. The contribution of cephalopods to the country's total marine fish production during 1984-85 was about 24,000 ton (Anon., 1986b). Raje and Savaria (1987) recorded the occurrence of Oceanic Squid (*Symplectoteutis oulaniensis*) at 80 m depth along Saurashtra coast. Further they found that this species carried out diurnal vertical migration from surface at night to deeper layer during day. Sudhakar Rao (1987) made a preliminary study on the shrimps fishery along north east coast of India and estimated the potential yield of shrimps between Pentakota and Sunderbans to be 6559 ton. Exploratory survey of shrimps resources off Kakinada conducted by Sudhakara Rao (1988) indicated that almost all the penaeid species were being harvested at the optimum level. He further indicated that any further increase in fishing effort might lead to over fishing of the stock. Najah and Thamer (1988) in their study conducted during 1975 and 1976 on the demersal fish resources of the northern part of the Arabian Sea, found the highest catch rate to occur in April.

Radhakrishnan *et al.,* (1990) reported the occurrence of Spiny lobster (*Panulirus penicillatus*) for the first time off Madras. A study on the shrimps fishery of the mouth of Gulf of Kutch by Antony and Soni (1990) showed that *Metapenaeus kutchensis* was the most prominent species representing the fishery,in substantial quantities, throughout the season. During the study conducted from 1986-87, Rajamani and Manickaraja (1990) noted that the seasonal prawn fishery along the Periathalai coast, in the Gulf of Mannar was constituted exclusively by *Panaeus indicus* with the maximum catches during the month of July. Sivaprakasam *et al.* (1991) conducted studies on the marine fishery resources off the lower east coast of India. According to his study the depth range of 50-100 m was found to be more productive for demeral resources such as perches, pomfrets, carrangids, ribbon fish, barracuda and mackerel. As per the demersal trawl survey conducted along the Northern east coast of India between latitude 18° N and 21° N, it was found that the depth zone of 50-100 m was dominated by clupenoids, cat fish and leiognathids. According to James *et al.* (1994) stated that perches dominated the catch in Indian waters, the peak fishing season extending between October and April. Kripa *et al.* (1995) working on the cephalopod fishery at Cochin found Kerala to rank first among all the maritime states of India in cephalapod production. Kunjipalu *et al.* (1994) in his study conducted in September 1992 reported on the occurrence of African black mouth Croaker (*Atrobucca marleyi*) off North West coast of India with the catch rates varying between 500 kg/hr to 1000 kg/hr An account of the fishery of green tiger prawn (*Penaeus semisulcatus*) off Tuticorin, during the five year period from 1986 to 1991, was discussed by Rajamani and Manickaraja (1995). They found that 59.6% of this species contributed to the total average annual catch of shrimps estimated to be 251 tonnes. Meiyappan *et al.* (1995) studied the stock assessment of Indian Squid *(Loligo desvauceli)* along Kerala, Maharashtra and Gujarath and found out they account for 80% of the all India squid production (23, 941 ton) during 1989.

The status of non-penaeid shrimps fishery of India off Maharashtra coast was given by Deshmukh (1995) according to him an average annual catch of 57,000 ton of non-penaeid shrimps formed 3.7% of toatal marine fish production in Indian. Sukumaran *et al.*, (1995) in their study during the year 1985-89 estimated the potential stock for *Metapenaeus dobsoni* for the whole country to be 25,000 ton. Crustacean fishery resources of India were studied by Suseelan and Pillai (1995). They reported that during 1995 average production of shrimps obtained from 0-50 m depth zone was 2,25,000 ton. According to the study on the reproductive biology of the sand lobster (*Thenus orientalis*) Kagwade and Kabli (1996) found that the maturity sizes of both males and females were about 107 mm, which spawned between September and April with a peak in November. Further, they also reported that female lobster spawned twice in a year. Penaeid shrimps resources in the Palk Bay off Mandapam was studied during 1986-93 by Maheshwarudu *et al.* (1996) who informed that it contributed 16.70% of the total trawl landings of that area. According to postlarvae of *Chanos chanos* collected in April 1985 by Bensam

(1996), it was found that the spawning grounds of this fish can extend to deeper depths off 1,125 m. Chandra Kumar (1996), in the study on the sardine fishery resources along Srikakulam coast, reported that the peak landings occurred in the month of February with 200-205 mm size group fishes predominating the fishery. Four species of full beak (Belonids) and two species of half beaks (Hemiramphids) contributed to good fishery in Gulf of Mannar (Kasim et al. 1996). Fernandez *et al.*, (1996a) with the help of the prediction model estimated the total catch of *Coilia dussumieri* as 22,540 ton in the year 2000 provided the efforts remained constant. The Bombay duck fishery along the northwest coast of India was studied by Fernandez *et al.* (1996b) for the period 1947 to 1986. They made use of prediction model to describe the state of the stock. Details on the status of trawl fishery from 1990 to 1994 and catches has been given by Joel *et al.* (1996). In the basis of observation on the oil sardine landings along the Tuticorin coast during 1996 Arumugam (1997) found that fishes with a size range of 120-185mm dominated the catch. Annam (1997) studied the status of Sciaenid fishery along Orissa coast during 1983-95 and noted an increase in the catch from 1983 to 1993 and the fishing season was between October to March. Observations on the landings of Ribbon fishes at Vishakapatnam during October 1997 was done by Satya Rao *et al.* (1998). They found that fishes with a size range of 540-560 mm dominated the catch. Exploratory analysis on the predictability of oil sardine landings in Kerala was given by Srinath (2004). Yohannan and Abdurahiman (1988) found that the upwelling phenomenon along the Malabar Coast that normally occurs during March to October period produced plankton bloom, which helped in increasing the reproductive output of mackerel. Further, he found that mackerel preferred a temperature of 27° C and hence they remain immediately above the thermo cline. Scariah *et al. (1999)* revealed that there was a tangible change in the composition of the total marine fish landings in Maharashtra. This was attributed to the gradual decline in the dolnet fishing and increase in case of trawl fishing. There was decrease of production of elasmobranchs, crustaceans along north west coast., perches and croakers along south west coast., silver belly along south east coast and cat fish along north east coast (Anon., 2000). However, north west cost contributed to 40% of country's marine fish production followed by south west coast (32%), south east (22%) and north east coast (6%). Highest catch rate of 75.16 kg. was recorded from the 50-100 m depth zone of at 16° N, followed by 47.90 kg/hr from 30-50 m depth zone of latitude 15° N , 38.92 kg/hr from 50-100 m depth zone of latitude 17° N and 34.43 kg/hr from 50-100 m depth zone of latitude 15° N. (Anon., 2005). The survey vessels of Fishery Survey of India surveyed along the south south Maharastra, Goa, Karnataka and north Kerala between 11° N to 18° N from 20-200 m depth zone and resources found to be more in lat. 15 ° followed by lat. 17° N lat. 12° N and 13° N (Anon., 2006).

3.7. Selectivity of trawl

3.7.1. Size selectivity

Selectivity can be considered as the factors that causes the size composition of the catch to be different from that of the population or that causes fishing mortality to vary with size of the fish (Pope *et. al.* 1975). The size and shape of codend meshes are main factors, which determine its selectivity (Pope, 1966). Mesh size and gear operation pattern are the factors, which affect size selectivity (Karlsen, 1985). Reeves *et. al.* (1992) and Galbraith *et al.* (1994) noticed that the mesh size and codend diameter have a greater influence on selectivity. The chief area of size selection of *P. borealis* was the codend; negligible loss of fish occurred through wing and belly (Nilssen and Larsen, 1986a).

As early fishing experiment (1910) was to study the relative escapement of fish from codends (Todd 1911). The use of large mesh sizes to reduce juvenile catch was recommended by the International Council for the Exploration of the sea (ICES) for the fisheries of Northern Europe (Great Britain Parliament, 1933). FAO recommended that to catch fish of certain size, the selection of mesh size should be such that it retains half of the fish of critical size (FAO, 1968). Panicker and Sivan (1965) suggested an increase in codend mesh size to capture larger shrimps and to reduce depletion of bottom fauna. Alagaraja *et. al.* (1986) noticed the instance of heavy landings of undersized shrimps along the coast of Kerala due to the use of small meshed trawls.

International Council for Exploration of Sea (ICES) has recommended an increase in the mesh size from 105 mm to 120 mm for the cod (*Gadus morhua*) fishery in the Baltic Sea (Lowry *et. al.* 1994). The larger mesh size (40 mm) in codend of dol net (Bag net) has an adverse effect on the catch of secondary species like non-penaeid shrimps and total catch (Kunjipalu *et at.* 1993). George *et al.* (1974) suggested suitable mesh size for the codend of the stake nets. Valdemarssen (1988) showed that size selectivity of shrimp (*Sandalus borealis*) has little effects due to increased mesh sizes in codend. Armstrong *et al.* (1998) have observed the few small fishes retained in the large mesh sized codend. Lehman *et al.* (1993) reported significant reduction of small shrimp in 60 mm mesh codend than codend with mesh size of 45 mm. Kunjipalu *et al.* (1993) found that the Bombay duck catch was consistently better in experimental bagnet with 30 mm and 40 mm codend meshes.

Swan (1989) stated that, the very large meshes (up to 25.6m) in trawls are seen to be effective in herring fish and very large catches may be taken when fishes are light in weight, *i.e.,* buoyant with high oil content. Lhomme (1978) compared the results of shrimps catches of trawls of different mesh sizes in the body of the net and found that average size of shrimp caught in 80 mm size was greater than 60 mm size.

The larger size shrimp would be caught only if a much larger mesh size was adopted and the immediate effects would be loss, which could not be economically endured (Lindner, 1966). After an under- water observation of haddock trawling, Serebrove (1989) concluded that increasing mesh size cannot be an effective method of protecting young fish, since the hydrodynamic conditions of catch formation traumatize a considerable part of the fish of any size. Fujishi (1974) discussed the difficulties in developing a criterion for mesh size of gears engaged in multi species fishery. Hoidal *et al.* (1982) presented a model using "Von Bertalanffy and Beverlon and Holt equation" to estimate effective mesh sizes and suggested that this model can be used to estimate the stock.

Fridman (1986) defined the selection factor as the ratio of fish length to mesh lumen length at which 50% of the fish escape and 50% do not. Goni (1985) found out that, increase in mesh size has increased the selection factor in selectivity experiments for European hake and rose shrimp. The selection factors of 0.85 and 0.84 were estimated for the two species of sepiidae (Pereira, 1993). The selection factor for the 34 mm mesh codend for species of Cypris was in the range of 2.80 to 3.75 (Livadas, 1989).

Walsh *et al.* (1989) found that, selection factors were higher for American plaice (*Hippoglossoides platessoides*) in diamond meshed codend. The 50% retention lengths for *Penaeus semisulcatus* were 1.96 and 2.27 cm for 30mm and 40 mm codend of high opening bottom trawl respectively (Siddeek, 1986). Underwater observation conducted by Stewart and Robertson (1985a) showed that covered codend causes obstruction for fish escape. Vooren (1985) compared the selection factors and escapement with respect to different mesh sizes for three different species namely castanha (*Umbrina canosai*), Pescada (*Cynoscion strialus*) and Pescadinha (*Macroden anaylodon*) by means of regression analysis.

Polet and Redant (1994) noticed that the 90 mm mesh size codend is less selective for nephrops and whitings. Hickey *et al.* (1993a) found that 155 mm diamond mesh codend produces better selection for Atlantic cod (*Gadus morhua*). The simple way to improve size selectivity in existing trawl is to shorten the lace rope in the codend that catches fewer small fishes (Jacobson 1991). A codend of 135 mm meshes with lastrich ropes has selectivity comparable to a 150 mm conventional codend (Isaksen and Valdemarson, 1990). Armstrong *et al.* (1989) noticed that the length of the extension piece and codend diameter also influence codend selectivity. Matsushita Yoshiki *et al.* (1996) have suggested that the over -lapped meshes decrease the mesh area, resulting in the low efficiency of mesh selection. Campos *et al.* (2003) have reported that the effect of an increased results in codend 20 – 50% escapement through the mesh.

3.7.1.1. Influence of square mesh on size selectivity

Mesh shape also influences the gear design parameters in the same way as mesh sizes. Several scientists have worked on trawls with different mesh shapes and studied their influence on selectivity. Fish size selectivity is related not only to the mesh size of codend but also to the shape of the mesh as determined by rigging of the codend webbing (Robertson, 1982; Robertson and Stewart, 1988; Casey and Warnes, 1987). As the codend gets progressely filled up, the drag of the catch close up the diamond shaped meshes preventing under sized fish from wriggling through and jumping them in the mass of the catch. Further, it is found that even if small fish do escape, a large proportion are likely to die because of damage while passing through a mesh where as damage is minimum in square mesh codend. Further, square mesh panels in the top of the trawl in the extension ahead of the codend do not close together when under load and have been found effective in allowing many under sized fish to swim, through them and escape (Sainsbury, 1996). Robertson (1983) compared fish escape rates of square mesh and diamond mesh codends and concluded that square mesh codends had higher escape rates of juveniles because of larger mesh opening and caused less damage to fish. Isaksen and Larsen (1988) found that square mesh codends gave improved selectivity for cod and haddock and considerable reduction of undersized fish.

Cooper and Hickey (1987) observed the reduction of haddock and cod by about 25% in square meshed codend while comparing with that of diamond meshed codend and observed higher value of 50% retention length (L_{50}) of the fish. Averill and Carr (1987) indicated that square mesh sections in trawl, not only improves the catch rates but also reduce the discard rates. Larsen *et al.* (1988) compared the proportion of undersized cod caught by 95mm square meshed codend with that of diamond-meshed codend. Diamond mesh seems to catch 48% more of undersized fish in terms of number and 10.4% by weight. Robertson (1986a) discussed the design and construction of square meshed codends. Robertson (1986b) in another experiment concluded the selection ranges of square meshed codend. Robertson and Stewart (1988) found that L_{50} values for square mesh codends were larger than for diamond mesh codend of same mesh size for, whitings. Thorsteinsson (1989) noticed a drastic reduction of 0 group of fish and catch of undersized shrimps in square meshed netting. Suuronen (1990) compared the size selectivity of 36 mm square meshed codend with that of diamond meshed codend of same mesh size and concluded that square mesh codend will have a sharper selectivity and will retain fewer juveniles of herring (*Clupia harengus*).

Square mesh netting provides an adequate escape route for all undersized fishes before they are trapped in the codend (Sterling, 1991). Whitings have better escapement from the net with the square panel than from the conventional diamond net (Briggs, 1991 and Moth-Poulsen, 1994). The conventional codend retained all sizes of fish and 135 mm and 110 mm knotless square meshed codends had a tendency to free small fish of walleys Pollack *Theragra chalcogramma* (Matsushita *et al.* 1993). The mean selection lengths with respect to *Sarida tumbil* and

Dussumieria acuta were greater in 30 mm square meshed codend than in diamond-meshed codend (Kunjipalu et al., 1994). Amos (1984a) suggested that square mesh in throat would be useful in allowing small and unwanted fish to escape from the trawl. Hillis *et al.* (1991) inserted square mesh panels on the front part of the codend and observed a substantial reduction in both undersized and commercial sized whitings. Briggs (1992) observed in the Irish sea nephrops fishery that, the square meshed codend in nephrops trawl yielded very good escapement of whitings than the conventional diamond net and thus could be used as conservation tool in whiting fishery. Ulmestrand and Lareson (1991) tested with 70 mm square mesh window in the top panel of a Nephrops Trawl and noticed a significance difference in the size of whiting (*Micromesistuis poutassov*). Robertson and Shanks (1994) observed a significant increase in the escape of juveniles of haddock and whiting in nephrops trawls with 80 mm square mesh window on top panel and 70 mm square meshed codend and extension. Kunjipalu and Varghese (1989) have suggested that square meshed codend in demersal trawls could be used as a tool for conservation and management of fishery resources.

Wray (1990b) concluded that, hexagonal meshes have better let- through characteristics of undersized fish than diamond meshes in the body of trawl. Suuronen *et. al.* (1991a) observed that the 50% retention length for the hexagonal mesh codend was considerably smaller for herring. Hameed and Boopendranath (2000) have reported that size selectivity in gear using netting for retention of the catch can be achieved by controlling mesh sizes and mesh shapes (square) optimized the target species or size group. Talwar and Hanumanthappa (2006) have shown that 50% of retention lengths of mackerel, pompfrets, soles and ribbon fishes were comparatively found better in HOBT with 28mm mesh size square meshed codend. They also reported that the average by-catch was about 5.5 times lesser in square meshed in the forward part of the trawl net than in the conventional trawl net.

3.7.2. Species selectivity:

Species selectivity in mobile gears such as trawl is achieved using separator panels or grid by making use of behaivioral difference in species in the fishing area (Hameed and Boopendranath, 2000). Further they also stated that separation of species such as shrimps and fish is possible to some extent by reducing the length of the trawl, adjusting the head rope height and controlling the towing speed, making use of principles of differences in the swimming speed and vertical distribution. Isaken *et al.* (1992) said that a new concept of separator panel, and grid installation was developed in Norway in order to have species selectivity by avoiding the by-catch of fish in a shrimp trawl. Design of trawl with separator panel terminating into two codends for dual purpose of fish conservation and effective separation of catch was discussed by Wray (1990a). He also reported that effective separation of fishes could be attained based on their behaviour, while the fish conservation could be effected by using large mesh in one of the codends or through escape catches. Main and Sangster (1982) noticed the separation of finfish from shellfish in trawl having a horizontal separator panel. William (1983) found that a successful separation of shrimpsprawns from red fish in Canadian separator trawl was possible by allowing the juveniles of red fish to escape. Chuck and Seidel (1984) found that the fish deflector has the ability to reduce the by- catch of jellyfish and finfish.

It has been reported that an effective separation of shrimps and whitings by using horizontal separating panel in trawl can be effective. Main and Sangster (1985) rigged the conventional fish or shrimp trawl with a horizontal separating panel dividing the codend into two compartments and were able to minimize the undersized Gadoid by-catch. Main and Sangster (1986) made underwater observations and indicated that the entry height of fishes into the trawl mouth differs from species to species and it is possible to have species separation by adjusting the height of separator panel. They also concluded that the smaller fishes could be released by keeping top codend open or providing it with large mesh. Friis and Yngvessen (1987) reported on the design and operation of a separation trawl used in Denmark. Hillis and Carrol (1988) and Hillis (1989) investigated vertical separation of whitings and Nephrops by two separator trawls, and found nephrops in a lower codend. Ashok and Sheshappa (1989) in their study on separator trawl experiment have observed total separation of crustaceans into the lower codend of trawl.

Moth-Poulsen (1994) has developed a trawl with separator panel with two compartments and found that upper compartment had gainful whitings. Among the horizontal separator panels, the square mesh panel and grid in trawls, the horizontal separation panel had less separation effect (Wileman and Main1994). Sujastani

(1984) reported that "By-catch Excluder Device" in shrimp trawls reduced the catch of unwanted fishes and can be helpful for conservation of fishery resources. Monintja and Sudjastani (1985) revealed that the implementation of BED on the standard commercial trawl shrimps had a by-catch reduction of 42.5%. Finfish (excluder) device installed in the codend of a shrimp trawl is reported to be very efficient in decreasing the by-catch of finfish (Anon, 1990). Olsen (1990) opined that the 'shrimp grid' developed at Norway is very effective in reducing by-catch. Valdemarsen (1990) could reduce juvenile by-catch of haddock in shrimp trawl by providing the codend with grid made of parallel bars. Wray (1990c) illustrated about the successful operation of Norwegian grid device "Troll X" which could release juveniles and undersized fish from trawl. Hickey *et al.* (1993a) have developed a shrimp trawl rigged with excluder device with different Nardmore Grates having 22 mm, 25 mm and 28 mm bar spacing and 43 mm square meshed codend and by-catch reduction of 60-90% depending on species. Marlen *et al.* (1994) made observation of large pelagic trawls through 'RCTV', and found that codend cover can have significant effect on the escapement behaviour of fish. Rulifson *et al.* (1992) showed the effectiveness of by-catch reduction devices (BRDS) in South Atlantic Coastal waters when compared to the unmodified nets. Matsuoka *et al.* (1991) carried out a series of experimental shrimps trawling tests with a simple Trawl Efficiency Devices (TED) and observed slight reduction in the catch of shrimps. Brewer *et al.* (1995) tested a trawl with by-catch reduction device called "Fish-Eye" and a square mesh window and observed higher shrimps yield with a reduced by-catch.

3.7.3. Catching efficiency

Catching efficiency of the gear is influenced by its design, mesh size, and mesh shape and other operational techniques. However, mesh size and mesh shape can be chosen so as to bring about a compromise between the conservation measures and catching efficiency.

3.7.3.1. Influence of mesh size and mesh shape

Large meshes in gear have a good guiding effect, but when fishing close to bottom, big meshes do not appear to have the same guiding effect (Anon., 1980). Lan (1989) reported from his experiment conducted in east China that, large meshed trawl had a higher mouth opening and higher catch than the conventional trawl.

Pinhorn (1970) has opined that, even though there will be immediate losses in the use of large mesh size, it will lead to potential benefit in the subsequent years. Lower average catch was obtained in large mesh size during a comparative experiment (Claesson, 1986). Nilssen and Larsen (1986b) compared catching efficiency of 20 mm codend mesh with and without fine meshed cover for lobster fishing. The net with fine meshed cover retained about 27 times more catch of lobster than the other one. Naidu *et al.* (1987) have reported the effect of the variation in the mesh size on the catching efficiency of trawl. Chen *et al.* (1987) compared the percentage retention of shrimps in different mesh sized codends by covered codend experiment. Fujishi (1985) also reported increased catch rate from a six-panel high opening bottom trawl with large meshes in the frontal body.

Larger meshes in the front part influence fishing efficiency, species selection and length of fish (Ji 1986). Chow *et al.*(1988) worked on optimizing mesh size for harvesting dominant species of demersal fish in the Taiwan strait. Andrew and Butter worth (1988) examined the effect of changes in mesh size of trawl on catchability co-efficient and sustainable yield of Southern African hake stock. Kondratyuk *et al.*(1988) have studied on the optimal mesh size of the trawl codend for direct beaked red fishery. Kunjipalu *et al.* (1989) have discussed the suitability of large mesh trawl for efficient harvesting of .demersal fish resources in North West coast of India. Siddeek (1989) has stated that, the new fish-cum-shrimp trawl with large mesh size performed better by bringing a slightly larger amount of shrimp and a greater quantity of fish. Vijayan *et al.*(1990) observed 31.5% higher catch of shrimp and 37% more revenue using the improved gear in traditional motorized craft. Suuronen *et al.*(1991) observed that, in pelagic herring trawling, large numbers of juvenile herring were caught with 32 mm diamond meshed codend. Nayak (1991) investigated the effect of large meshes in the body of the newly developed four seam bottom trawl (NLMT) and found that, the average catch was about 37% higher in NLMT than that of HOBT. Vijayan *et al.*(1992) have got 29.6% increased fish catch in rectangular trawl with larger meshes in forward parts. Talwar (1997) reported that trawl gear with square mesh panels in the front and codend parts of the trawl gear had higher percentage of the commercially valuable fishes than conventional trawl. HOBT with square meshed codend invariably caught less number of under sized fish when compared to the diamond-meshed codend

(Badami, 2005). Lehmann *et al.* (1993) compared the catch results in 60 mm and 45 mm mesh sized codends and found that, 60 mm size codend yielded 40-50% reduction of small shrimp and 15-30 % reduction of large shrimps. Lowery *et al.* (1994) found that, the catch of cod was reduced by approximately 40% in 120 mm mesh sized codend and total catch value was reduced by approximately 35%, when compared to the reference net having 105 mm in the codend.

Moth-Poulsen (1994) in his study on the selectivity of whiting trawl observed the whiting gaining access to upper codend while the cod in the bottom codend. An average separation of 50% of the whiting in the top codend was accompanied by only 19% of the haddock and the catch of number of unmarketable fish as a means of decreasing by-catch was reduced from 53.4% to 16.7% without reducing the catch of the main target species and small shrimps in Seto Sea of Japan (Tokai *et al.* 1994). Fonteyne and Rabet (1992) suggested that, application of square mesh might reduce the catch of small round fish. Broadhurst and Kennely (1996) reported while comparing the catch of the gear with conventional codend that, the catch of the trawl with codend made entirely of square meshes has shown a 52% reduction in the mean weight of shrimps prawns caught and 95% reduction in the number.

CHAPTER IV

MATERIALS AND METHODS

In simple terms, bottom trawl net is a large conical bag. Usually it is towed along the seabed or near the bottom. Its operating characteristics can be altered depending on the manner of its shaping and rigging. Such alterations in particular; to achieve relatively high vertical opening, enhance its catching efficiency of various bottom-dwelling and off- bottom species of fish and shrimp. As mentioned earlier, the present study aimed to evaluate the High Opening Bottom Trawl (HOBT) as it is the most widely used trawl net along Karnataka coast. Compared to that of traditional bottom trawls, HOBT's higher vertical opening offers better catching efficiency in demersal waters.

4.1 Sampling area and schedule

4.1.1. Exploratory trawl fishing

Samples were collected on a fortnightly basis during the fishing season commencing from September 2003 – May 2004. Sampling was carried out in the off shore waters at different depths (from 30m to 90M isobaths) and locations between 12° – 14° N latitude and 73° - 74° E longitude along Karnataka coast (Table 5 and Fig. 1). Details of different locations are provided in Table 5.

4.1.2. Selectivity studies in trawl fishing gear

In order to compare the efficiency of High Opening Bottom Trawl (HOBT) with square mesh and diamond mesh codends, experimental fishing was carried out at various depths off Mangalore. HOBT with (a) square and (b) diamond mesh cod-end were used for comparing the efficiency of mesh-shape and size. Specifications of this net are furnished in Table 10 & 11. Samples were collected regularly every fortnight from September 2004 to May 2005. The sampling was carried out in shore waters of Karnataka at different depths and locations provided in Fig. 2.

Table: 5. Details regarding the exploratory fishing grounds during the period of study from 2003-2004

Sl. No.	Month	Trip. No.	Location of fishing ground from where fishing started	Depth in Meters
1	September 2003	1	Lat. 13° 15' 02" and Long. 74° 10' 00"	51
		2	Lat. 13° 25' 25" and Long. 74° 22' 00"	55
2	October	3	Lat.13° 30' 25" and Long. 74° 08' 75"	48
		4	Lat.13° 38' 00" and Long. 74° 11' 70"	86
3	November	5	Lat.14° 01' 72" and Long. 73° 39' 81"	85
		6	Lat.13° 57' 66" and Long. 73° 38' 57"	38
4	December	7	Lat.12° 47' 34" and Long. 74° 39' 85"	31
		8	Lat.13° 07' 28" and Long. 74° 36' 85"	40
5	January 2004	9	Lat.13° 11' 47" and Long. 74° 39' 72"	38
		10	Lat.12° 36' 80" and Long. 74° 39' 72"	45
6	February	11	Lat.13° 16' 30" and Long. 74° 29' 22"	47
		12	Lat.13° 05' 98" and Long. 74° 34' 46"	45
7	March	13	Lat. 13° 56' 05" Long. 74° 15' 50"	45
		14	Lat.14° 05' 60" and Long. 74° 12' 10"	40
8	April	15	Lat.13° 24' 25" and Long. 74° 20' 45"	43
		16	Lat.14° 06' 02" and Long. 74° 11' 50"	51
9	May	17	Lat.13° 02' 00" and Long. 74° 32' 17"	38
		18	Lat.13° 15' 50" and Long. 74° 30' 30"	40

Fig: 1. Exploratory Trawl fishing ground

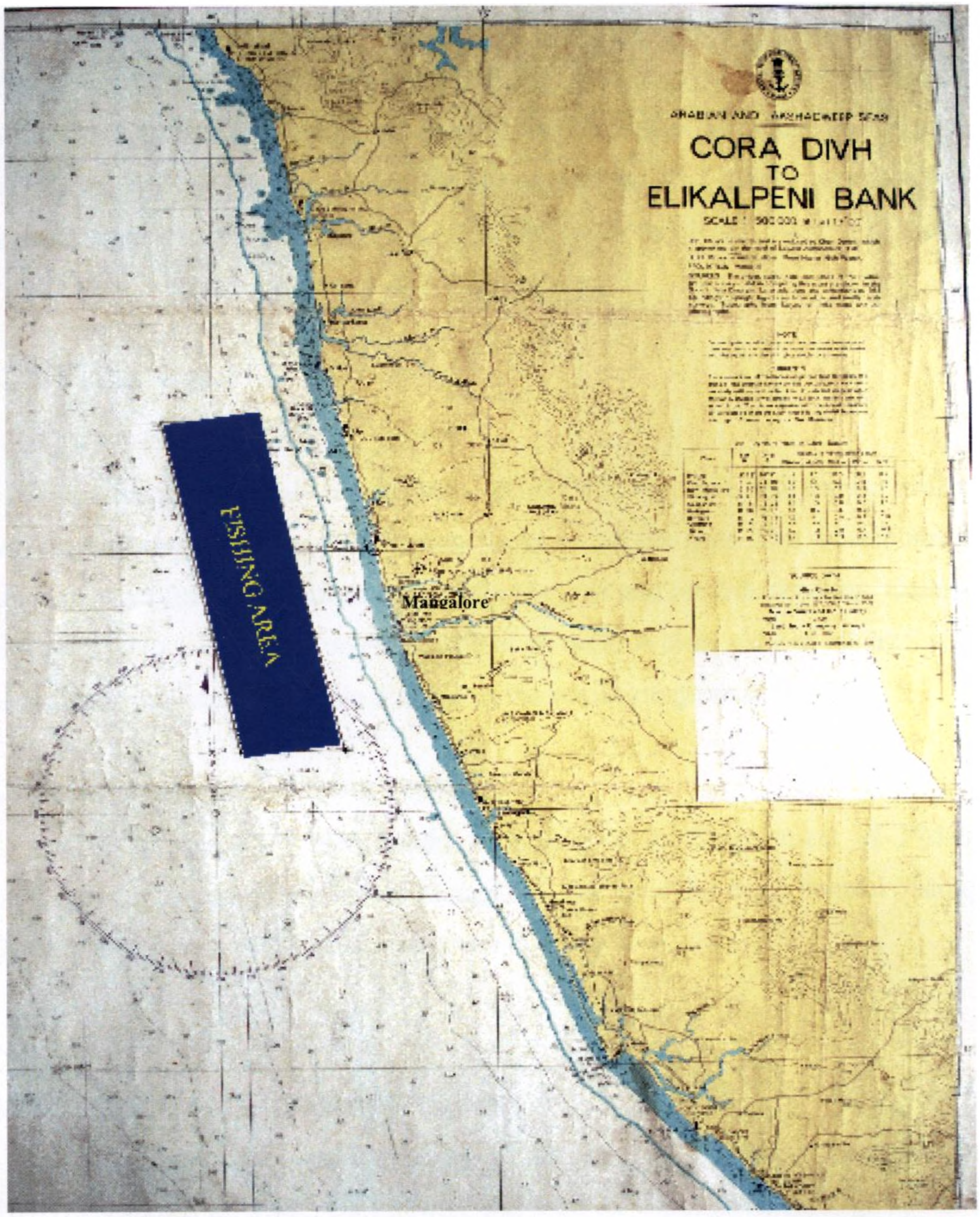


Fig: 2. Selectivity trawl fishing ground

In order to compare the efficiency of High Opening Bottom Trawl (HOBT) with square mesh and diamond mesh codends, experimental fishing was carried out at various depths off Mangalore. HOBT with (a) square and (b) diamond mesh cod-end were used for comparing the efficiency of mesh-shape and size. Specifications of this net are furnished in Table 10 & 11. Samples were collected regularly every fortnight from September 2004 to May 2005. The sampling was carried out in shore waters of Karnataka at different depths and locations provided in Fig. 2. The trawling operations were carried out during daytime. The fishing ground within the depth range of 20 to 50 meters in Lat. 12° 35′ 7′′ N to 74° 40′ 50′′E was chosen as it has been exploited by other commercial trawlers

4.2. Fishing vessel

4.2.1. Commercial fishing vessel

For the present study trawler MFV SHRUTHI was used. The trawler utilizes maximum towing power and has arrangements to set the gear. The wheelhouse is placed forward leaving the aft deck clear for the gear and for fish handling. Gallows with towing blocks are fixed on either side of aft deck. A clear view of aft deck from the bridge is provided. The main features of the vessel are given in the Table 5.

4.2.2. Experimental fishing vessel:

The trawler RTV Nethravathi belonging to the Department of Fishery Engineering, College of Fisheries, Mangalore was used for experimental fishing. The technical details of the vessel are given in Table 7.

4.3. Trawl fishing gear

4.3.1. Exploratory trawl fishing gear

A two-seam fish-cum-shrimp trawl net, the High Opening bottom Trawl (HOBT) designed for a 48.5-foot trawler was used for commercial fishing. The trawl net was fabricated using polyethylene twine as per the local practice with 45 mm mesh size in the forward part and 18 mm in the codend part. The length of the head-rope and foot-rope was 29.80 and 41.60 meters respectively. Spherical plastic floats were provided on the head rope and sinker chain was attached along the footrope. The sweep line of 11.00 meters was provided between wings and the flat rectangular otter boards of 80 kg each. The specification drawing of the net is given in Table 8 and Fig. 3.

Table: 6 Details of mechanized trawler on which exploratory fishing was carried out in the this study

Type of vessel	Mechanised stern trawler
Name of the vessel	MFV Shruthi
Year of construction	1996
Hull material	Wood
Length overall (LOA)	48′ 5″
Beam	16′.0″
Depth	7′ 3″
Draught	5′ 2″
Engine	Ashok Leyland water cooled marine Diesel engine
Make	ALMU 400, Sl.no. 033759
Power	98 Bhp
Revolutions	2000 rpm
Cruising speed	7.0 knots
Propeller	Bronze three blades type

Table: 7 Details of mechanized trawler on which experimental fishing was carried out in the study

Type of vessel	Mechanized stern trawler
Name of the vessel	RTV Nethravathi
Year of construction	2002
Hull material	Wood
Length overall (LOA)	51′ 06″
Beam	16′ 06″
Depth	08′ 09″
Draught	05 ′09″
Engine	Ashok Leyland water cooled marine Diesel engine
Make	ALMU 400
Power	98 Bhp
Revolutions	2000 rpm
Cruising speed	7.0 knots
Propeller and diameter	Bronze three blades type 1.13 m
Fuel tank capacity	2000 liters
Fuel consumption	10 liters per hour
Fresh water tank capacity	1000 liters

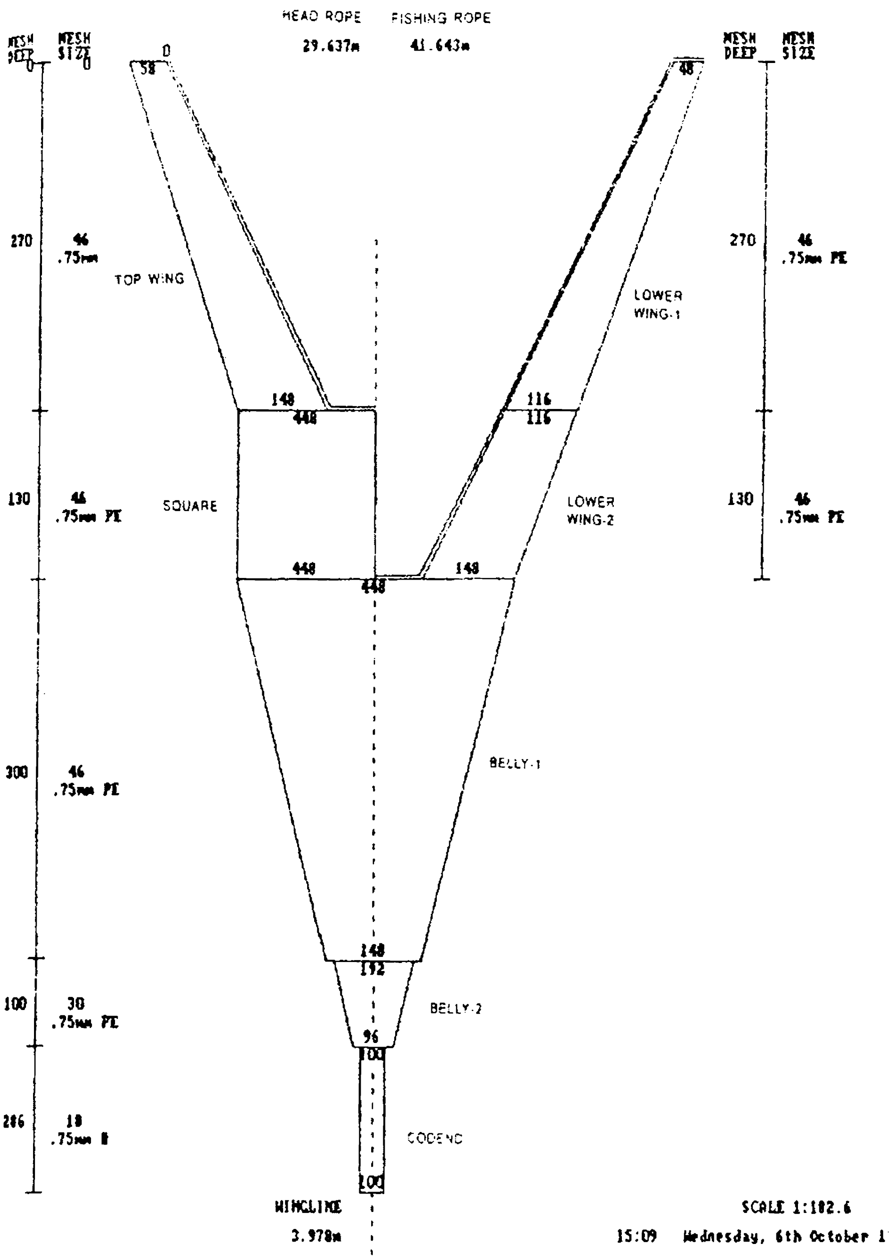


Fig: 3. Exploratory trawl fishing gear.

4.3.2. Experimental trawl fishing gear

The HOBT is a two seam fish-cum-shrimps trawl developed for 50 footer vessels based on the design suggested by the Bay of Bengal Programme (BOBP). The HOBT is an overhang trawl net having the footrope length of 37.77 m longer than the head rope length of 27.28 m. One set of trawl had diamond shaped mesh in codend and the other as square shaped mesh of 20, 30 and 40 mm size. Nets were fabricated with 1 mm diameter polyethylene (PE) twine. During operation, the nylon webbing of 10 mm mesh size was used to cover both the cod-ends, as suggested by Gulland (1969). All sets of trawls were used for the fishing experiments in sequential rotation. The constructional details and specifications are presented in Table 9 and fig.4.

4.4. Design of HOBT

The size of the trawl gear is expressed in terms of head rope length or footrope length or number of mesh in circumference of the gear. The design of a trawl gear is a process of preparing technical specification and drawing for a trawl to satisfy gear handling, operation, and economic and legal requirements. By and large, the design of trawl gear is based on the engine horsepower of the fishing vessel. Based on the horsepower of the engine, the head rope length of a trawl can be calculated by using a formula

$$H.R. = \sqrt{43.6P + 660} \times 0.3048 \text{ meters}$$

Where, HR = Head rope length and P = BHP of the engine.

Based on the head rope length, the size of the belly part is calculated. As the belly forms the largest section of a trawl webbing, the length of the upper edge of this section is taken as the unit length for considering the proportionate sizes of other sections such as wings, throat and cod-end, which is calculated as suggested by Koyama (1984). All the design details of the HOBT were worked out to carry out the study. The details of the gears are given in the Tables 8 & 9, Fig. 3 & 4.

Table: 8 Drawing specifications of exploratory trawl fishing gear

Parts	No. of meshes		Mesh size (mm)	Stretched length in meters	Length as per drawing specification (M)	Length as per scale (M)
Upper wing	M	58	46	2.60	1.33	1.33
	N	148	46	6.80	3.40	3.40
	H	270	46	12.42	12.42	6.21
Lower wing	M	48	46	2.98	1.49	1.40
	N	148	46	6.80	3.40	3.40
	H	400	46	18.40	18.40	9.20
Square	M	448	46	20.60	10.30	10.30
	N	448	46	20.60	10.30	10.30
	H	130	46	5.98	5.98	2.99
Belly	M	448	46	20.60	10.30	10.30
	N	148	46	6.80	3.40	3.40
	H	300	46	13.80	13.80	6.90
Throat	M	192	30	5.76	2.88	2.88
	N	96	30	2.88	1.44	1.44
	H	100	30	3.00	3.00	1.50
Codend	M	100	18	1.80	0.90	0.90
	N	100	18	1.80	0.90	0.90
	H	286	18	5.15	5.15	2.58

Table: 9 Constructional details of exploratory High Opening Bottom Trawl (HOBT)

Section	No. of mesh at top	No. of mesh at bottom	No. of meshes at depth	Mesh size (mm)	Twine diameter (mm)	Cutting rate	Details of lines and ropes		
								Head rope	Footrope
Upper wing	58	148	270	46	1.0	1N4Bx90	Length	29.64 M	41.64 M
Lower wing	48	148	300	46	1.0	1N4Bx100	Diameter	12mm	12mm
Square	448	448	130	45	1.0	All N	Material	PP	PP
Belly	448	148	300	40	1.0	1N2Bx150	Hanging coefficient	1.0	1.0
Throat	192	96	100	30	1.0	1N 1B x 8 1N 2Bx44	Hanging coefficient at bossom	0.30	0.30
Diamond codend	100	100	286	18	1.0	All N			

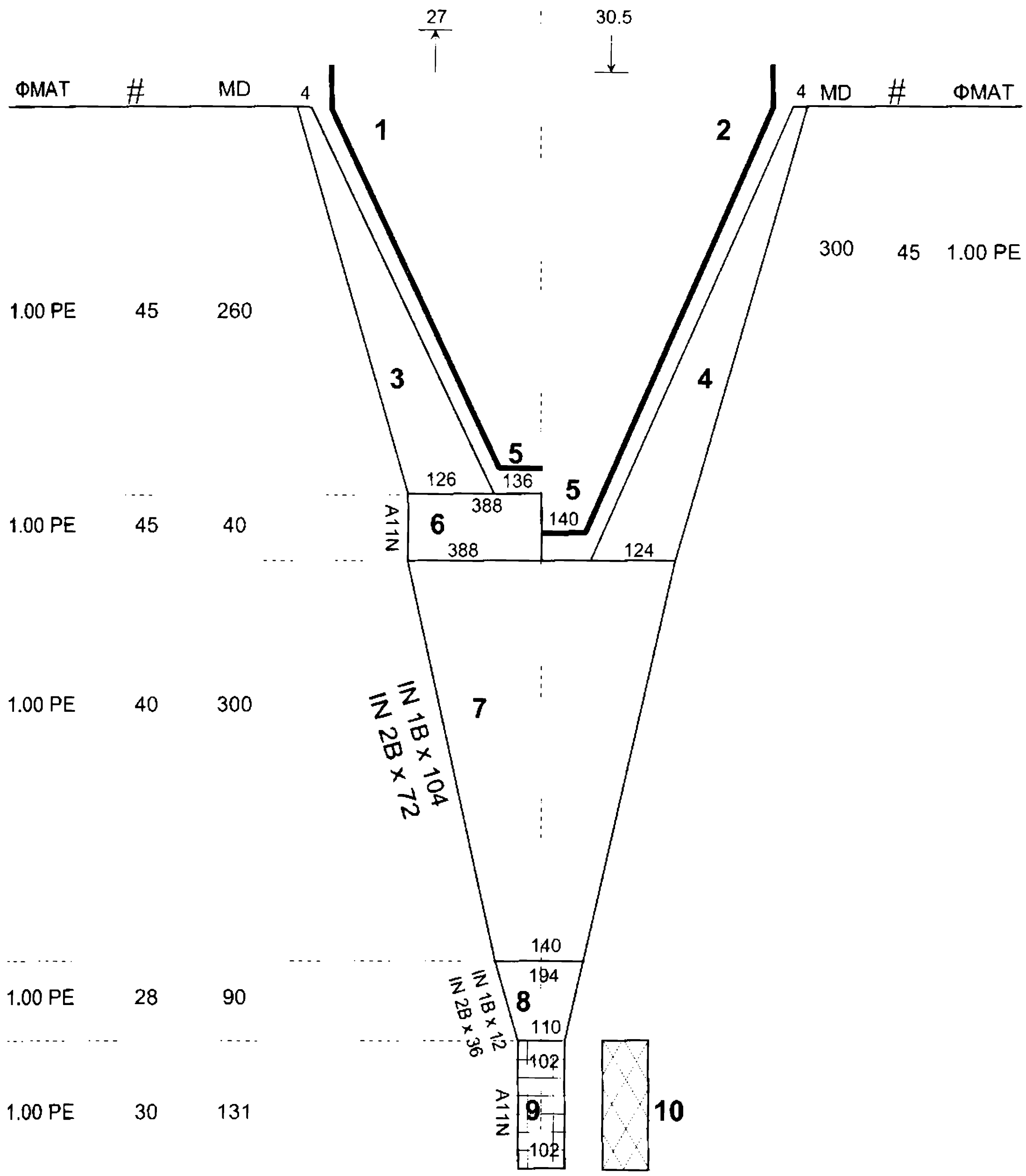


Fig: 4. Experimental trawl gear (HOBT).

Table: 10 Drawing specifications of experimental High Opening Bottom Trawl (HOBT)

Parts	No. of meshes		Mesh size (mm)	Stretched length in meters	Length as per drawing specification (M)	Length as per scale (M)
Upper wing	M	4	45	00.18	00.09	00.05
	N	126	45	05.67	02.83	01.42
	H	260	45	11.70	11.70	05.85
Lower wing	M	4	45	00.18	00.09	00.05
	N	124	45	00.58	02.75	01.38
	H	300	45	13.50	13.50	06.75
Square	M	388	45	17.46	08.73	04.36
	N	388	45	17.46	08.73	04.36
	H	40	45	01.80	01.80	00.90
Belly	M	388	40	15.52	07.76	03.88
	N	140	40	05.60	02.80	01.40
	H	300	40	12.00	12.00	06.00
Throat	M	194	28	05.43	02.72	01.36
	N	110	28	03.08	01.54	00.77
	H	90	28	02.52	02.52	01.26
Codend	M	102	30	03.06	01.53	00.77
	N	102	30	03.06	01.53	00.77
	H	131	30	03.93	03.93	01.97

Data Sheet-11: Constructional details of experimental high ope

Section	No. of mesh at top	No. of mesh at bottom	No. of meshes at depth	Mesh size (mm)	Twine diameter (mm)	Cutting rate	Details of lines and ropes		
								Head rope	Footrope
Upper wing	4	126	260	45	1.0	1N 10B x10 1N 17B x16	Length	27 M	30.5 M
Lower wing	4	124	300	45	1.0	1N 2B x12 1N 3B x112	Diameter	12mm	12mm
Square	388	388	40	45	1.0	All N	Material	PP	PP
Belly	388	140	300	40	1.0	1N 1B x104 1N 2B x72	Hanging coefficient	1.0	1.0
Throat	194	110	90	28	1.0	1N1B x12 1N 2B x36	Hanging coefficient at bossom	0.4	0.45
Square codend	102 bars	102 bars	131bars	15	1.0	All N			
Diamond codend	102	102	131	30	1.0	All N			

4.4.1 Choice of netting material for bottom trawl net

While selecting the netting material for trawl construction the physical properties like breaking strength, specific gravity, knot stability, abrasion resistant, twist coefficient, extension and elasticity were taken into account for fabrication. Accordingly, "Polyethylene"(HDPE) material was used as main material for the construction of the trawls and polyamide material was used for the cover codend during the present study.

4.4.2. Constructional details of trawl fishing gear

From Figs. 3 and 4, the trawl nets can be seen as large bag shaped nets wide at the forward end. The mouth which opens and leads to the body of the net that tapers towards the closed cod-end. The mesh sizes are usually bigger, their largest in the mouth of the trawl and, reduce progressively towards the codend. Construction details of materials and different sections of trawl net such as the square, bellies, throat, codend and other parts are shown in Tables 5 and 6.

4.4.3. Construction of top wings.

Top wings are the two sections of netting usually shaped diagonally opposite to one another to form the upper mouth. The lower part of both, the top wings were attached to the either side of the square piece. Headline was attached from one top wing end to the other along the diagonal shape, across the bosom and along the opposite top wing to the end with E value 0.4 and 1.0 respectively.

4.4.4. Construction of lower wings

Two narrow sections of netting fitted between the lower belly and the top wings to form lower jaw of the trawl. The foot rope was attached from one wing end to other along the bar cuts and across bosum with E value 0.4 and 1.0 respectively. The two lower wings are the parts of the netting, which are subjected to the most abrasion, and consequently they are the sections that had to be continually repaired during this study.

4.4.5. Construction of square piece

The section of the netting fitted between the top body and the two top wings so that it partially over-hangs the footrope. Top wings were attached on either side of the upper belly leaving the bosum in the middle. This forms the forward running cover to restrict the upward escape of the fish.

4.4.6. Construction of belly

Belly is the upper and lower part of the tapered funnel of the net that guides the fish to codend. It was inserted to improve the flow of the net, close to meshes in front of the codend and to make hauling easier.

4.4.7. Construction of codend

4.4.7.1 Construction of diamond mesh codend

Codends are two rectangular pieces of netting, manufactured with heavy double twine. The top edges were joined to the narrow end of the bellies. The selvedges are laced together and a cod-line was reeved through the lower meshes for securing the section into a bag where the fish are held until emptied onboard.

4.4.7.2. Construction of square mesh codend

Diamond shape nettings of 20 mm, 30 mm and 40 mm were selected for construction of square mesh codend of 20 mm 30 mm and 40 mm respectively. As per the calculation, the required lengths of netting were cut into bar cuts on both sides of the netting and twisted to form. Attachment of the cod-end to the last part of the belly was done as shown in Fig. 9. Similarly, the 20 mm, 30 mm and 40 mm square mesh cod-ends were fabricated (Fig. 5a & 5b).

4.4.7.3. Construction of cover codend

During the study period the codend was fitted with a small meshed nylon cover codend with help of circular ring. The ring was fabricated with steel material. The thickness of the steel and diameter of the ring were 6.0mm and 1.25 meter respectively. The ring was fitted in the front part of the codend with 10mm nylon webbing cover transversely and it was longer than the codend. There was plenty of lateral slack in the cover after fitting. To maintain the space in side the cover codend floats were provided along the central line of the upper portion of the cover codend.

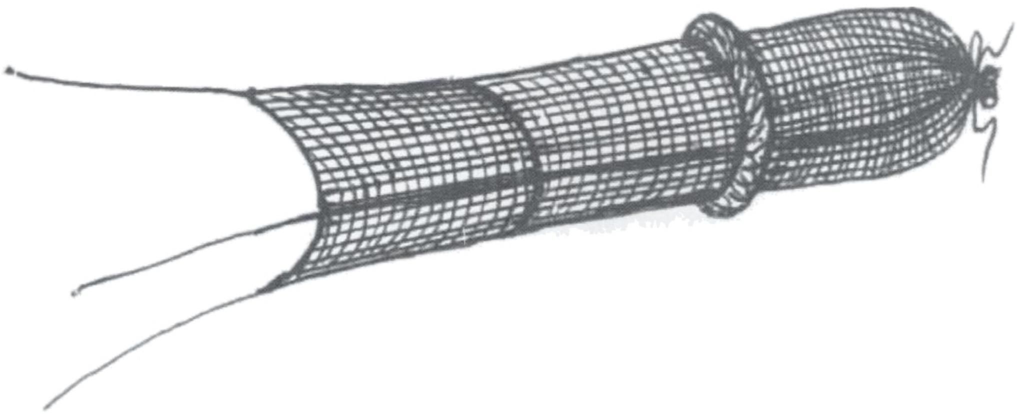


Fig: 5a. Square mesh codend.

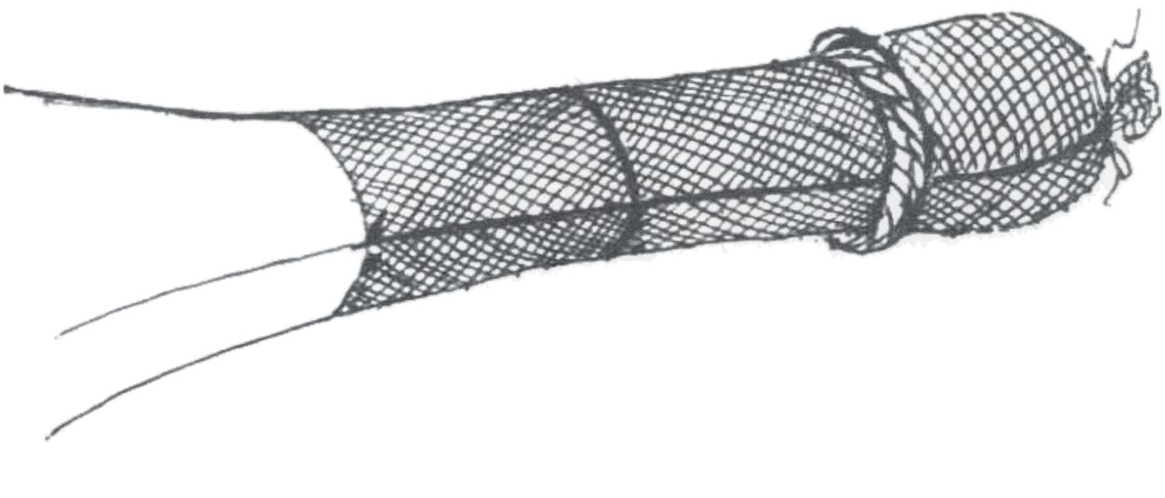


Fig: 5b. Diamond mesh codend.

4.5. Rigging of HOBT

Correct rigging of the trawl, i.e., the foot rope arrangements, the rigging of head rope, codend, and the otter boards are very important for smooth and efficient operation of the trawls. The details of the specifications of the gear are given in Table 5 and 6 and the specification drawing of the trawl is shown in Figs. 3 and 4.

4.5.1. Footrope rigging

The footrope is designed to protect the lower netting panel of the trawling gear and the fishing line against breaking and premature wearing. The foot rope was attached from one wing end to other along the bar cuts and across bosum. For mounting purpose, stapling method was used with E values of 1.0 and 0.4 all along the wings and bosum respectively. Link chains of galvanized iron were used as sinkers for HOBT and to serve as tickler chain. A total weight of 30.00 kg of link chains and 10.00 kg of lead sinks were used.

4.5.2. Head rope rigging

The head rope or headline of the trawl net is rigged with floats to provide the trawl net with fishing height. Head line was mounted from one top wing end to the other along the diagonal shape, across the bosum and along the opposite top wing to the end. Here also, hanging coefficient used was the one similar to that of footrope rigging. Nine spherical plastic floats of 16cm diameter with buoyant force of 12 kgf were used.

4.5.3. Rigging of nets to otter boards

4.5.3.1. Flat rectangular otter board

The most widely used otter board is rectangular flat otter board. A pair of flat rectangular otter boards each measuring 1500 mm x 750 mm and weighing 80.00 kg was used for the horizontal spreading of the nets. The details of the otter boards are given in the Fig. 9. These otter boards were constructed with combination of wood and steel. The board is assembled by joining the planks and fixed them together with long bolt and nuts. A wide shoe was provided to prevent the digging in the mud and was rounded off at the leading edge so that it can ride over the obstacles. The weight of the board was distributed along its length and breadth to get stability on otter board. Back strops are provided for attachment of bridles and warp head rope . On

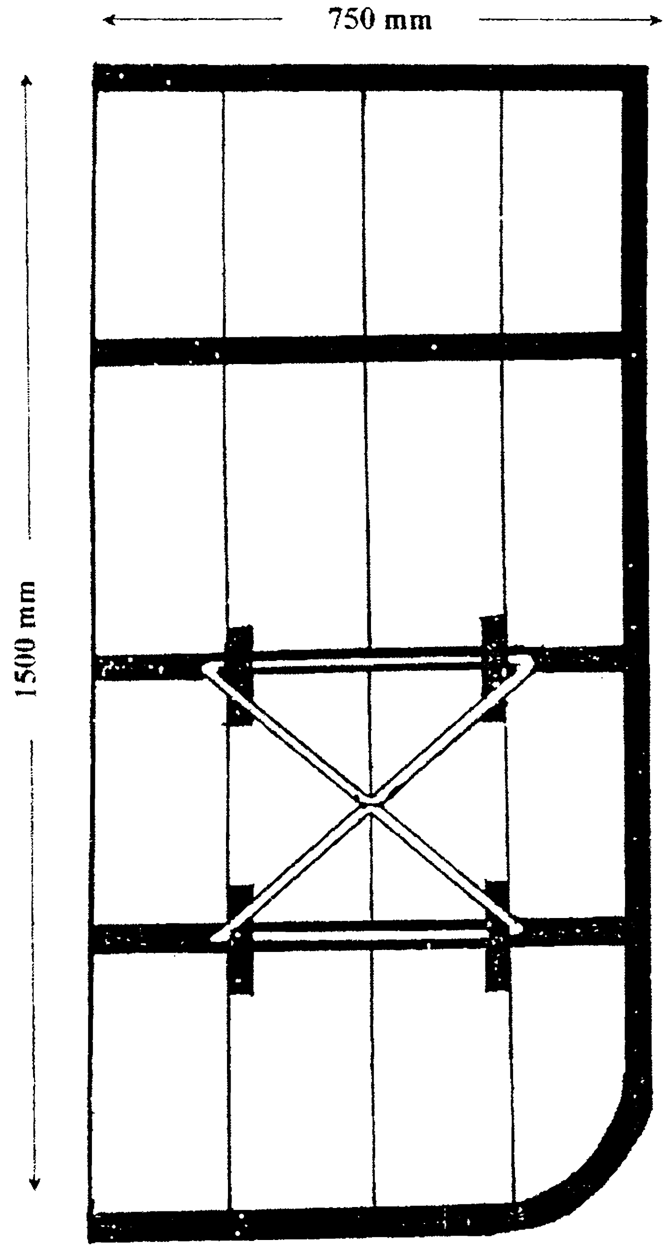


Fig: 6. Flat rectangular otter board.

other side of the board was provided with rings in vertical position. Head rope and foot rope were connected directly to upper and lower rings of the flat rectangular otter board respectively.

4.6. Fishing experiments

4.6.1. Exploratory trawl fishing

A wooden mechanized trawler, MFV Shruthi (48.5 footer) belonging to local fishermen was used for exploratory trawling. 20 trawling cycles were completed on each of the multi-days trips consisting of 4-6 days. , the fishing location was fixed by a global positioning system (GPS) fitted onboard. For deciding on the fishing depth, water column depth was determined using echo sounde. The. Details of fishing operation are as follows.

4.6.1.1. Preparation of trawl fishing gear

For successful operation trawl gear, before starting the fishing journey, necessary maintenance works of the hull, engine and gear was under taken. On the way to fishing ground, the wing ends of the trawl net was connected through the bridles to the otter boards and the otter boards which in turn connected to the main warps. Sweep line was provided between the wings through the bridle lines. The warps lines were connected to the backstops of the otter boards and head rope and footrope to the upper and lower rings of the otter boards respectively. The net was stalked at stern in such a way its shooting was smooth.

4.6.1.2. Shooting of trawl net

On reaching the fishing ground, availability of fish , depth and nature of sea bottom in a fishing ground were ascertained with help of fish finder, GPS and previous experiences of the skipper. The air and surface seawater temperature, wind and current directions were recorded besides the latitude and longitude. After ensuring that the codend was securely tied, deckhands shot the net into water cod-end first and main body next in sequence with the vessel steering forward. When the net was out in water with sweeps connected to the otter boards for proper opening of the net and to keep sweeps and bridles in proper position. the vessel kept steering ahead. The winch brakes were released and the warp line paid out at 4.8 : 1 (warp line : depth of water) ratio. The otter boards were then lowered few meters below the surface and after ensuring their proper position and desirable spread. The gear was then lowered to the fishing depth by releasing required lengths of warp.

4.6.1.3. Towing speed and duration of trawling

The towing speed, maintained at about 3.0 knots, was more than that of the 'normal' swimming speed of fish. The towing and steaming speeds were recorded directly from the GPS navigator. Further, towing was maintained roughly parallel to the coast. As commercial trawlers tow usually for three hours, the same period was maintained throughout the sampling for this study.

4.6.1.4. Hauling of trawl net

After dragging the gear for the specified duration, hauling operations began. After considering the direction of wind and current, the boat was reaccelerated. The warp lines were heaved up evenly on to the winch drums until the otter boards reached the gallows. Then otter boards were then fixed to the gallows and boat throttled to full speed in order to collect the fish from the body of the net in to the codend. Then the sweeps, bridles, foot rope head rope and finally, the net were hauled in. The cod-end was taken onboard with the help of mast and derrick with care to avoid entangling of the net with propeller.

4.6.1.5. Sorting out the catch

Total weight of the catch was recorded using a electronic digital balance. The catch was then sorted out group/species-wise. Representative sample of at least 10 specimens from each group was kept aside for measuring individual length and weight.

4.6.2. Experimental trawl fishing operation

For this experiment, fishing was carried out during daytime between 0700 and 1500 Hours. Since the present experiment was to study the selectivity of the two different types of cod-end of the gears for catching demersal and off bottom fish resources, the fishing ground was selected at random within the depth range of 40-45m off Mangalore. Depth for a particular day's operation was however, chosen based on the fishing operation of commercial trawlers in the area. Both the HOBT with diamond mesh and square mesh codends with 20 mm, 30 mm and 40mm mesh

Fig: 7. Trawler RTV Nethravathi

Fig: 8. On the way to the fishing grounds.

Fig: 9. Replacing the codend.

Fig 10: Preparation of codend for fishing.

Fig 11: Releasing of cover codend

Fig 12: Releasing of otter boards

Fig 13: Releasing of warp line

Fig 14: Hauling of trawl net.

Fig 15: Retrieving of cover codend

Fig16: A view of fish catch obtained in the cover codend.

Fig 17: A view of inner codend

Fig 18: A view of fish catch obtained in the inner codend

size were operated in the same depth and in the same direction successively in the sequential rotation. During operation, both diamond and square cod-end were covered with nylon webbing of 10 mm size as suggested by (Gulland, 1969) to know the extent of escapement of juveniles/smaller sized fish species during trawling. The other operations such as from shooting of trawl net to sorting out the catch are as described in sections 4.4.1.

4.7. Performance of the trawl gear

The trawl fishing was conducted as per the procedure explained in section 3.4.1. During operation, it was necessary to know the performance of the gear such as towing speed, horizontal spread, vertical opening and drag of the net. Some of these parameters were calculated using the established methods (Koyama, 1984).

4.7.1. Horizontal spread

Horizontal opening between the two wing tips of the trawl net was calculated as follows:

$$W = \frac{2L1 + L_3}{L_2+L_3} \times \frac{\sin \theta}{2} + \frac{F L_3}{L_2+L_3}$$

Where,

W is the distance between two wings (in meters - M),

L_1 is the length of the warp (M),

L_2 is the length of bridles (M),

L_3 is the distance between the wing tip of the net and codend starting point (M),

F is the distance between two warp where it meets parallel at the last point or distance between both towing block (M),

$$\sin \theta = \frac{0.86\,L}{Rt}$$

$$L=0.5 * 0.92 * \rho \; V^2 S$$

Where,

Rt is the total gear resistance (Kg),

L is the lift force of an otter board =

ρ is the 105 kgf. $Sec^2/\ m^4$

V is the towing velocity (m/sec)

S is the area of otter board

4.7.2. Calculation of vertical opening

As there were no instruments available to measure the vertical height of the trawl gears, the same was estimated by the numerical formula given by Koyama (1984).

$H = 0.16\ av^{-0.84}$

Where

H = Vertical opening of mouth (m)

a = Maximum circumference of the widest part of the belly (m)

v = Towing velocity (m/sec)

4.7.3. Estimation of trawl gear resistance

The trawl gear resistance is computed by determining the resistance offered by various gear components such as netting panels, sweep lines, bridles, floats, sinkers, otter-boards and warp. In the present study, same length of warp was released for both the gears since the fishing was done at equal depths by the same vessel fitted with the same engine running at known rpm, further the otter-boards used were also the same for both the gears. The total drag of the gear was calculated as shown below.

$R_T = R_n + R_f + R_x + R_s$

R_T – Total gear resistance excluding otter-boards and warps

R_n – Resistance offered by netting panel

R_f – Resistance due to floats

R_x – Resistance offered by lines and ropes

R_s – Resistance due to sinkers

4.7.4. Calculation of net drag (rn)

The net alone accounts for about 75% of the total drag of a single boat otter trawl (Stewart and McLennan, 1987). Since the engine power, otter-boards, length of warp released. were same for both the gears, it was expected that drag of the gears was mainly a function of their twine area. Twine area of the trawl net were calculated according to the formula given by Ferro (1981). In this method, the area of individual trapezium shaped net pieces are calculated and then summed up to get total net area. The empirical formula for calculating the net area is given below.

$$A = \frac{L\ D\ (M + N)}{1000}$$

Where,

A = Twine area (m^2)

L = Stretched length of panel (m)

D = Twine diameter (mm)

M = Number of meshes across the foot of panel

N = Number of meshes across the top of panel

The details of determining the total twine area of the HOBT with square mesh cod-end and HOBT with diamond mesh cod-end are presented in Tables 8 and 10.

MacLennan (1981) has suggested the method of estimating the drag of demersal trawl. This formula can be used to estimate the drag of different sizes of the same type of net to a precision of 10% without any reference to net mouth-geometry and it also takes care of ground friction. The empirical formula used is,

$$R_n = A\ \left(0.0062 + \frac{V^2}{(13.49\ V + 210.5)}\right)$$

Where,

R_n = Drag of the net panels (tons)

A = Total twine area of the panels (m^2)

V = Towing speed (knots)

4.7.5. Drag due to floats (R_f)

Two different sizes and types of floats were used for the nets. Even spherical plastic floats were used for HOBT. The basic hydrodynamic formula used for estimating the drag due to floats (Fridman, 1986) is as follows.

R_f = N.C_f. q. A .... (3)

Where,

R_f = Resistance due to floats (Kgf)

N = Number of floats

C_f = Drag coefficient (0.5 for all spheres as per FAO fishing manual,

q = Hydrodynamic stagnation pressure (kgf/m^2)

$$= \frac{PV^2}{2}$$

p = Sea water density = 105 kgf – sec^2/m^4

V = Velocity of tow (m/Sec)

A = Reference area – Diametric plane for spheres (m^2)

C_f = Drag coefficient (0.5 for all spheres as per FAO fishing manual.

4.7.6. Drag due to lines and ropes (r_x)

First approximation of the resistance of lines and ropes of the trawl gear was calculated by the formula given by Fridman (1986).

Accordingly, Rx = Cx.L.D.q

Where,

R_x = Drag Coefficient

L = Length of rope (m)

D = Diameter (m)

q = Hydrodynamic stagnation pressure (kgf/m^2)

$$= \frac{PV^2}{2}$$

where, p = 105 kgf, sec^2/m^4 for sea water

v = Velocity (m/sec)

The drag coefficient varies with angle, between rope and flow direction. For bottom trawls the angle between sweep lines, legs, bridles and breast lines are assumed to be zero and the corresponding value of 0.12 was taken for $Cx_{..}$ from the data published in the FAO fishing manual (Fridman, 1986). The lengths and diameters of the lines and ropes are presented in Fig 3.

4.7.8. Drag due to sinkers (r_s)

The resistance offered by the sinkers (R_s) was calculated using basic hydrodynamic formula given by Fridman (1986).

$R_s = C_s.A.q.$

Where,

C_s = Drag coefficient

A = Reference area (m^2)

q = Hydrodynamic stagnation pressure(Kg/m^2)

In the experimental trawls, link chains were used as sinkers. Since link chains were elliptical in shape, the C_s value of 0.6 was taken as presented by Fridman (1986). The reference area (A) is the cross sectional area of the link chain perpendicular to flow. In link chains, the side of one link is facing flow direction, the side of the adjacent link is parallel to the flow direction. In view of this, it may be appropriate to take 50% of the cross sectional area of the entire links as the total area facing normal to the water flow. Though this is not very accurate, it was felt that it would be a good approximation in determining the drag due to sinkers in the present study. Slide-calipers was used to determine the cross sectional area of the link correctly.

4.7.9. Drag due to otter boards (Rob)

Resistance due to otter boards was calculated as per the formulae (Fridman 1986)

$R_{ob} = C_{ob}\ A\ q.$

Where,

R_{ob} = Resistance due to otter board.

C_{ob} = Drag coefficient

A = Area (m^2)

q = Hydrodynamic stagnation pressure(Kg/m^2)

4.8. Catch analysis

In addition sorting, weighing and morphometry (section---above) species identification was made based on FAO species identification sheets.

4.9. Statistical analysis

Analyses of variance and "t" test were adapted to test whether there is significant difference between the total catches from HOBT with square and diamond meshed cod-end. The median lengths of species determined from the percentage cumulative frequency curves caught in both the trawls were also compared to find out any significant difference between the gears with respect to their selectivity and catching efficiency.

CHAPTER V

RESULTS AND DISCUSSION

5.1. Exploratory Fishing Gear

The HOBT is a two-seam overhang trawl (Fig.3). The gear has a head rope length of 29.637 m. and a footrope length of 4.64 m. The forward part of both upper and lower panels of the net have a mesh size of 46 mm which diminishes gradually through its body till it terminates in the codend at 18 mm mesh size. The net is connected to a pair of flat rectangular of otter boards through sweep lines and bridles. The other gear details are presented in Table 1 and 2.

5.1.1. Otter Boards

Otter boards (Fig. 5) each measuring 1500 x 750 cm. and weighing 65 kg were used to achieve a horizontal spreading of the trawl net. For the present experiment, otter boards were attached to the wings by means of sweep lines and bridles. These are wooden plates reinforced with flat iron strips. A heavy metal shoe is fitted to lower edge of the trawl board to render it suitable and prevent the board from swimminf up. For the present dtudy each trawl was equipped with two otter boards, a port and starboard one. Brackets are designed for connections with warp are fitted to the inner sode of each trawl board. Two shackles, to which backstrops are attached, are fitted at the rear edge of the otter board. Backstropes are connected to the sweep line. The rectangular otter boards have number of shortcomings. Their angular form with a slightly rounded lower corner does not provide for smooth passage of he board over obstacles on the sea bottom and when trawling on the soft ground, these boards may strongly dig the ground, causing the warp to part (Kostyunin and Nikonorov, 1971.

Otter boards are are connected through the sweep line and bridles. The length of the sweep line, varying from 20-60 m depending on the fishing conditions. Where trawls are worked out at towing speed exceeding 3 knots, it is advisable to increase the length of the sweep line. Jayanaik *et al.* (2004) have connected the bottom trawl with variation in bridle length and found that 19-20 m bridle had an optimum mouth opening during bottom trawling. Further they also they also reported the highest catch in the above bridles arrangement when compared to other combinations. This increases the effective swept area through the herding effect of sweep line and otter board on finfishes.

The otter board spreading force and drag are directly proportional to the projected area. It has been established that otter board spread & drag force increases with square and drag is obtained by dividing the force by the projected area of otter board, square of towing speed and density of water (FAO, 1974). During trawling otter board contribute about 25% of the total drag of the trawl system and is responsible for about 16% of total fuel consumed in trawling operation (Wileman, 1984).

5.1.2. Floats and Sinkers

A total of 9 spherical plastic floats each with 15.00 cm diameter and buoyancy force of 14.40 kgf was used. These floats were selected because of the following requirements and features, that it should be able to withstand high pressure in deep sea, it should be strong enough to absorb sudden shock and abrasion and above all these floats should be easily available in the market. Numbers of floats are attached on the head rope at regular intervals in order to get an upward thrust.

Link chains of galvanized iron were used as sinkers on the foot rope of the fishing gear to get sufficient sinking force which also serve as tickler chain. A total weight of 50 kg. was used for the HOBT. The buoyancy of floats and Sinkers in HOBT helped to achieve a vertical height of the trawl mouth.

5.1.3. Fishing Experiment

The HOBT developed is to be used by a 50 ft wooden mechanized trawler RTV Nethravathi fitted with 98 bhp water-cooled engine. The fishing grounds were selected at random in the depth ranges of 31-86 m off Mangalore based on the fishing operation of commercial trawlers in the area.

The duration of towing was fixed at 2-3 hours for each haul excluding the period of shooting and hauling of the gear. The towing was done parallel to the coast to maintain a constant depth. The warp-scope ratio was kept varying between 1:5

and 1:6 depending upon the depth of fishing ground in order to ensure that foot rope sweeps the sea bed. The depth of the fishing ground was determined with the help of lead line which was again checked in the Fish finder. Towing speed was directly recorded with the help of Global Positioning System (G.P.S.). In addition to positions (latitudes & longitudes) GPS was also used to know the towing & cruising speed and compass course.

5.1.3.1 Distribution of Fishery resources along off shore waters of Karnataka

The details of the exploratory fishing trips, such as location of the fishing ground, fishing effort, depth of operation during the fishing season 2003-2004 is shown in Table 9. During the nine months of study period of 2003-04, samples were collected by carrying out experimental fishery at different depths ranging from 31 to 86 m (Table 5). This study involves the listing of different commercially important fishes of the faunal complex in the overall area and depth zones of investigation. Hence the data, when discussed, would give an idea of the distribution pattern of fishery resources.

The fish catch obtained was separated into species/groups. The month -wise catch of different groups pertain to the catch obtained from two fortnightly sample surveys conducted by the commercial trawler (Table 12a, 12b &12c). Normally the commercial vessel conducts 3-4 trips per month. Table 13 gives the consolidated total catch of different species/groups for the entire fishing season with their percentage composition and thus the total catch presented in table, represented the average actual catch harvested by the commercial vessel in a month.

The percentage composition of different species/group and their average catch rates are given in Table 12a, 12b 12c. The average catch rate was found to be highest during the months of November 2003 with 76.31 kg/hour. During the months, the average catch rate of the fin fishes was found to be highest when compared to other groups caught in the gear. Among the fishes, threadfin bream dominated the catch (46.04 kg/hour - 60.5%) followed by ribbon fish (6.40 kg/hour - 8.3%), lizard fish (4.85 kg/hour - 6.3%) and rock cod (4.00 kg/hour - 5.2%) followed by shrimp (1.7 kg/hour - 2.3%). Crabs did not constitute the group. The

Table: 12a Average catch rate (Kg. / hour) and month- wise catch composition (kg.) in trawl catch

Sl. No.	MONTH / Species/ Groups	September				October				November			
		Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month	Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month	Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month
		Trip-1	Trip-2			Trip-1	Trip-2			Trip-1	Trip-2		
1.	Thread fin breams	4.17	11.90	8.04	30.50	13.09	25.00	19.05	43.50	68.18	23.90	46.40	**60.50**
2.	Bulls eye	3.54	--	1.77	7.40	--	10.41	5.21	12.40	4.00	2.27	3.13	4.20
3.	Lizard fish	1.67	--	0.80	3.50	3.57	125	2.41	5.20	9.09	0.61	4.85	6.30
4.	Barracuda	0.25	--	0.13	0.50	--	0.11	0.60	0.10	1.59	1.02	1.30	1.70
5.	Flat fish	0.73	--	0.37	1.40	--	1.25	0.63	1.50	--	--	--	--
6.	Seer fish	--	--	--	--	0.48	0.31	0.40	0.90	--	--	--	--
7.	Ribbon fish	--	--	--	--	--	0.21	0.11	0.20	5.90	6.81	6.40	8.30
8.	Pomfret	--	--	--	--	--	6.25	3.12	7.50	--	--	--	--
9.	White fish	---	--	--	--	--	0.11	0.06	0.10	--	--	--	--
10.	Rock cod	2.91	--	1.50	6.10	--	4.17	2.09	5.00	6.25	1.70	4.00	5.20
11.	Croakers	--	--	--	--	--	--	--	--	--	--	--	--
12.	Anchovies	--	---	--	--	--	--	--	-	-	-	-	-
13.	Mackerel	--	--	--	--	--	--	--	--	--	--	--	--
14.	Shrimps	1.04	--	0.52	2.70	--	--	--	--	0.45	3.13	1.79	2.30
15.	Crabs	0.21	--	0.11	0.40	--	0.83	0.42	1.00	--	--	--	--
16.	Cephalopods	6.67	6.43	6.55	25.50	5.33	4.58	5.00	11.00	5.11	1.02	3.10	4.10
17.	Miscellaneous	5.31	6.0	5.66	22.00	3.12	6.88	5.00	11.60	6.81	4.54	5.70	7.50
	TOTAL	26.50	24.33	25.45	100	25.59	61.35	43.20	100	107.38	45.00	76.31	100

Table: 12b Average catch rate (Kg. / hour) and month- wise catch composition (kg.) in trawl catch

Sl. No.	MONTH / Species / Groups	December				January				February			
		Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month	Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month	Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month
		Trip-1	Trip-2			Trip-1	Trip-2			Trip-1	Trip-2		
1.	Thread fin breams	9.61	4.81	7.21	14.91	3.33	2.78	3.06	14.48	9.72	1.55	10.14	30.161
2.	Bulls eye	--	--	--	--	0.83	0.69	.76	3.60	0.90	1.17	1.04	3.13
3.	Lizard fish	5.20	--	2.60	5.38	0.56	0.42	.49	2.32	0.13	0.116	0.15	0.44
4.	Barracuda	--	0.51	0.26	0.54	--	--	--	--	--	--	--	--
5.	Flat fish	--	--	--	--	--	--	--	--	0.70	0.60	0.65	1.96
6.	Seer fish	--	--	--	--	--	--	--	--	--	--	--	--
7.	Ribbon fish	6.41	5.12	5.76	11.93	0.97	1.11	1.04	4.93	0.27	0.46	0.37	1.10
8.	Pomfret	1.28	2.56	1.92	3.97	0.90	1.0	.95	4.50	0.15	0.30	0.23	0.68
9.	White fish	1.12	3.46	2.29	4.74	0.28	0.97	.63	2.96	0.45	0.40	0.43	1.28
10.	Rock cod	5.12	3.97	4.55	9.41	1.94	1.39	1.67	7.90	0.18	0.43	0.31	0.92
11.	Croakers	0.75	8.58	4.67	9.66	2.91	--	0.42	1.97	--	--	--	--
12.	Anchovies	--	--	--	--	0.96	2.22	2.57	12.18	0.55	1.52	1.04	3.13
13.	Mackerel	--	--	--	--	0.42	0.15	0.56	2.63	--	--	--	--
14.	Shrimps	1.68	1.70	1.70	3.51	0.50	.68	0.55	2.62	0.83	1.38	1.11	3.38
15.	Crabs	--	--	--	--	5.30	.30	0.40	1.88	0.18	0.35	0.27	0.80
16.	Cephalopods	1.70	4.70	3.20	6.62	0.50	6.25	5.78	27.37	8.20	7.36	7.78	23.50
17.	Miscellaneous	8.33	20.00	14.17	29.32	3.00	1.50	2.25	10.36	9.70	9.58	9.64	29.12
	TOTAL	41.21	55.40	48.31	100	22.73	19.46	21.10	100	31.96	34.26	33.11	100

Table: 12c Average catch rate (Kg/hour) and percentage of catch composition in trawl catch during the period ofstudy (2003- 2004)

Sl. No.	MONTH / Species / Groups	March				April				May			
		Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month	Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month	Average catch rate (Kg/hr)		Average catch rate (Kg./hr) for the month	% of total catch for the month
		Trip-1	Trip-2			Trip-1	Trip-2			Trip-1	Trip-2		
1.	Thread fin breams	6.25	20.83	13.54	40.50	5.13	12.82	9.00	34.80	11.90	19.04	15.47	33.30
2.	Bulls eye	0.41	2.50	1.46	4.40	0.51	0.51	0.51	2.00	0.95	0.95	0.95	2.00
3.	Lizard fish	0.41	0.41	0.41	1.20	--	--	--	--	0.48	4.80	2.64	5.60
4.	Barracuda												
5.	Flat fish	0.31	0.52	0.42	1.20	0.64	0.51	0.57	2.30	0.60	0.71	0.66	1.40
6.	Seer fish	--	--	--	--	0.26	0.38	0.32	1.20	0.71	--	0.36	0.80
7.	Ribbon fish	0.21	0.21	0.21	0.60	0.21	0.26	0.23	0.90	1.07	0.90	0.99	2.10
8.	Pomfret	0.62	0.41	0.52	1.60	1.28	4.61	3.00	11.60	1.42	1.67	1.55	0.80
9.	White fish	--	-=-	--	--	0.26	0.26	0.26	1.00	0.24	0.48	0.36	0.80
10.	Rock cod	0.52	0.31	0.42	1.20								
11.	Croakers												
12.	Anchovies	1.56	1.66	1.61	4.90	0.38	0.64	0.51	2.00	1.31	1.42	1.37	2.90
13.	Mackerel					0.76	0.89	0.82	3.20	3.30	2.40	2.90	6.10
14.	Shrimps	1.04	1.04	1.04	3.10	0.51	1.28	0.90	3.70	0.83	0.90	0.50	1.90
15.	Crabs	0.31	0.31	0.31	0.90	0.38	--	0.19	0.70	--	--	--	--
16.	Cephalopods	6.71	9.89	8.40	24.80	2.56	8.33	5.45	21.30	6.00	10.00	8.00	16.60
17.	Miscellaneous	6.77	3.65	5.21	15.60	7.69	0.51	4.10	15.30	10.60	10.70	10.65	22.90
	TOTAL	25.12	41.74	32.98	100	20.25	31.00	25.86	100	39.41	53.97	46.41	100

lowest average catch rate was recorded during the month of 2004 with 19.62 kg/hour. During this month average catch rate of fin fish was 11.69 kg/hour (55.4%) followed by shellfish group 6.65kg/hour (31.4%). The average quantity of miscellaneous group was found to be 13.2 kg/hour (9.7%). Table 13 gives the consolidated total catch of different species of groups for the entire fishing season with their percentage composition. This information will suppose to understand the distribution pattern and the availability of fish in different months of the season. From table 13, it can be noted that the catch increased from September to November with a peak in the month of November and then decreased from December onwards. Mathew (1978) has reported that the month of November recorded the maximum catches along the West Coast of India. Table 14 also shows that the contribution of threadfin breams was was present in all the months and followed by ribbon fish, lizard fish, rock cod, bull's eye and barracuda. Among shell fish the catch was dominated by cephalopod throughout the season followed by shrimps. Though the month of March had the highest catch of both cephalopods and shrimp, their availability in different months were considerable, but the crabs represented a very meagre portion of the total catch. The lowest total catch of finfish group was during January and for shellfish during December.

The abundance of ribbon fish along Karnataka coast has been recorded by several authors (Puthran, 1981, Mohan Krishna, 1985 and Ashok, 1989). Kunjipalu *et al.* (1979) reported higher catches of ribbonfish in two -seam trawl. The findings of Deshpande et *al.* (1968) also show higher catches of ribbonfish. Table 11 gives an idea of the contribution of finfish groups to the total catch of off shore trawlers. This ranges from about 43% to as high as 86% during the season. Similarly the shell fish group ranged from a low of about 6% to a high of about 31%. The contribution of miscellaneous fishes to the total catch ranged from 7.4% in November to 32.10% in December. This indicates the wide variations in the contributions of different species during different months. Since the sampling was done at different depths, it could be difficult to exactly quantifying them among various species/groups except the trends of their contribution to the total catch. However, the total annual catch and percentage composition is presented in table 14 and fig 20.

Table: 13. Month-wise catch composition (Kg.) obtained during exploratory fishing

Sl. No.	Month / Species/ groups	September		October		November		December		January		February		March		April		May	
		Catch (Fg.)	%	Catch (Fg.)	%	Catch (Fg.)	%	Catch (Fg.)	%	Catch (Fg.)	%	Catch (Fg.)	%	Catch (Fg.)	%	Catch (Fg.)	%	Catch (Fg.)	%
1.	Thread fin breams	700	31.93	1750	43.53	4052	60.41	375	10.90	220	14.50	770	31.84	1300	40.47	700	34.77	1300	33.29
2.	Bulls eye	70	3.19	500	12.44	275	4.10	0	00	55	3.64	75	3.10	140	4.36	40	1.99	80	2.05
3.	Lizard fish	80	3.65	210	5.23	427	6.37	200	5.80	35	2.31	11	0.45	40	1.25	0	0	220	5.63
4.	Barracuda	12	0.55	5	0.12	115	1.71	0	00	00	00	00	00	0	0	0	0	0	0
5.	Flat fish	35	1.60	60	1.50	0	00	20	0.58	00	00	45	1.87	40	1.25	45	2.24	55	1.41
6.	Seer fish	0	0	35	0.87	0	00	0	00	00	00	00	00	0	0	25	1.24	30	0.77
7.	Ribbon fish	0	0	10	0.25	560	8.35	450	13.08	75	4.94	27	1.12	20	0.62	18	0.89	85	2.18
8.	Pomfret	0	0	300	7.50	0	00	150	4.36	35	2.31	15	0.62	50	1.56	230	11.43	130	3.33
9.	White fish	0	0	5	0.12	0	00	135	3.92	45	2.97	27	1.12	0	0	20	0.99	30	0.77
10.	Rock cod	140	6.38	200	4.80	350	5.22	355	10.32	120	7.91	21	0.87	40	1.25	0	0	0	0
11.	Croakers	0	0	0	0	0	00	335	9.74	30	1.98	00	00	0	0	0	0	0	0
12.	Anchovies	0	0	0	0	0	00	00	00	185	12.19	75	3.10	155	4.83	40	1.98	115	2.94
13.	Mackerel	0	0	0	0	0	00	00	00	40	2.64	00	00	0	0	65	3.23	240	6.15
14.	Shrimps	50	2.28	0	0	158	2.36	67	1.95	38	2.50	80	3.31	100	3.11	70	3.48	75	1.92
15.	Crabs	10	0.47	40	1.0	0	00	00	00	25	1.65	17	0.70	30	0.93	15	0.75	0	0
16.	Cephalopods	590	26.92	444	11.04	270	4.03	249	7.24	415	27.28	560	23.16	797	24.81	425	21.11	650	16.65
17.	Miscellaneous	505	23.03	461	11.60	500	7.45	1105	32.11	200	13.18	695	28.74	500	15.58	320	15.90	895	22.92
	TOTAL	2192	100	4020	100	6707	100	3441	100	1518	100	2418	100	3212	100	2013	100	3905	100

Table: 14. Total annual catch and the percentage composition

Name of the species/ group	Total annual catch (Kg.)	Percentage composition (%)
Thread fin breams	11,127	46.20
Bulls eye	1235	5.10
Lizard fish	1223	5.10
Barracuda	132	0.50
Flat fish	300	1.20
Seer fish	90	0.40
Ribbon fish	1245	5.20
Pomfret	910	3.80
White fish	262	1.10
Rock cod	1226	5.10
Croakers	365	1.50
Anchovies	570	2.40
Mackerel	345	1.40
Shrimps	638	2.70
Cephalopods	4400	18.30
TOTAL	24,068	100

Fig 19: Month-wise catch composition (Kg.) obtained during exploratory fishing

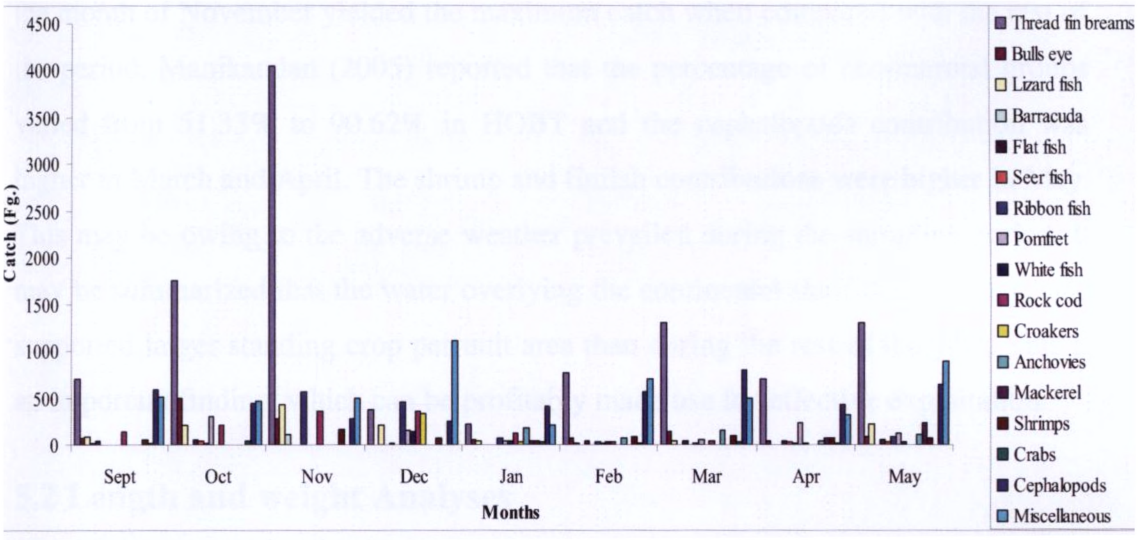
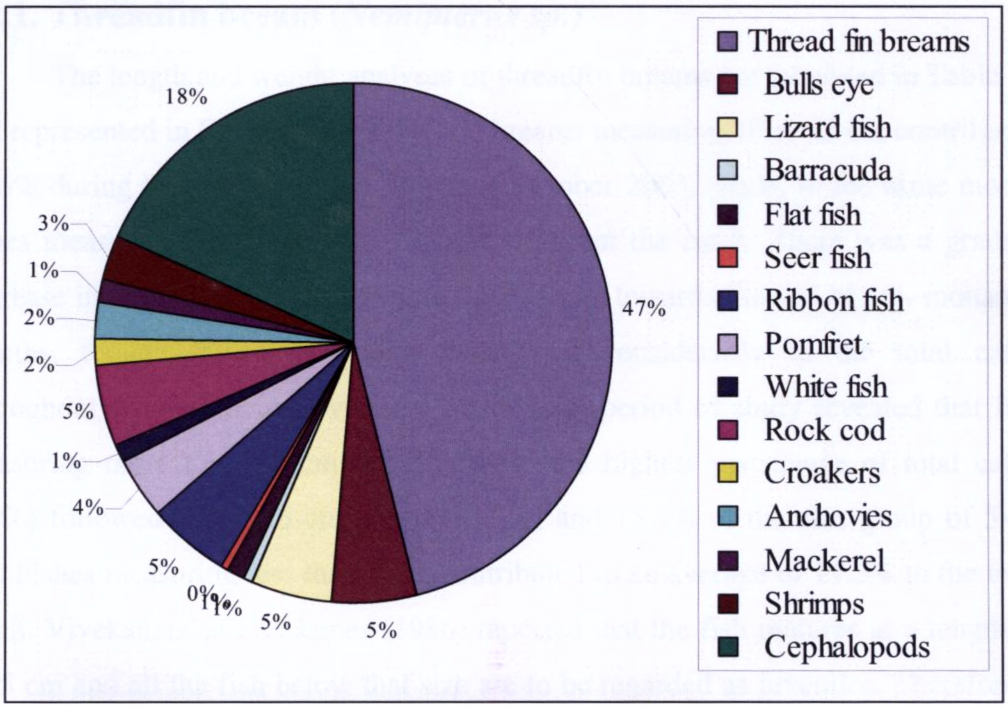


Fig 20: Total annual catch in percentage composition



A perusal of Table 12a, 12b and 102, it could be seem that in off -shore trawling, the catch rates (Kg/hour) varied widely from trip to trip with a low of 19.62 kg/hour in January to 76.31 kg/hour in November. This trend was mainly attributed to the catch rates of threadfin bream alone as reduced. From the fact that the month of November yielded the maximum catch when compared with the rest of the period. Manikandan (2005) reported that the percentage of commercial groups varied from 51.33% to 90.62% in HOBT and the cephalopods contribution was higher in March and April. The shrimp and finfish contributions were higher in May. This may be owing to the adverse weather prevailed during the sampling period. It may be summarized that the water overlying the continental shelf during this period supported larger standing crop per unit area than during the rest of the year. This is an important finding, which can be profitably made use for effective exploitation.

5.2 Length and weight Analyses

A length and weight analysis has been conducted to know two-size composition of various types of commercially important fishes caught during the period of survey and also to judge the percentage of juveniles captured by the trawler. Therefore, fish caught were grouped into four different groups measuring lengths less than 5 cm, 5-10 cm, 10-15 cm and more than 15 cm respectively.

5.2.1. Threadfin bream (*Nemipterus sp.)*

The length and weight analyses of threadfin breams are tabulated in Table 15 and represented in Fig. 21. The thread fin breams measuring 10 to 15 cm contributed 37.6% during the post monsoon month of October 2003, while, in the same month fishes measuring less than 5 cm did not represent the catch. There was a gradual decrease in the fishes measuring more than 15 cm. towards the end of pre- monsoon months, though this fish species constituted considerably to the total catch throughout the period. An overview of the total period of study revealed that fish measuring more than 15 cm contributed to the highest percentage of total catch (40%) followed by 10-15 cm group (33.2%) and 15.3% of the size group of 5-10 cm. Fishes measuring less than 5 cm contributed to an average of 11.5% to the total catch. Vivekanandan and James (1986) reported that the fish matures at a length of 14.5 cm and all the fish below that size are to be regarded as juveniles. Therefore it can be noted that 26.8% of the fishes landed during the study period represented the

Table: 15. Length and weight analyses of Threadfin breams (*Nemipterus sp.)* obtained in exploratory trawl fishing from September 2003 to May 2004

Size range	<5.0 cm.		5.0 -10.00 cm.		10.00 – 15.00 cm		> 15.00 cm.		Total
Monthly catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Total catch 9Kg.)
September 2003	102.60	14.70	124.60	17.80	125.90	18.00	346.00	49.50	700.00
October	00	00	119.60	6.80	657.90	37.60	972.50	55.60	1750.00
November	417.90	10.30	509.00	12.600	1050.30	37.10	1620.80	40.00	3598.00
December	36.50	9.70	38.80	10.30	136.30	36.40	163,60	43.60	375.00
January 2004	20.70	9.40	25.40	11.50	81.30	37.00	92.60	42.10	220.00
February	80.60	11.00	118.00	16.20	295.50	40.50	235.90	32.30	730.00
March	184.90	14.20	220.80	17.00	434.30	33.40	460.00	35.40	1300.00
April	137.20	19.60	169.60	24.20	181.20	25.90	212.00	30.30	700.00
May	294.60	22.70	379.80	29.20	281.90	21.70	343.70	26.40	1300.00
Total	1275	11.50	1705.60	15.30	3244.6	33.20	4448.00	40.00	10673.00

juveniles that are less than 10 cm size range. Considering the size range of 10-15cm. as immature fishes as stated by Vivekanandan and James (1986), the catch of immature fish thus contributed 60% to its total. Considering the month wise catch it can be seen from Table 15, contribution of matured fish to the total catch ranged from 26.4% in May to 55.6% in October. It has been reported that mean size of threadfin bream landed by Mangalore trawlers was 11.00 cm, which suggested over exploitation of threadfin bream in Mangalore coast (Anon., 2003b). Manikandan (2005) also corroborated to the above findings. Thus, it it is necessary to take up management measures to prevent exploitation of juveniles and immature fishes for the conservation of the resourses. The total contribution of this individual species to the sum of the total of the entire group is 46.2% (Table 14).

5.2.2. Bull's eye (*Priacanthus sp.)*

The length and weight analyses of Bull's eye is presented in Table 16 and depicted in Fig. 22. During the month of January 2004, fishes measuring 10-15 cm contributed to the maximum percentage (66.9%) of the total catch, while fishes measuring less than 5.0 cm were not caught during the entire period of the study. 16.2% of fishes in the range of 5-10 cm were caught during November month only. However Bull's eye did not constitute the catch during December 2003. In the present investigation it can be seen that fishes measuring between 10-15 cm contributed to the highest percentage (52.2%) of total catch. The bull's eye fish catch formed with the good representation of the size groups of 10-15 cm and above only. An average percentage contribution this group was represented by 43.9%. Further, fish size group of more than 15cm. ranged from 33.1% in January to 61.1% in May.

There is no catch of Bull's eye in December. Since, the fishing ground where the trawling was conducted was a range of 31-40 m. depth, which is a shallow region, and the Bull's eye normally remains at deeper. The total contribution of this individual species region to the sum of the total of all the groups as only 5.1% (Table 14).

Table: 16. Length and weight analyses of Bull's eye (*Priacanthus sp*) obtained in exploratory trawl fishing from September 2003 to May 2004

Size range	<5.0 cm.		5.0 -10.00 cm.		10.00 – 15.00 cm		> 15.00 cm.		Total
Monthly catch	**Weight (Kg.)**	**% of Total catch**	**Weight (Kg.)**	**% of Total catch**	**Weight (Kg.)**	**% of Total catch**	**Weight (Kg.)**	**% of Total catch**	**Total catch 9Kg.)**
September 2003					34.76	49.70	35.24	50.30	70.00
October					308.60	61.70	191.40	38.30	500.00
November			44.60	16.20	108.40	39.50	122.00	44.30	275.00
December									
January 2004					36.80	66.90	18.20	33.10	55.00
February					41.20	54.90	33.80	45.10	75.00
March					68.00	48.60	72.00	51.40	140.00
April					19.40	48.60	20.60	51.40	40.00
May					31.10	38.90	48.90	61.10	80.00
Total			44.60	3.60	648.26	52.50	542.14	43.90	1235.00

Fig 21: Length and weight analyses of Threadfin breams (*Nemipterus sp.)* obtained in exploratory trawl fishing from September 2003 to May 2004

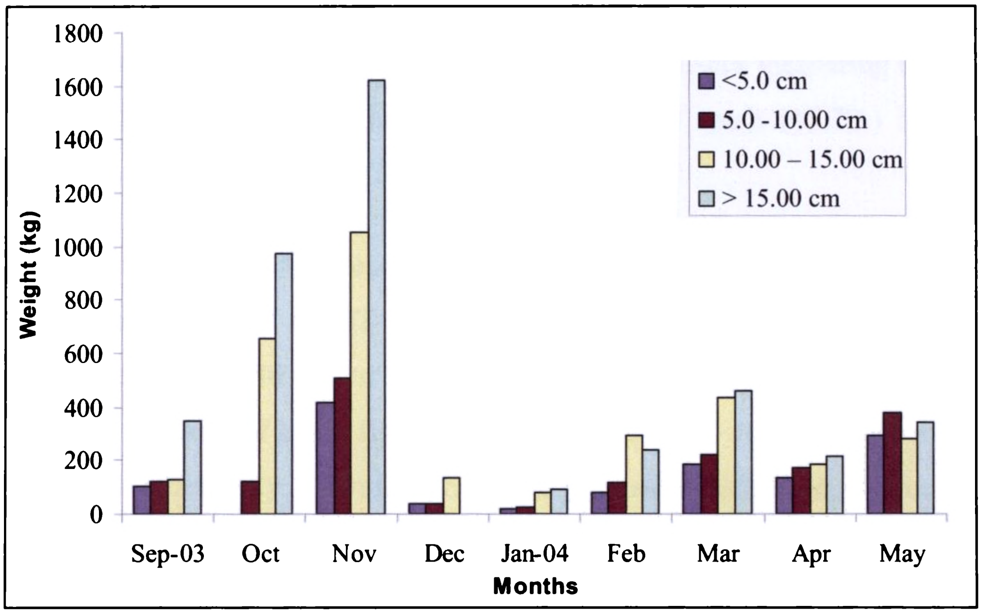
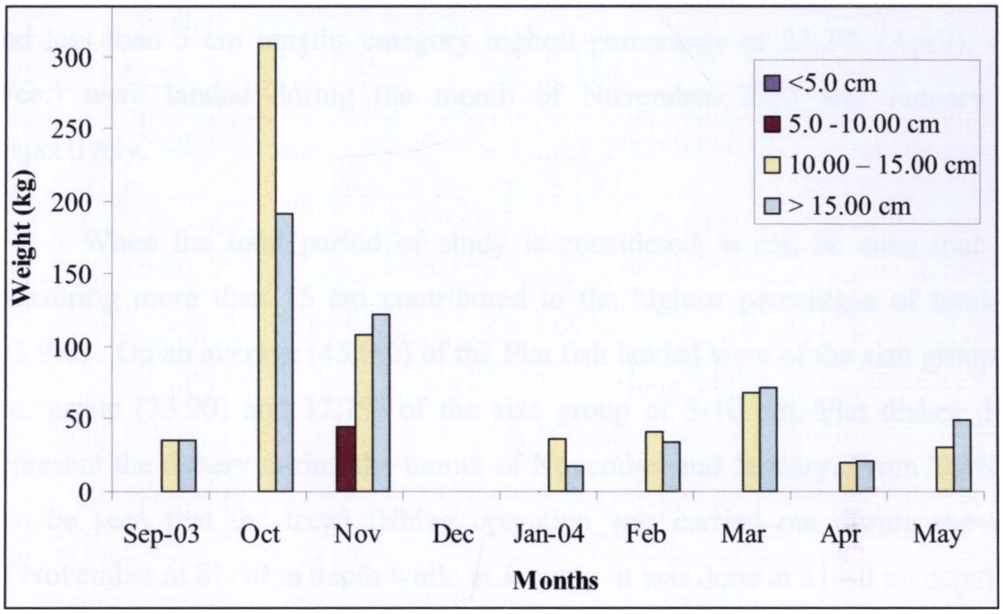


Fig 22: Length and weight analyses of Bull's eye (*Priacanthus sp*) obtained in exploratory trawl fishing from September 2003 to May 2004



5.2.3. Lizard fish (*Saurida sp.*)

From the Table.17 and Fig.23 it can be clearly seen that the majority of the fishes caught were more than 10 cm in length. The highest percentage (61.3%) of total catch, measuring more than 15 cm. length was seen during the month of January 2004, while minimum percentage (35.9%) was recorded during the month of November. Fishes less than 5 cm did not represent the catch. From the data obtained during the period of study it can be seen that fishes measuring between 10-15 cm contributed to the highest percentage of total catch (45.7%) followed by fishes measuring more than 15 cm (44.5%).

Manikandan (2005) reported that median length lizardfish caught in LMT (large mesh trawl) and HOBT were 16.20 cm and 14.00 cm respectively and the length varied from 8.40 cm. to 81.00 cm. According to Sivakami *et al.* (2003), the size at first maturity of lizard fish at Mangalore was 25.00 cm and 26.40 cm in male and female respectively. Therefore, from the present investigation, it is evident that majority of the fish caught were mostly immature lizard fish.

5.2.4. Flat Fish

Table 18 and Fig.24 clearly indicate that during the month of December 2003 fishes measuring more than 15 cm constituted highest percentage of 82.8%, while the minimum percentage of 31.3% was recorded in the month of February. In 10-15 cm group categories, 42.7% in the month of October and 7.1% in December month contributed maximum and minimum quantities respectively. In the case of 5-10 cm and less than 5 cm lengths category highest percentage of 22.2% (April), 44.1% (Feb.) were landed during the month of November 2003 and January 2004 respectively.

When the total period of study is considered, it can be seen that fishes measuring more than 15 cm contributed to the highest percentage of total catch (45.9%) . On an average (45.9%) of the Flat fish landed were of the size group of 15 cm. group (33.90) and 12.7% of the size group of 5-10 cm. Flat dishes did not represent the fishery during the month of November and January. From Table 16 it can be seen that the trawl fishing operation was carried out during the month of November at 81-90 m depth while in January it was done at 31-40 m. depth.

Table: 17. Length and weight analyses of Lizard fish (*Saurida sp.)* obtained in exploratory trawl fishing from September 2003 to May 2004

Size range	<5.0 cm.		5.0 -10.00 cm.		10.00 – 15.00 cm		> 15.00 cm.		Total
Monthly catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Total catch (Kg.)
September 2003					32.40	40.50	47.60	59.5O	80.00
October					94.70	45.10	115.30	54.90	210.00
November			86.70	20.30	187.00	43.80	153.30	35.90	427.00
December			33.50	16.80	93.80	46.90	72.70	36.30	200.00
January 2004					13.50	38.70	21.50	61.30	135.00
February					5.60	51.00	5.40	49.00	111.00
March					20.10	50.80	108.30	49.20	220.00
April									.00
May					111.70	50.80	108.30	49.20	220.00
Total			120.00	9.80	558.80	45.70	544.00	44.50	1223.00

Table: 18. Length and weight analyses of flat fishes (Cynogloses *sp.*) obtained in exploratory trawl fishing from September 2003 to May 2004

Size range	<5.0 cm.		5.0 -10.00 cm.		10.00 – 15.00 cm		> 15.00 cm.		Total
Monthly catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Weight (Kg.)	% of Total catch	Total catch (Kg.)
September 2003	3.00	8.60	2.00	5.70	12.80	36.60	17.20	49.10	35.00
October	5.90	9.90	2.70	4.40	25.60	42.70	25.80	43.00	60.00
November	00	00	00	00	00	00	00	00	00
December	1.60	7.90	0.40	2.20	1.40	7.10	16.60	82.80	20.00
January 2004	00	00	00	00	00	00	00	00	00
February	4.10	9.10	9.70	21.50	17.20	38.10	14.00	31.30	45.00
March	2.40	5.90	4.50	11.30	13.30	33.30	19.80	49.50	40.00
April	3.20	7.10	10.00	22.20	13.60	32.20	26.20	47.60	45.00
May	2.30	4.20	8.80	16.00	17.70	32.20	26.20	47.60	55.00
Total	22.50	7.50	38.10	12.70	101.60	33.90	145.80	45.90	300.00

Fig 23: Length and weight analyses of Lizard fish (*Saurida sp.)* obtained in exploratory trawl fishing from September 2003 to May 2004

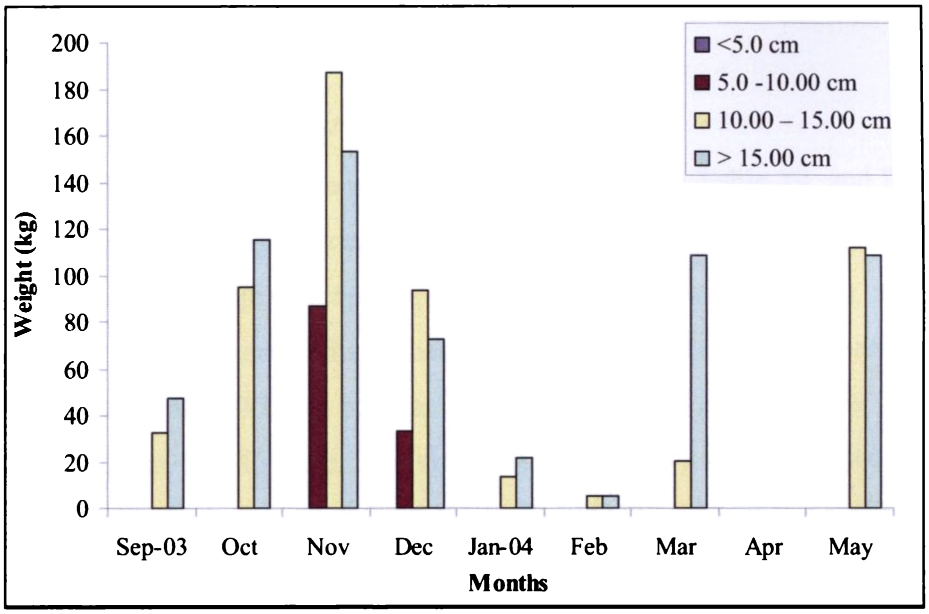
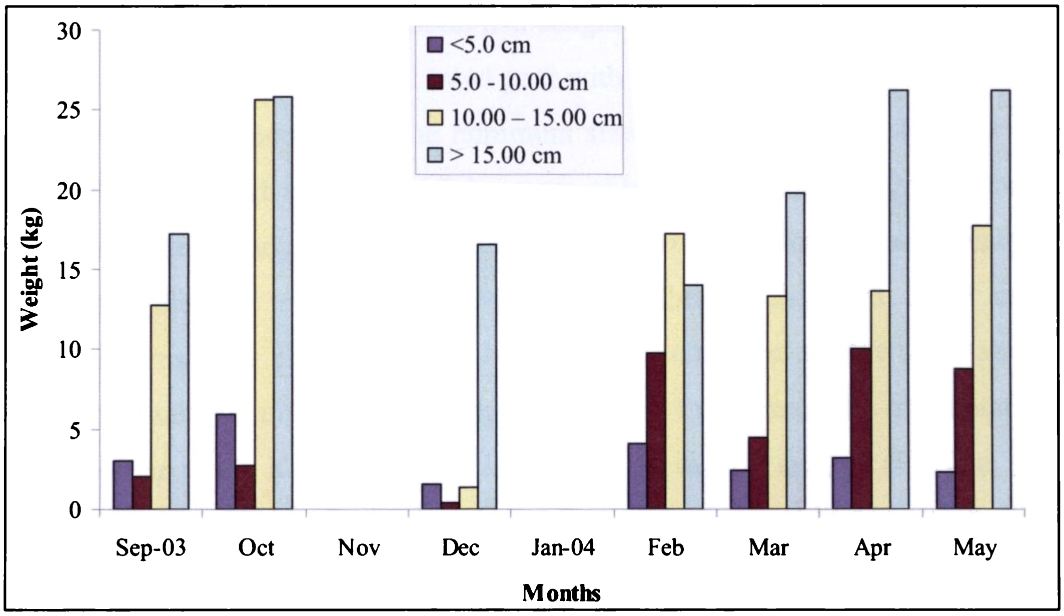


Fig 24: Length and weight analyses of flat fishes (Cynogloses *sp.*) obtained in exploratory trawl fishing from September 2003 to May 2004



Therefore it can be noted that the 20.2 % of the fishes landed during this study represents the juveniles that are less than 10 cm.

Considering the month wise catch, it can be seen from Table 18 that contribution of mature fishes to its total formed only 31.3% in February and 82.8% in October. Thus it indicates that there was a steady catch of fishes of commercially exploitable size during the period of study.

5.2.5. Ribbon fish (*Trichiurus* sp.)

According to the length and weight data tabulated in Table 19. and Fig.25, it can be seen that ribbon fishes measuring less than 15 cm were caught only during November. In other months except September, the catch was measuring more than 15 cm besides, it was observed that fishes measuring more than 15 cm contributed to the highest percentage (90.6%) of total catch and the rest was by fishes with size group of 10-15 cm (9.4%) only. The size group of 10-15 cm represented the total annual catch only during the month of November. Fish measuring less than 10 cm did not represent the fishery during the whole period of study. The total contribution to the sum of the total of all groups is only 5.2% (Table 14).

The size group of 15 cm and above represented the total annual catch in all the months except in the month of September. The highest catch (450 kg) was recorded during the month of December followed by November (442 kg), while minimum catch (10 kg) was recorded in the month of October. Talwar (1997) reported the maximum size of ribbon fish caught in experimental gear was higher in number than that in conventional trawl gear with the size range of 4-40 cm. Bal and Rao (1990) have reported that the minimum size at first maturity is 47- 48 cm for ribbon fishes. Though majority of fishes were of bigger size measuring more than 15 cm in the present study, the fishes less than 15 cm size range has not been quantified and hence the true contribution of immature fishes in the total could not be estimated. From the Table 19 it can be seen that maximum catch was obtained in November and December. Regarding the season, the abundance of ribbon fish, *Trichiurus sp* along Karnataka coast is reported by several authors (Puthran, 1981; Mohan Krishna, 1985 and Ashok, 1989). Kunjipalu *et al.* (1979) reported higher catches of *Trichiurus sp.* in two-seam large mesh trawl than in the HOBT operated

Table: 19. Length and weight analyses of Ribbon fish (*Trichrus sp.)* obtained in exploratory trawl fishing from September 2003 to May 2004

Monthly average catch	< 5.00 cm.		5.00 to 10.00 cm.		10.00 to 15.00 cm		> 15.00 cm		Total catch (Kg.)
	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	
September 2003	--	---	---	--	--	--	--	--	--
October	--	--	--	--	--	--	10.00	100.00	10.00
November	--	--	--	---	117.20	20.90	442.80	79.1	560.00
December	---	---	---	--	--	--	450.00	100.00	450.00
January 2004	---	--	---	--	--	--	75.00	100.00	75.00
Febraury	---	--	--	--	--	--	27.00	100.00	27.00
March	--	--	--	--	--	--	20.00	100.00	20.00
April	--	--	--	--	--	--	18.00	100.00	18.00
May	--	--	--	---	--	--	85.00	100.00	85.00
Total	--	--	--	--	117.20	9.40	1127.80	90.60	1245.00

along North West Coast of India. The findings of Deshpande *et al.* 1968 also showed the higher catches of Ribbon Fish in four seam bottom trawl than HOBT.

5.2.6. Pomfret (*Pampus sp.*)

From the Table 20 and Fig. 26, it can be seen that during March, fishes measuring more than 15 cm constituted the highest percentage (88%) of total catch. There was no catch during September and November. On an average, 78.9% of the Pomfret caught were of the size group of 15 cm and above followed by 10-15 cm group (19.0%). Fishes measuring 5-10 cm contributed to an average of 2.1% of total catch only.

Higher catches of Pomfrets in HOBT was reported by Mohankrishna (1985) along Mangalore coast. It is also expected that the Pomfret catch would be more in larger mouth opening trawls than in lower mouth opening trawls. Talwar (1997) reported more number of pomfrets in the length range of 10-21 cm. Jayanaik (2002), reported a higher catch of 2100 kg in the size range of 10-15 cm. Kuthalingum (1967) has reported that size at first maturity of *Pampus sp.* ranges from 16 to 18 cm. The present study showed that about 21.1% of the fishes landed represented the juveniles that are less than 15 cm. Considering the month-wise catch, it can be seen from Table 20 that contribution of matured fish to its total formed 88.0% in February and 88.0% in March and their total contribution to the sum of the total of all groups is only 3.8% (Table 14).

5.2.7. White fish (*Lactarius sp.*)

During the month of October, fishes measuring between 5-10 cm constituted the highest percentage (70.6%), while minimum landings of 18.9% was recorded during January. There was no catch during September, November and March. When the whole period of study is considered it can be seen that fish measuring between 10-15 cm contributed to the highest percentage of total catch (64.5%) followed by 5-10 cm range (24.4%) and less than 5 cm (11.10%). However, there was no catch in the length range of more than 15 cm range group.

The white fishes those were landed during the study period were of size less than 15 cm (Table 21 and Fig. 27). Mathew (1978) has reported that the commercial size of white fish was found to be in the range of 12 cm to 15 cm and fishes

Table: 20. Length and weight analyses of Pomfret (*Pampus sp.)* *ob*tained in exploratory trawl fishing from September 2003 to May 2004

Monthly average catch	< 5.00 cm.		5.00 to 10.00 cm		10.00 to 15.00cm.		> 15.00 cm		Total catch (Kg.)
	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	
September 2003	--	---	00	00	00	00	00.00	--	--
October	--	--	5.40	1.80	64.10	21.40	230.50	76.80	300.00
November	--	--	00	00	00	--	00.00	00	--
December	---	---	00	00	41.30	27.50	108.70	72.50	150.00
January 2004	---	--	0.80	2.30	8.20	23.50	26.00	74.20	35.00
Febraury	---	--	0.70	4.80	3.70	24.70	10.60	70.50	15.00
March	--	--	0.90	1.70	5.10	10.30	44.00	88.00	50.00
April	--	--	9.20	4.00	28.00	12.20	192.70	83.80	230.00
May	--	--	2.20	1.70	22.50	17.30	105.30	81.00	130.00
Total	--	--	19.20	2.10	172.90	19.00	717.80	78.90	910.00

Fig 25: Length and weight analyses of Ribbon fish (*Trichrus sp.)* obtained in exploratory trawl fishing from September 2003 to May 2004

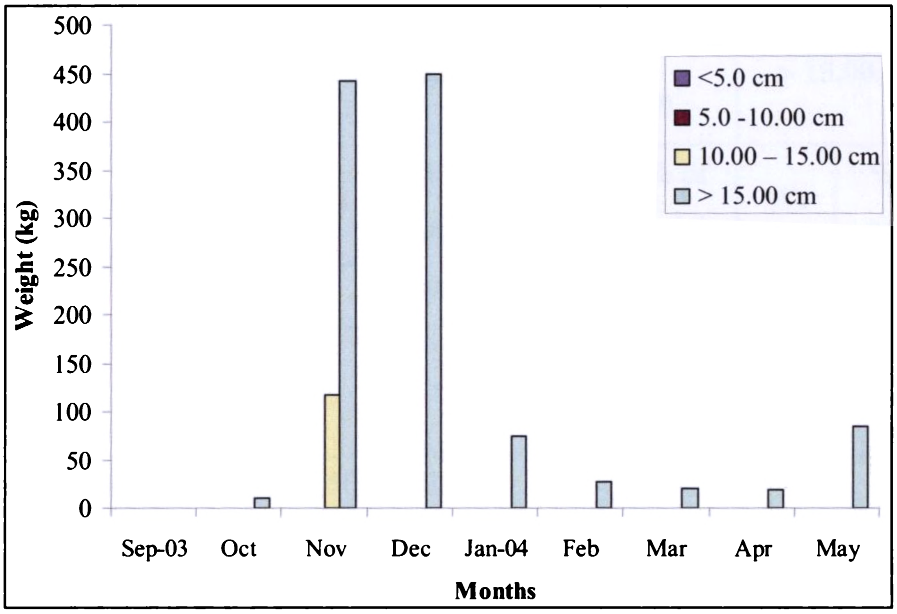


Fig 26: Length and weight analyses of Pomfret *(Pampus sp.) ob*tained in exploratory trawl fishing from September 2003 to May 2004

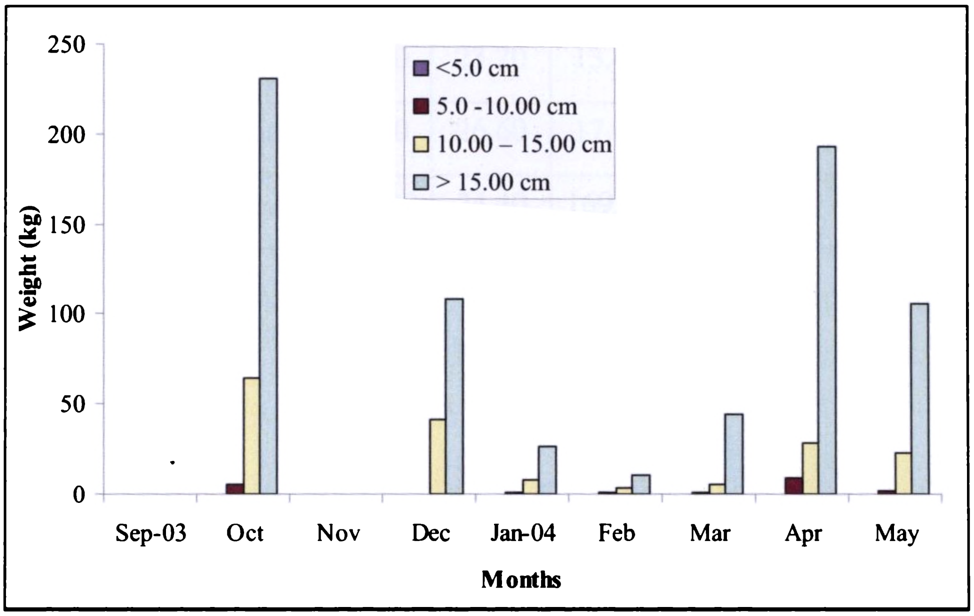


Table: 21. Length and weight analyses of white fish (*Lactarius sp.*) obtained in exploratory trawl fishing from September 2003 to May 2004

Monthly average catch	< 5.00 cm.		5.00 to 10.00		10.00 to 15.00cm		> 15.00 cm		Total catch (Kg.)
	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	
September 2003	--	---	--	--	--	--	--	--	--
October	1.50	29.40	3.50	70.60	--	--	--	--	105.00
November	--	--	--	--	--	--	--	--	--
December	11.90	8.80	33.60	24.90	89.50	66.30	--	--	135.00
January 2004	5.30	11.80	8.50	18.90	31.20	69.30	--	--	45.00
Febraury	3.40---	12.80	5.60	20.80	18.00	66.40	--	--	27.00
March	--	--	--	---	--	--	--	---	---
April	2.00	10.10	4.60	23.20	13.40	66.70	--	--	20.00
May	5.00	16.50	8.00	26.60	17.00	56.90	--	--	30.00
Total	29.10	11.10	63.80	24.40	169.10	64.50	--	---	262.00

measuring less than that are considered juveniles. Vivekanandan *et al.* (2003) reported the length at first maturity of white fish as 13.50 cm The mean length in trawl fishery off Mangalore was very close to the length at first maturity. In the present study, considering the size range of 5-10 cm as immature fishes, 35.5% of those fishes landed could be declared as juveniles. Further, Table 21 indicates that the contribution of mature fishes formed from 56.9% in May to 69.3% in January.

5.2.8. Rock cod (*Epinephelus sp*)

From the Table 22 and Fig. 28, it can be clearly indicated that a gradual increase in catch was seen in the fishes measuring more than 15 cm from December till March with the highest percentage of total catch during March (80.8%). Rock cod of size more than 15 cm comprised 61.2% followed by 10-15 cm group (27.70) and 5-10 cm group (8.4%). Fish measuring less than 5 cm comprised as an average of 2.7% of whole catch during the fishery. Further, fishes of size group more than 15 cm ranged from 80.8% in March to 48.5% in October. The size range of 10-15 cm represented the catch in good quantities with as high as 37.7% in October to as low as 17.1% in November. In the size group of 5-10cm. the percentage of total catch ranged from 4.1% in Feb. to 15.4% in Dec. Fish measuring less than 5 cm contributed to an average of 2.7% to the total catch. From the Table 22 it can be clearly understood that all the size groups represented the total annual catch.

5.2.9. Croaker

From the Table 23 and Fig. 29, it can be clearly understood that croaker represents the fishery only during the month of December & January. Fish measuring 15 cm and above did not represent the fishery throughout the period of study. Fishes measuring between 5-10 cm constituted the highest percentage (77.3%) of the total catch during December followed by January (70.60). On an average, 40.20% of the fishes caught were of the size group 5-10 cm followed by 10-15 cm (35.70%) and 24% of the size group of 5 cm and below. Somashekar Nair (1977) has reported that minimum size at first maturity is 11.5 cm for females and 12.5 cm for males. Nayak (1991) reported highest percentage of 15 cm size range and total catch length ranges of croaker caught are found to be 8-24 cm. Manikandan (2005) reported the median lengths of croakers in large mesh trawl and HOBT to be

Table: 22. Length and weight analyses of Rock cod (*Epinephelus sp.*) obtained in exploratory trawl fishing from September 2003 to May 2004

Monthly average catch	< 5.00 cm.		5.00 to 10.00cm		10.00 to 15.00cm		> 15.00 cm		Total catch (Kg.)
	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	
September 2003	6.90	5.00	11.50	8.20	48.00	34.30	73.60	52.50	140.00
October	9.70	4.90	17.50	8.80	75.60	37.80	97.20	48.50	200.00
November	8.60--	2.50	--	--	60.00	17.10	281.40	80.40	350.00
December	--	--	54.50	15.40	122.00	34.40	178.50	50.20	355.00
January 2004	5.90	4.90	13.20	15.20	22.00	18.20	74.10	61.70	115.00
Febraury	0.60	3.10	0.90	4.10	6.30	30.10	13.20	62.70	21.00
March	1.80	4.60	--	---	6.00	14.60	32.30	80.80	40.00
April	--	--	--	--	--	--	--	--	--
May	--	--	--	--	--	--	--	--	--
Total	33.50	2.70	97.60	8.00	339.60	27.80	750.30	61.50	1221.00

Fig 27: Length and weight analyses of white fish (*Lactarius sp.*) obtained in exploratory trawl fishing from September 2003 to May 2004

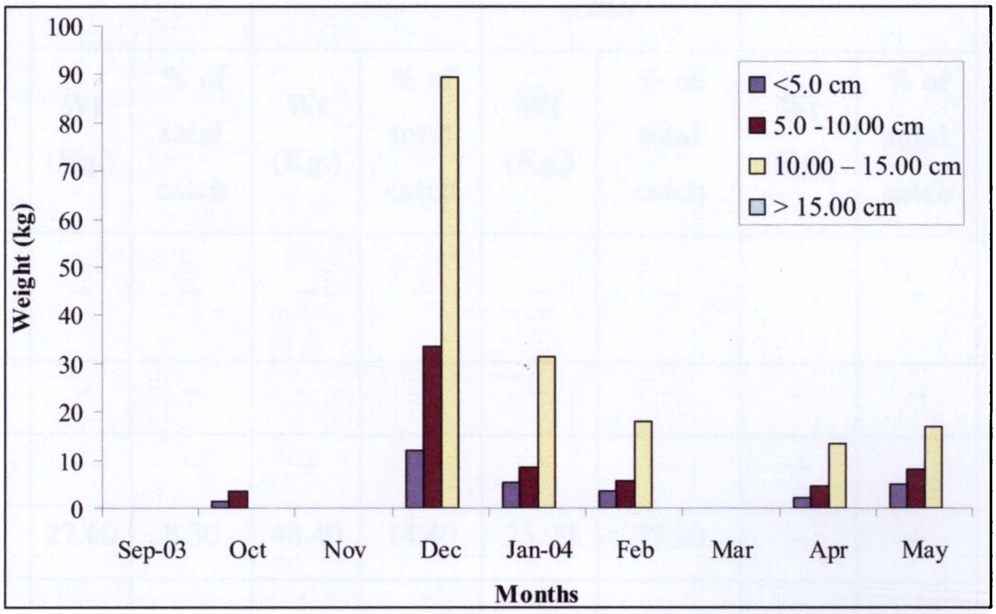


Fig 28: Length and weight analyses of Rock cod (*Epinephelus sp.*) obtained in exploratory trawl fishing from September 2003 to May 2004

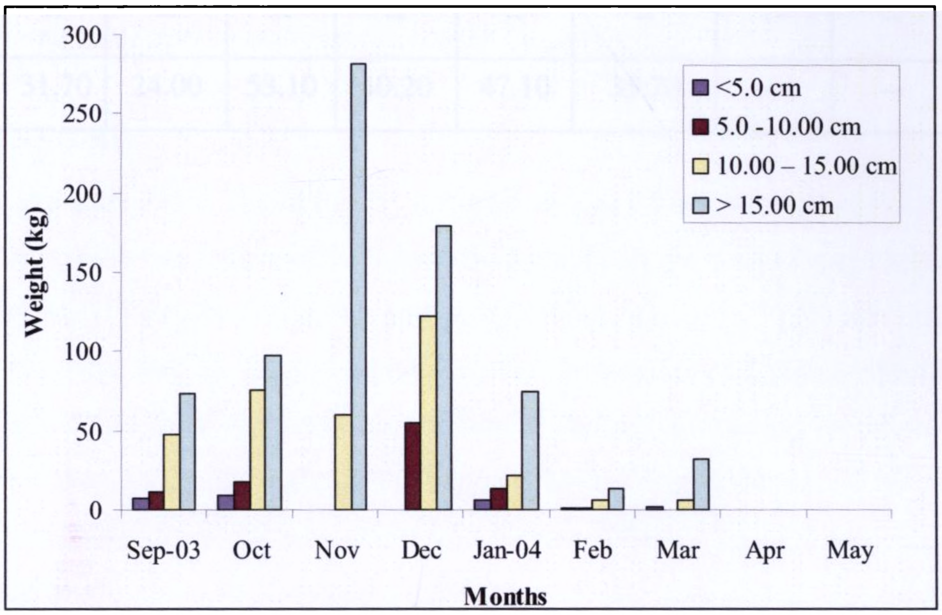


Table: 23. Length and weight analyses of Croaker fish obtained in exploratory trawl Fishing from September 20023to May 2004

Monthly average catch	< 5.00 cm.		5.00 to 10.00		10.00 to 15.00 cm.		> 15.00 cm		Total catch (Kg.)
	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	
September 2003	--	--	--	--	--	--	--	--	--
October	--	--	--	--	--	-	--	--	--
November	----	--	--	--	--	--	--	--	--
December	27.60	8.30	48.40	14.40	25.90	77.30	--	--	102.00
January 2004	4.10	13.60	4.70	15.80	21.20	70.60	--	--	30.00
Febraury	--	--	--	---	---	--	--	--	--
March	--	--	--	---	--	--	--	--	--
April	--	--	--	--	--	--	--	--	--
May	--	--	--	--	--	--	--	--	--
Total	31.70	24.00	53.10	40.20	47.10	35.70	--	--	132.00

13.60 cm and 13.00 cm respectively. About 64.2% of crocker fish catch formed the juveniles and immature during this study.

5.3. Cephalopods

From the Table 24 and Fig. 30 it can be seen that cephalopods represented the catch during all the months of the study period. During the month of May, cephalopods measuring more than 15 cm represented the highest percentage (68.6%) of total catch while lowest (36.4%) was recorded in November and cephalopods measuring less than 5 cm were never caught during the period of study. On an average 54.3% of the cephalopods caught were of the size group of 15 cm and above followed by 5-10 cm (23.0%) and 10-15cm groups (22.7%). Silas (1985) reported that females of *Loligo duvaucelii* mature at a length of 19 cm and for males, it was 28.5cm Syda Rao (1997) stated that *Sepia aculeata* reached a length of 18.1cms at the end of one year. Therefore it can be noted that the 45.7% of the cephalopods landed during the study period represented the juveniles with less than 15 cm. Mohankrishna (1985) and Nayak (1991) have reported the maximum catch of cephalopods in April along Mangalore coast. It is believed that during these months they remain close to the bottom. However, Manjunath (1986) recorded very low catch rates of this group in bottom trawling during May. From the present investigation it could be seen that the contribution of mature fish ranged from 36.5% in November to 68.6% in May. Since the immature cephalopods are landed in considerable quantity, there is scope for resource personnel, management experts and gear technologists to study on the conservation aspects.

5.3.1. Shrimp

From the Table 25 and Fig. 31 it can be seen that shrimp represented the total catch only in the size ranges of 5-10 and 10-15 cm. In all the size groups, shrimp did not represent the fishery during the month of October. However, in the size range of 10-15 cm there was no fishery during October, November and March, during the study period and there was no representation of shrimps measuring less than 5 cm and more than 15 cm throughout the fishing season. On an average, 72.5% of the shrimps caught were of the size group of 5-10 cms followed by 10-15 cm (27.5%). The total contribution of this individual species of the sum of the total of all the groups is only 2.7% (Table 12). Bal and Rao (1990) have reported that the minimum

Table: 24. Length and weight analyses of Cephalopod obtained in exploratory trawl fishing from September 2003 to May 2004

Monthly average catch	< 5.00 cm.		5.00 to 10.00 cm.		10.00 to 15.00cm		> 15.00 cm		Total catch (Kg.)
	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	
September 2003	--	--	195.80	33.20	149.40	25.30	244.80	41.50	590.00
October	--	--	140.90	32.00	72.00	16.20	213.30	52.10	444.00
November	--	--	83.10	32.00	88.30	32.70	98.60	36.40	270.00
December	--	--	--	--	107.70	43.30	141.30	56.70	249.00
January 2004	--	--	92.20	22.00	107.60	25.90	215.20	51.90	415.00
Febraury	--	--	101.3	18.00	123.00	22.00	335.70	60.00	560.00
March	--	--	221.80	28.00	161.30	20.00	413.90	52.00	797.00
April	--	--	76.80	18.00	85.20	20.00	263.00	61.80	425.00
May	--	--	101.50	15.60	102.30	15.80	446.20	68.90	650.00
Total	--	--	1013.40	23.00	996.00	22.70	2390.00	54.30	4400.00

Fig 29: Length and weight analyses of Croaker fish obtained in exploratory trawl Fishing from September 2003 to May 2004

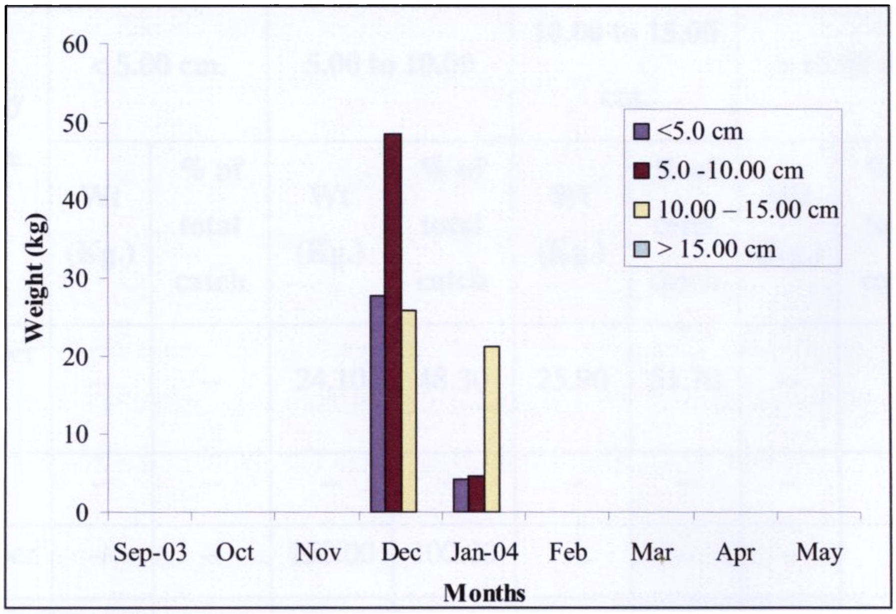


Fig 30: Length and weight analyses of Cephalopod obtained in exploratory trawl fishing from September 2003 to May 2004

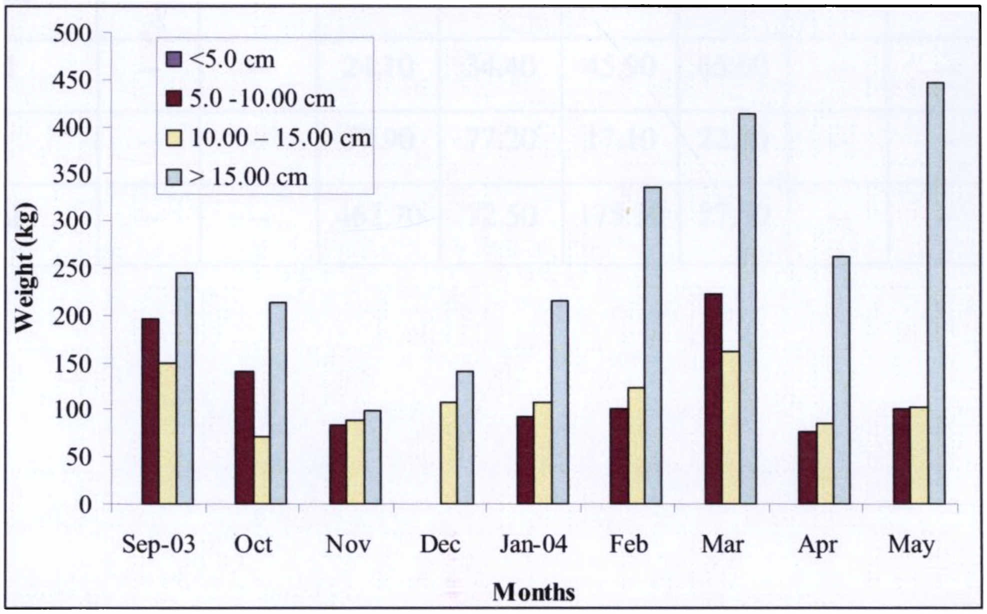


Table: 25. Length and weight analyses of shrimps obtained in exploratory trawl fishing from September 2003 to May 2004

Monthly average catch	< 5.00 cm.		5.00 to 10.00		10.00 to 15.00 cm.		> 15.00 cm		Total catch (Kg.)
	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	Wt (Kg.)	% of total catch	
September 2003	--	--	24.10	48.30	25.90	51.70	--	--	50.00
October	--	--	--	--	--	--	--	--	--
November	--	--	158.00	100.00	--	--	--	--	158.00
December	--	--	43.30	64.60	23.70	35.40	--	--	
January 2004	--	--	20.70	54.50	17.30	45.50	--	--	38.00
Febraury	--	--	34.60	43.20	45.00	56.80	--	--	80.00
March	--	--	100.00	100.00	--	--	--	--	100.00
April	--	--	24.10	34.40	45.90	65.60	--	--	70.00
May	--	--	57.90	77.20	17.10	22.80	--	--	75.00
Total	--	--	462.70	72.50	175.30	27.50	--	--	638.00

size at sexual maturity for shrimp ranges from 6.5 cm to 8.8 cm. Therefore, it can be noted that 100% of the shrimps landed during the study period represents the mature shrimp. Talwar (1997), Jainaik, (2002) and Manikandan (2005) have reported the median length of shrimps caught in the trawl gear was 10.00 cm and 10.05 cm. respectively. These findings support the present study. Hence, it can be seen that shrimps caught during the study period were mature.

5.4. Analysis of total catches at different depth zones

Total catch of commercially important fishes at different depth zones is tabulated in Tables 26, 27, 28 and 29. Since the catches were made randomly at different depth zones during the study period, the data collected may not give a true picture of the catch distribution and abundance. However the analyses provide general distribution trends of the resources along these depth zones.

5.4.1. Depth range of 31-40 m.

The distributions of the catch of different groups are shown in Tble 26 and Fig. 32. In this depth range, the trawling operations were conducted during the months of September, December, January, August and May. At this depth the catch of thread fin breams was highest (2575 kg) followed by cephalopods (684 kg), rock cod (475 kg), lizard fish (455 kg), promfret (365 kg), shrimp (200 kg) and bulls eye (135 Kg.). Nair *et al.* (1986) reported that *Nemipterus japonicus* and *Nemipterus mesoprion* were the two main species of threadfin breams caught during south west monsoon from 35-40 m. depth. The highest catch (1300 kg.) of threadfin bream was caught during the month of May (Table 26). From Table 15 which gives the length and weight analysis and percentage contribution of thread fin breams, it can be noted that in the month of May 73.6% of thread fin breams caught were measured less than 15 cm. Vivekanandan and James (1986) reported that length of 14.5 cm and all the fish below that size are to be regarded as juveniles. Therefore, it can be inferred that the population of threadfin breams at this depth were dominated by immature species. Kuttalingam (1967) reported that immature individuals of this species dominated the catch at 20-30 m. depth zone. He further concluded that the population of this immature species dominated in shallow waters and the stages of maturity increased as a function of depth.

Table: 26. Depth wise catch composition of commercially important species / group at depth zone of 30- 40 meter during the study period

Months / Species/group	September 2003	October	November	December	January 2004	February	March	April	May	Total (Kg.)
Threadfin bream in kg.	500			375	220			200	1300	2595
Bulls eye in kg.					55				80	135
Lizard fish in kg.				200	35				220	455
Pomfret in kg.				150	35			50	130	365
Rock cod in kg.				355	120					475
Shrimp in kg.				67	38			20	75	200
Cephalopods in kg.	270			249	415			100	650	`1684

Fig 31: Length and weight analyses of shrimps obtained in exploratory trawl fishing from September 2003 to May 2004

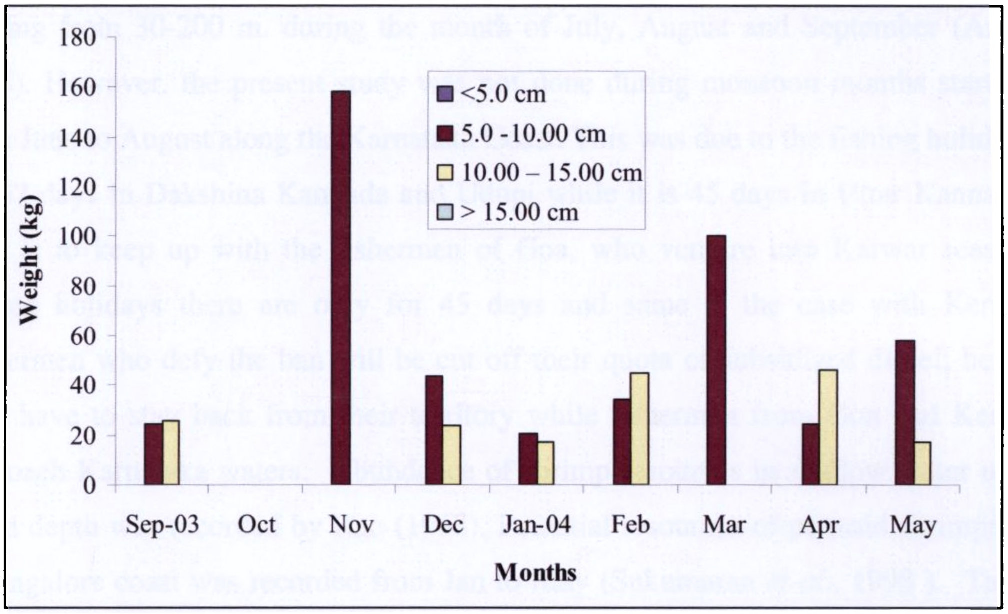
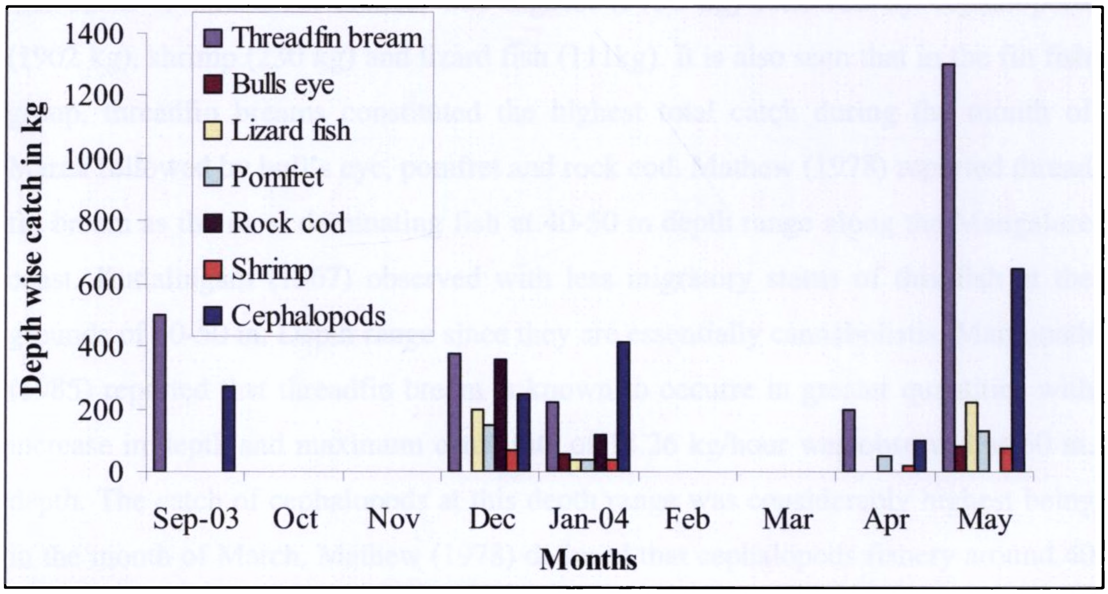


Fig 32: Depth wise catch composition of commercially important species/group at depth zone of 30- 40 meter during the study period



In the shellfish group in the month of May, the catch of cephalopods was about 8 times more than shrimp (Table 26). In general catch rates of cephalopods were much more than shrimps. Good resources of squids along the south west coast of India, between the latitude 8° N and latitude 13° N, were recorded from the depth, ranging from 30-200 m. during the month of July, August and September (Anon 1995). However, the present study was not done during monsoon months starting from June to August along the Karnataka Coast. This was due to the fishing holidays for 57 days in Dakshina Kannada and Udupi while it is 45 days in Uttar Kannada. This is to keep up with the fishermen of Goa, who venture into Karwar seas as fishing holidays there are only for 45 days and same is the case with Kerala. Fishermen who defy the ban will be cut off their quota of subsidized diesel; hence they have to stay back from their territory while fishermen from Goa and Kerala encroach Karnataka waters. Abundance of shrimp resources in shallow water upto 30 m depth was recorded by Rao (1968). Potential resources of peneaid shrimps of Managalore coast was recorded from Jan to May (Sukumaran *et al.*, 1998). Table 26 indicated the availability of shrimp in this depth range in considerable quantities.

5.4.2. Depth range of 41-50m.

In this depth range, the trawling operation was conducted during the months of October, February, March and April. From Table 27 and Fig. 33, it can be noted that catch of thread fin breams was highest (3730 kg) followed by cephalopods (1902 kg), shrimp (230 kg) and lizard fish (111kg). It is also seen that in the fin fish group, threadfin breams constituted the highest total catch during the month of March followed by bull's eye, pomfret and rock cod. Mathew (1978) reported thread fin bream as the most dominating fish at 40-50 m depth range along the Mangalore coast. Kuttalingam (1967) observed with less migratory status of this fish at the grounds of 40-50 m. Depth range since they are essentially cannabolistis. Manjunath (1985) reported that threadfin bream is known to occurre in greater quantities with increase in depth and maximum catch rate of 14.26 kg/hour was observed at 50 m. depth. The catch of cephalopods at this depth range was considerably highest being in the month of March. Mathew (1978) deduced that cephalopods fishery around 40 m. depth ranges to be highly rewarding. But cephalopods, which are basically off bottom in nature, were observed in greater concentration at 50 m depth. Moreover, this group has also showed an increasing pattern with depth (Manujnath 1986). This

Table: 27. Depth wise catch composition of commercially important species / group at depth zone of 41- 50 meter during the study period

Months / Species/group	September 2003	October	November	December	January 2004	February	March	April	May	Total (Kg.)
Threadfin bream in kg.		1200				730	1300	500		3730
Bulls eye in kg.		500				75	140	20		735
Lizard fish in kg.		60				11	40			111
Pomfret in kg.		300				15	50	180		545
Rock cod in kg.		200				21	40			261
Shrimp in kg.						80	100	50		230
Cephalopods in kg.		220				560	797	325		1902

finding corroborates the results of the present study. Landings of inshore trawlers operated off Mangalore coast up to 50 m. depth were also reported by Syda Rao (1988).

5.4.3. Depth range of 51-60m.

The distributions of catch of different groups are shown on Table 28 and Fig. 34. In this depth range the trawling operation was conduced during the months of September and October months only. From the above Table it can be noted that thread fin bream constituted the highest catch followed by lizard fish and rock cod. Commenting on the biology of some of the Nemipterids from Indian waters, Eggleston (1972) has remarked that threadfin bream could be present from shallow waters, while specimens from greater depth are uniformly large, especially those occurring beyond 50 m depth. At this depth range the percentage of mature fishes are more than their percentages in the shallow water depth range (Table 28). In October month 55.6% of total catches of thread fin breams measured more than 15 cms, while it is 49.50% percentage in September. This corroborates the statement made by the previous workers. The catch of shellfish group at this depth range was constituted more by cephalopods and there was no catch of shrimp during October. At this depth zone the catches of threadfin breams was highest (750 kg) followed by cephalopods, lizard fish (230 Kg), rock cod (140kg), bull's eye (70kg) and shrimp (50kg).

5.4.4. Depth range of 81-90m.

November was the only month during which the fishing operation was conducted in this depth zone. The distributions of catch of different groups are shown in Table 29 & 30 and Fig. 35. At this depth zone the catch of threadfin breams was highest (4052 kg) followed by lizard Fish (427 kg), rock cod (350 kg), bull's eye (275 kg), cephalopods (270 kg) and shrimp (158 kg). There was no catch of pomfret at this depth zone. Here again the contribution of threadfin breams was highest with 4052 kg per month when compared to all the other depths. Sriramchandra Murthy (1986) has revealed that threadfin breams are the most abundant in the depth range of 75-125 m contributing to about 75% of the total catch. George *et al.* (1968) also reported on the catch of thread fin bream in greater quantities in relatively deeper waters. Nair *et al.* (1986) have said that threadfin

Table: 28. Depth wise catch composition of commercially important species / group at depth zone of 51- 60 meter during the study period

Months / Species/group	September 2003	October	November	December	January 2004	February	March	April	May	Total (Kg.)
Threadfin bream in kg.	200	550								750
Bulls eye in kg.	70									70
Lizard fish in kg.	80	150								230
Pomfret in kg.										
Rock cod in kg.	140									140
Shrimp in kg.	50									50
Cephalopods in kg.	320	224								544

Fig 33: Depth wise catch composition of commercially important species / group at depth 41-50 m

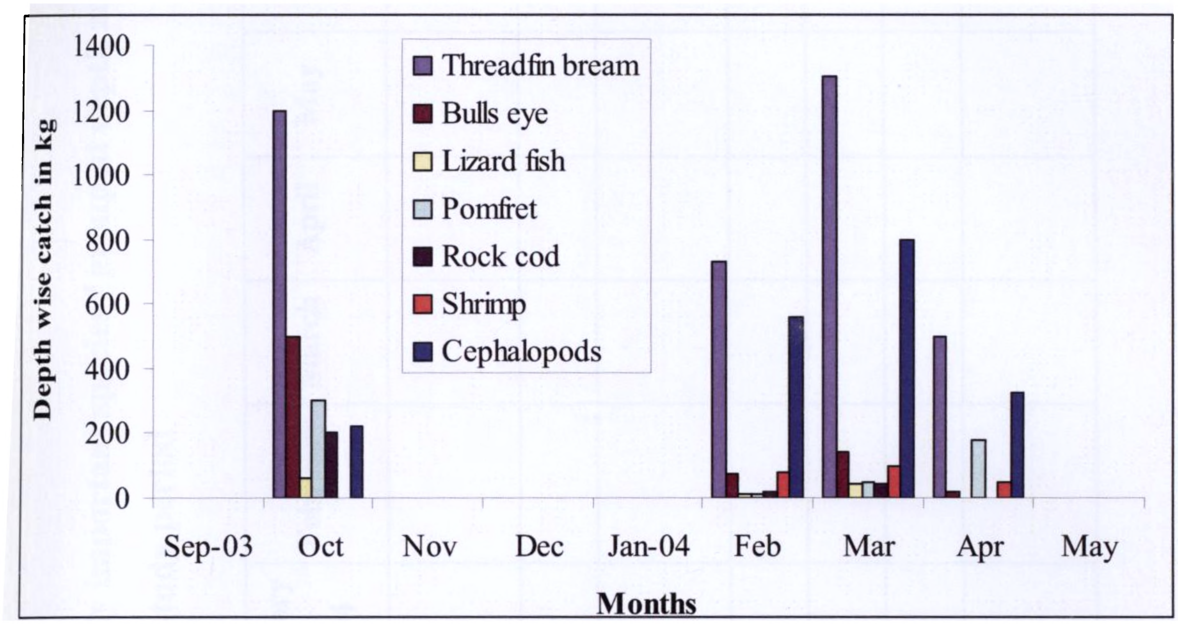


Fig 34: Depth wise catch composition of commercially important species / group at depth zone of 51- 60 meter during the study period

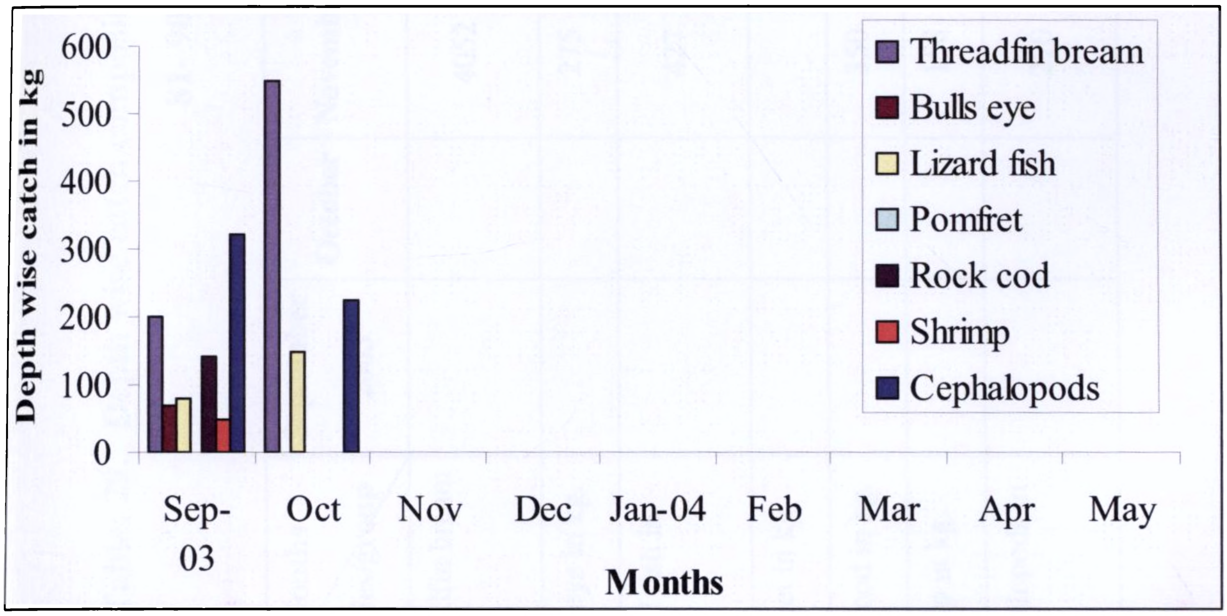


Table: 29. Depth wise catch composition of commercially important species / group at depth zone of 81- 90 meter during the study period

Months / Species/group	September 2003	October	November	December	January 2004	February	March	April	May	Total (Kg.)
Threadfin bream in kg.			4052							4052
Bulls eye in kg.			275							275
Lizard fish in kg.			427							427
Pomfret in kg.										
Rock cod in kg.			350							350
Shrimp in kg.			158							158
Cephalopods in kg.			270							270

Table: 30 Total catch of different groups at four different depth zones caught during the period of study

Species/group Depth range In meters	Threadfin bream	Bulls eye	Lizard fish	Pomfret	Rock cod	Shrimp	Cephalopods	Total caught
31- 40	2595	135	455	365	475	200	1684	5909
41- 50	3730	735	111	545	261	230	1902	7514
51—60	750	70	230	-	140	50	544	1784
81-100	4052	275	427	-	350	158	270	5532

Fig 35: Depth wise catch composition of commercially important species / group at depth zone of 81- 90 meter during the study period

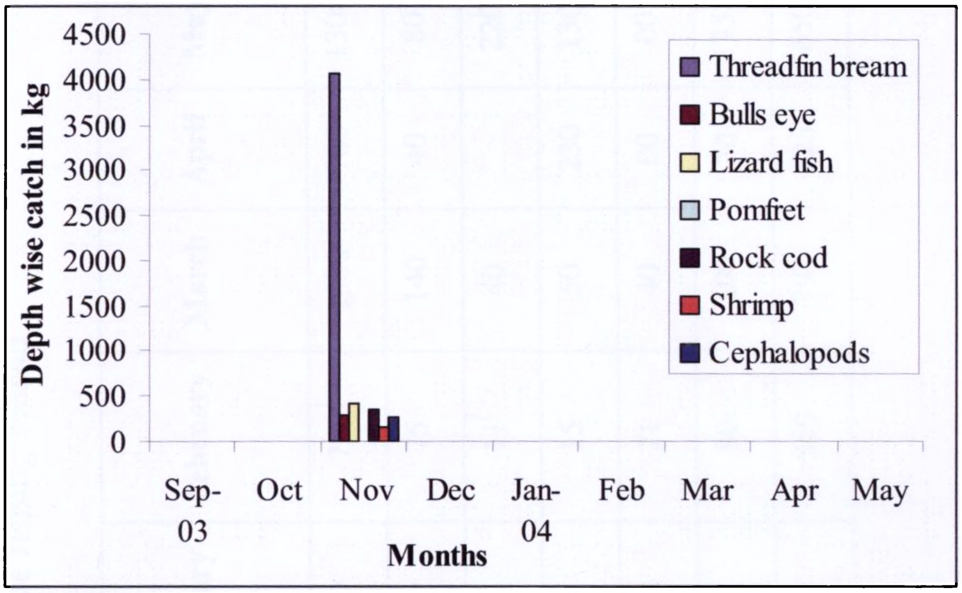


Fig 36: Total catch of different groups at four different depth zones caught during the period of study

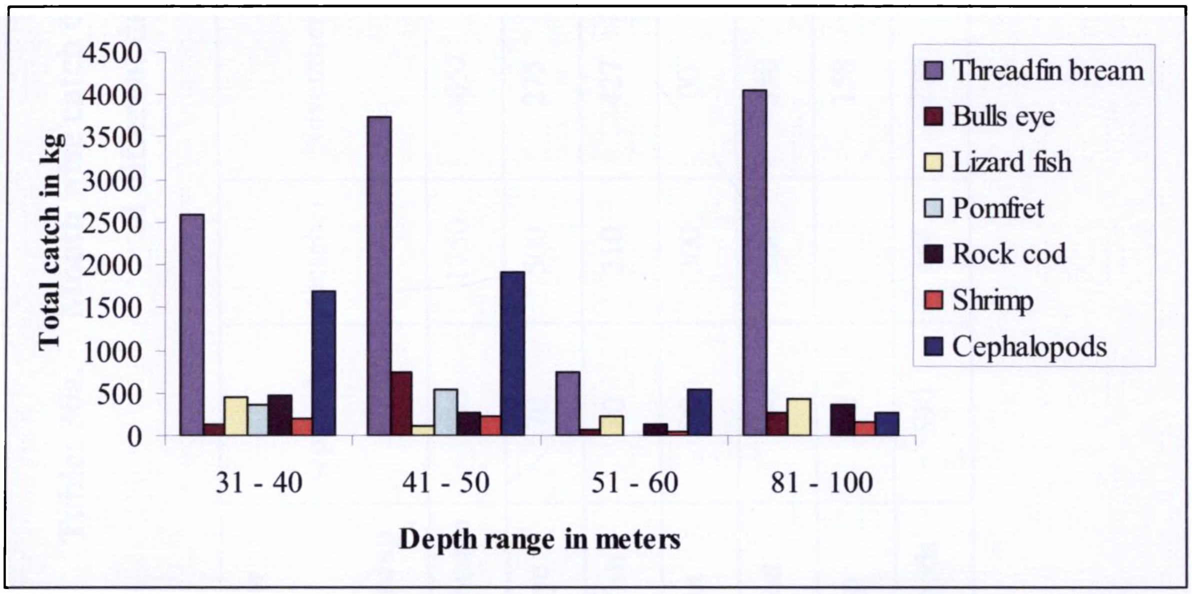
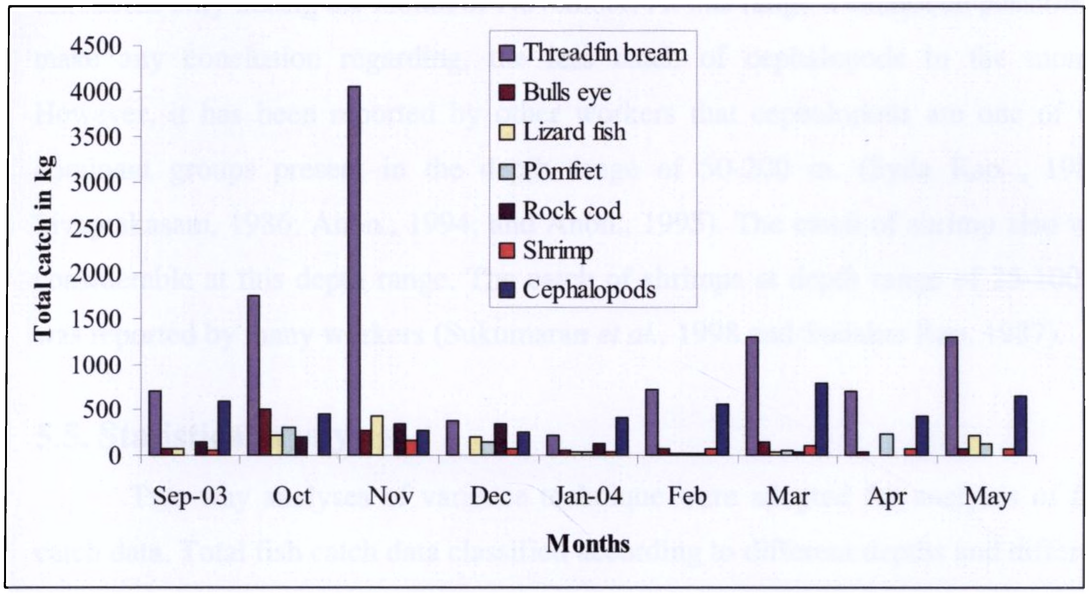


Table: 30a. Month wise catch composition of commercially important species / group at different depth zone during the fishing season

Months / Species/group	September	October	November	December	January	February	March	April	May	Total (Kg.)
Threadfin bream	700	1750	4052	375	220	730	1300	700	1300	11127
Bulls eye	70	500	275	00	55	75	140	40	80	1235
Lizard fish	80	210	427	200	35	11	40		220	1223
Pomfret	00	300	00	150	35	15	50	230	130	910
Rock cod	140	200	350	335	120	21	40	00	00	00
Shrimp	50		158	67	38	80	100	70	75	638
Cephalopods	590	444	270	249	415	560	797	425	650	4400

Fig 37: Month wise catch composition of commercially important species / group at different depth zone during the fishing season



breams could be harvested in good quantities from 75-100m depths. Report on the demersal fishery resources survey off Karnataka- Konkan coast between lat. 14° N and lat 18° N depicts that *Nemipteroids* were the dominant group upto the deeper depth of 300 m and other important species recorded in this region was lizard fish (Anon., 1988). Shivaprakasam (1998) reported the abundance of lizard fish at the depth range of 70-150 m.

In shell fish groups, cephalopods recorded the highest total catch followed by shrimps (Table.30). But, comparatively in this depth range, cephalopods had the least total catch compared to all other depths, since, the exploratory fishing was conducted only during the month of November. At this range it cannot be possible to make any conclusion regarding, the less catch of cephalopods in the month. However, it has been reported by other workers that cephalopods are one of the dominant groups present in the depth range of 50-200 m. (Syda Rao , 1988; Sivaprakasam, 1986; Anon., 1994; and Anon., 1995). The catch of shrimp also was considerable at this depth range. The catch of shrimps at depth range of 25-100 m was reported by many workers (Sukumaran *et al.,* 1998 and Sudakar Rao, 1987).

5.5. Statistical analyses

Two-way analyses of varience technique were adopted for analyses of fish catch data. Total fish catch data classified according to different depths and different species was considered for the analyses (Table 31). It reveals that there is no significant difference in the total fish catch at different depths. However, there is a significant difference of fish catch due to different species ($P<0.05$).

5.6. Selectivity studies in High Opening bottom trawl fishing

High opening bottom trawls (HOBT) with square and diamond meshed codends of 20, 30 and 40 mm were designed and fabricated. Their efficiency for catching demersal fishes was tested through fishing trials conducted in the fishing grounds off Mangalore coast. For this a number of fishing trails were carried out during October 2004 to May 2005. Total weight of each group/species of sample was recorded and used for evaluating the catching efficiencies of HOBT with square and diamond meshed codends.

Table: 31. ANOVA

Source of varience	Sum of square (ss)	Degrees of freedom (ds)	Mean square (MS)	F	P value	F crit
Row	2519674	3	839891.3	2.227923	0.1199653	3.159911
Column	21861301	6	3643550	9.664999	8E-05	2.161302
Error	7685712	18	376984			
Total	31166687	27				

5.6.1 Selectivity studies in trawl fishing gear

Selectivity is that property of any fishing gear, or method, which causes the probability of capture to vary with the characteristics of fish. It is mainly dependent on the methods of fish capture, on the intrinsic design features of the capture and, on the intrinsic design feature of the gear itself. Gear selectivity is an important aspect for biological investigations, fish stock assessment, fisheries management and fishing gear design and development. For a near-truth estimate of age structure of the population, it is necessary to account for the effect of selection of the sampling gear (Sparre *et al.,* 1989). Good fisheries management and responsible fishing regimes require that fishing gear should preferentially capture adult population at a particular age, which would maximize yield while permitting the juveniles and sub-adults to escape and also minimize the trapping of non-targeted and protected organisms.

Selectivity data are required to prescribe optimum mesh size for particular species or groups to meet the objectives of yield optimization and conservation of resources (Pope et al., 1975; ICNAE; 1963; Sparre *et al.,* 1989; McLennan, 1992 and DFO, 1995). Usually the size selectivity in trawls is quite low when compared to the high size selectivity in gill nets, lines and traps (Thompson & Ben-Yami, 1984; Hameed and Boopendranath, 2000). Mesh size of the netting has the greatest influence on capture and catch retention, which in turn govern the selectivity characteristic of the trawl. One of the prime intents of this investigation was to elucidate selectivity characteristics of trawls in the context of their relevance in conservation of resource, development of selectivity fishing gears leading to better steps in fisheries management.

5.6.2. Trawl selectivity characteristics

Beginning with the works of Todd (1911), Davis (1929, 1934), Jensen (1919), Clark (1952), Graham (1954), and Thompson & Ben-Yami (1984), continuous refinement of techniques and analytical procedures have led to substantial growth of knowledge on trawl selectivity. Frame work for investigation of selectivity of various fishing gears have been described in several works, e.g. Pope *et al.* (1975), ICNAF (1963), Pauly (1984), Sparre *et al.* (1989), McLennan

(1992), DFO (1995), Fryer (1991), Miller & Walsh (1992) and Wileman *et al.* (1996).

Among other intrinsic design features which influence selectivity of trawls are mesh configuration (diamond, square and hexagonal), load on twine, material and thickness of twine, hanging ratio, towing speed, towing duration, use of lastridge ropes in codend and type of ground rig (Brandt, 1963; Clark, 1963 and Brings, 1986). Most of the size selection occurs in the condend and hence codend selection has received greater attention of research workers. Escapes of fish are also known to the place through forward net panels and underneath the ground rope (Ellis, 1963; Clark, 1963; Bennett, 1984 and Godo and Walsh, 1992) indicating the importance of studies on whole trawl selection.

5.6.3. Determination of codend mesh selection

Selectivity of trawls is generally determined by codend selection experiments. In such experiments, the basic assumption is that size composition of the fish trapped in the net is usually larger than the whole size-range entering the mouth of trawl. Escapement of those sizes entering the net determines selectivity of the given trawl.

Internal mesh size (mesh lumen measured when the net is wet) is most commonly used for selectivity studies. It is the inside distance between two opposite knots in the same mesh when fully extended in the diagonal direction (Pope *et al.*, 1975). There are two systems of pressure gauges for measuring the mesh size. One is pushed vertically into the mesh and other operates longitudinally. The former type (Westhoff *et al.*, 1962) has been recommended as standard gauge for scientific purposes by ICES and is now widely used for mesh measurement during selectivity studies, with an operating pressure of 4 Kg. Average of a number of measurements taken at random on the operative part of the net is used and information on twine size, material, construction, whether single or double twine, knotted or knotless, wet or dry are recorded.

5.6.4. Total catch

Total catches obtained during the study period for both square and diamond shape-meshed codends are provided in Table 32. It can be noted that HOBT with 20 mm square mesh codend had higher catch rates of 22.75 kg/haul in the months of January and February followed by April (21.75 kg/haul), May (21.50 kg/haul). On the other hand, HOBT with 20 mm diamond shaped mesh codend landed highest catch (27.25 kg/haul) in February and the lowest (15.25 kg/haul) during December. The average catch with square mesh codend was 18.50 kg./haul while the corresponding catch with diamond mesh codend was 20.28 kg/haul. With 30 mm mesh size, the highest catch rates of 18.75 kg/haul were during March and April for square mesh and of 23.25 kg/haul for diamond meshed codend (Table 2). With 40 mm mesh size codend the highest catch rates were 12.75 Kg/haul and 16.75 Kg/haul respectively in square and diamond meshed codend (Table 3).

In order to get a comparative account on the efficiency of capture of HOBT with square meshed cod end and that of diamond meshed codend, the catches they retained during different months were summed up an average calculated. The average catch rates of 20, 30 and 40 mm square meshed codends were 18.50 kg/haul, 17.15 kg/haul and 10.56 kg./haul. The corresponding averages from HOBT with diamond meshed codends were 20.28 kg./haul 20.53 kg./haul and 15.03 kg/haul. Thus, it is apparent that catch rates of HOBT with diamond mesh codends were higher than the experimental gear HOBT with square meshed codends. Owing to the fact that square meshed codend effect more opening and that the opening remains rather stable (not excessively affected by the drag) through the hauling, there are greater escape chances for the small sized animals that entered the mouth. Hence, the possibilities of escapement of undersized fishes through the square openings are greater. Whereas the diamond shaped mesh though with similar area opens deeper vertically but narrowly across, retaining of smaller fishes, which reduces their escapement.

It is evident from the analysis that both mesh size and shape will determine chance of escapement for juveniles. The square meshed codend provides better chance of escapement of juveniles and sub-adults. Kunjipalu *et al.* (1997) have reported that the size of mesh is more effective than the shape of mesh. Talwar

Table: 32 Total average catch (in kg) obtained from hauls of 90 min each at 40-45 m depth in the fishing area using the HOBT with codends of three different mesh-sizes and, two different shapes

Sampling month	Mesh size					
	20 mm		30 mm		40 mm	
	Square	Diamond	Square	Diamond	Square	Diamond
October	13.00	16.50	12.25	16.75	7.25	11.00
November	12.25	16.00	15.75	21.75	11.00	15.50
December	18.50	15.25	17.25	20.75	9.00	14.25
January	22.75	22.00	17.75	19.75	9.50	12.50
Febraury	22.75	27.25	19.75	20.00	12.50	16.00
March	15.50	26.00	18.25	20.25	10.00	15.75
April	21.75	21.50	18.75	23.25	12.75	16.75
May	21.50	17.75	17.50	21.75	12.50	18.50
Avarage	**18.50**	**20.28**	**17.15**	**20.53**	**10.56**	**15.03**

(1997) reported that catch rates of diamond mesh (conventional trawl) was 1.7 times more than that of square mesh codend. Results of Mann Whitney U test applied to compare the average catch per haul also signifify that the catch from HOBT with square meshed codend is lower. This is also discernible from the higher percentages of escapement in the square meshed codend on the HOBT (Table 32). Similar results have been reported by Thorsteinsson (1989) during Icelandic investigations on the selectivity of square mesh codend in bottom trawls. Further, similar to the data obtained during this investigation, Kunjipalu *et al.* (2001) too observed that more juveniles and sub-adults were retained in 20 mm square meshed codend than in 40 mm square meshed codend that permitted escapement of many commercially important groups such as shrimps and squids.

5.6.4.1. Catch composition

Irrespective of the mesh-shape difference on the HOBTs used for this study, there were no noticeable differences in the group/species composition (Table 32). Anchovies pomfrets, Lactaricus, flat fish, mackerel, silver bellies and stomatopods were about the same quantity in both types of HOBTs. The HOBT with square meshed codend caught more pink perch (4.21 kg/haul), cephalopods (2.56 kg.), miscellaneous groups (1.94 kg.) and, ribbon fish (1.88 kg.) than the HOBT with diamond meshed codend. The total catch of those groups was considerably lower than that of threadfin bream cephalopod and ribbon fish. Higher and, identical catches of 27.25 kg/haul were recorded from both HOBTs with square- and diamond- meshed codends (Table 32). On the other hand, the lowest catch rates of HOBTs with square and diamond meshed codends respectively were: 13.00 kg/haul and 15.25 kg./haul. In general, the catch rates in HOBT with square meshed codend were higher during February and April and, low during October. The other HOBT with diamond meshed codend landed the highest catch of 27.25 kg/haul during February and the lowest catch of 15.25 kg/haul in December.

The average catches of HOBT with 30 mm square and diamond meshed codends were 16.92 kg/haul and 15.03 kg/haul respectively (Table 3). Catches from the net with square meshed codend were maximum (19.75 kg.) during February and, minimum (12.25 kg/haul) during October. Similarly, the HOBT with diamond meshed codend recorded the maximum catch (23.25 kg/haul) in the month of April

Table: 33 Average catch compositions (kg/haul) of different fish/shellfish groups caught in the HOBT with 20mm mesh size codend

Groups/species	HOBT Mesh shape	Sampling month								
		Oct	Nov.	Dec	Jan	Feb	March	April	May	Average
Anchovies	Square	0.25	1.25	2.00	0.75	0.50	0.75	1.75	1.50	1.09
	Diamond	0.50	0.25	.75	1.00	1.75	2.00	1.50	0.00	0.93
Pomfrets	Square	1.00	1.50	1.00	1.25	0.75	1.50	0.75	0.75	1.06
	Diamond	0.75	1.25	1.50	2.00	0.75	1.00	0.75	0.75	1.94
Pink perch	Square	2.50	4.50	5.50	4.00	3.50	2.50	8.00	3.25	4.21
	Diamond	3.50	3.75	2.50	7.00	8.00	5.75	3.25	4.50	4.72
Ribbonfish	Square	1.25	2.00	3.00	2.25	1.50	1.75	1.00	2.25	1.88
	Diamond	1.50	2.00	1.75	.75	1.00	2.50	2.25	0.50	1.53
Lactarius	Square	0.50	0.50	.50	1.25	0.00	0.75	1.50	0.50	0.69
	Diamond	0.00	0.25	0.75	0.50	1.50	1.50	0.50	0.00	0.63
Flatfish	Square	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.25	0.69
	Diamond	0.50	0.25	0.75	0 .75	1.00	1.50	0.25	1.00	0.75
Mackrel	Square	0.00	.00	1.50	3.25	0.00	0.00	2.00	2.50	1.20
	Diamond	0.00	0.00	0.00	0.50	2.00	3.00	2.50	0.00	1.00
Silver-bellies	Square	1.00	0.25	0.50	0.50	1.00	1.00	1.50	0.25	0.75
	Diamond	1.00	1.25	1.00	0.75	1.50	1.25	0.25	0.50	0.94
Lizardfish	Square	1.00	1.50	.50	1.25	1.00	.50	1.25	1.00	1.00
	Diamond	1.00	0.25	0.50	1.00	1.25	0.50	1.00	1.00	0.75
Clupeids	Square	1.00	1.50	0.50	1.25	1.00	0.25	1.25	1.00	0.97
	Diamond	1.00	0.25	0.25	1.00	1.25	0.50	1.00	1.00	0.78
Cephalopods	Square	0.75	1.75	3.50	1.00	3.50	2.50	3.25	4.25	2.56
	Diamond	3.50	2.00	2.50	3.50	3.25	2.75	4.25	4.00	3.22
Prawns/shrimps	Square	1.00	1.25	1.00	1.25	1.00	0.75	1.00	1.50	1.09
	Diamond	1.00	1.25	0.75	1.25	1.00	1.25	1.50	1.00	1.12
Stomatopods	Square	0.50	0.00	0.00	1.00	0.25	0.75	0.75	0.50	0.50
	Diamond	0.25	0.50	0.75	0.00	0.75	0.25	0.50	0.00	0.34
Miscellaneous	Square	1.50	2.00	2.50	1.75	2.00	1.50	2.25	2.00	1.94
	Diamond	2.00	2.75	1.50	2.00	2.25	2.25	2.00	3.50	2.28
TOTAL	Square	13.00	18.50	22.75	21.75	16.50	15.25	27.25	21.50	19.56
	Diamond	16.50	16.00	15.25	22.00	27.25	26.00	21.50	17.75	20.28

Table: 34 Average catch compositions (kg/haul) of different fish/shellfish groups caught in the HOBT with 30mm mesh size cod end

Groups/species	HOBT Mesh shape	Sampling month								
		Oct	Nov.	Dec	Jan	Feb	March	April	May	Average
Anchovies	Square	0.50	0.25	0.50	0.25	.75	0.25	0.00	.00	0.31
	Diamond	1.00	0.50	0.75	0.75	0.00	0.25	1.00	0.75	0.50
Pomfrets	Square	0.50	1.00	1.25	0.75	.075	1.00	1.50	1.50	1.03
	Diamond	0.75	1.00	1.25	0.75	1.00	1.50	2.00	1.50	1.22
Pink perch	Square	4.00	4.25	3.50	3.50	6.00	2.50	3.50	4.00	3.90
	Diamond	5.00	6.50	4.75	6.25	3.50	3.00	4.50	4.00	4.45
Ribbonfish	Square	1.50	1.75	2.00	3.00	1.50	1.75	1.75	2.00	1.94
	Diamond	1.75	2.25	3.25	1.50	2.50	2.25	1.75	0.00	1.91
Lactarius	Square	0.00	0.50	0.75	1.25	1.00	0.75	1.00	0.00	0.66
	Diamond	1.50	1.25	0.75	0.50	1.00	1.25	1.00	1.50	1.03
Flatfish	Square	0.50	0.75	0.25	0.75	0.50	0.50	1.00	1.50	0.66
	Diamond	1.00	0.75	1.25	1.00	1.00	1.50	1.25	1.25	1.13
Mackrel	Square	0.00	0.00	0.00	0.00	1.50	1.00	1.50	1.50	0.69
	Diamond	0.00	0.00	0.00	0.00	2.00	1.75	1.75	0.50	0.75
Silver-bellies	Square	0.50	1.25	0.75	0.75	1.00	1.75	1.50	1.50	1.10
	Diamond	0.50	1.50	1.75	0.75	1.00	1.50	1.25	1.25	1.19
Lizardfish	Square	0.00	0.00	0.50	0.50	1.25	1.00	1.00	1.25	0.69
	Diamond	0.00	0.00	0.00	1.50	1.00	0.75	1.25	1.50	0.81
Clupeids	Square	0.25	0.25	0.75	0.50	1.00	1.50	1.50	1.00	0.84
	Diamond	0.00	0.50	0.75	1.50	2.00	1.75	1.00	3.00	1.31
Cephalopods	Square	1.75	2.00	2.75	2.75	2.00	3.50	1.75	1.50	2.28
	Diamond	2.00	2.50	2.75	1.75	3.00	3.50	2.75	1.25	2.24
Prawns/shrimps	Square	0.75	1.00	1.25	1.00	0.75	0.00	0.75	0.50	0.75
	Diamond	0.75	1.25	1.00	2.75	0.25	0.25	1.00	0.25	0.69
Stomatopods	Square	0.50	0.25	0.00	0.25	0.00	0.75	0.25	0.25	0.28
	Diamond	0.00	0.75	0.50	0.50	0.00	0.00	0.25	0.25	0.28
Miscellaneous	Square	1.50	2.50	3.00	2.50	1.75	2.00	1.75	1.00	2.00
	Diamond	2.50	3.00	2.00	2.25	1.75	1.00	2.50	2.75	2.22
TOTAL	Square	12.25	15.25	17.25	17.75	19.75	18.25	18.75	17.50	16.92
	Diamond	16.75	21.75	20.75	19.75	20.00	20.25	23.25	21.75	20.53

Table: 35. Average catch composition (kg/haul) of different fish/shellfish groups caught in the HOBT with 40mm mesh size cod end

Groups/species	HOBT Mesh shape	Sampling month								
		Oct	Nov.	Dec	Jan	Feb	March	April	May	Average
Anchovies	Square	0.50	0.25	0.50	0.25	.75	0.25	0.00	.00	0.31
	Diamond	1.00	0.50	0.75	0.75	0.00	0.25	1.00	0.75	0.50
Pomfrets	Square	.50	1.00	1.25	0.75	.075	1.00	1.50	1.50	1.03
	Diamond	.75	1.00	1.25	0.75	1.00	1.50	2.00	1.50	1.22
Pink perch	Square	2.00	3.50	1.50	1.00	2.00	1.00	1.50	1.50	1.75
	Diamond	1.50	3.00	2.25	1.25	2.00	2.50	1.75	1.00	2.22
Ribbonfish	Square	1.50	2.00	1.00	2.50	1.75	1.25	1.75	2.00	1.72
	Diamond	1.75	2.50	2.50	1.50	2.25	2.25	1.75	1.00	1.86
Lactarius	Square	0.00	0.75	0.75	0.00	0.50	0.75	0.00	0.00	0.34
	Diamond	1.00	1.25	1.00	0.00	0.50	0.75	1.50	0.50	0.86
Flatfish	Square	0.00	0.00	0.50	0.00	0.00	0.50	1.25	1.00	0.41
	Diamond	0.75	0.50	0.25	0.50	0.75	0.75	1.25	1.50	0.66
Mackrel	Square	0.00	0.00	0.00	0.00	2.00	1.75	1.75	2.00	0.94
	Diamond	0.00	0.00	0.00	0.00	3.00	2.00	2.00	2.50	1.10
Silver-bellies	Square	0.50	0.50	0.00	1.00	1.00	0.75	1.50	1.50	0.84
	Diamond	0.75	1.00	1.25	1.00	0.75	1.25	1.00	0.00	1.20
Lizardfish	Square	0.00	0.00	0.25	0.50	0.50	0.50	0.50	0.25	0.31
	Diamond	0.00	0.25	0.25	0.50	0.50	0.00	0.25	0.00	0.21
Clupeids	Square	0.25	0.25	0.25	0.50	0.25	0.75	1.00	0.50	0.47
	Diamond	0.00	0.00	0.50	0.25	0.50	0.00	0.00	3.25	0.16
Cephalopods	Square	1.50	1.75	1.50	2.00	1.50	1.00	1.00	2.50	1.50
	Diamond	2.00	3.50	1.75	2.25	1.75	2.00	2.00	0.75	0.30
Prawns/shrimps	Square	0.00	0.00	0.50	0.25	0.50	0.00	0.25	0.50	0.25
	Diamond	0.00	0.00	0.50	0.75	1.25	1.00	0.50	0.50	0.60
Stomatopods	Square	0.25	0.25	0.00	0.00	0.50	0.00	0.25	0.25	1.90
	Diamond	0.00	0.50	0.00	1.00	0.25	0.25	0.50	2.00	0.38
Miscellaneous	Square	0.50	1.00	1.25	1.25	1.00	0.75	0.50	1.00	0.91
	Diamond	1.25	1.00	1.75	2.00	1.50	1.75	2.00		1.70
TOTAL	Square	7.25	11.00	9.00	9.50	12.50	10.00	12.75	12.50	10.56
	Diamond	11.00	15.50	14.25	12.50	16.00	15.75	16.75	18.50	15.03

which the lowest catch (16.75 kg/haul) was recorded in the month of October. During April, the catch/haul was higher in both the HOBTs with 40 mm diamond (12.75 kg) and square (16.75 kg) meshed codends (Table 4). The lowest catches of 7.25 kg/haul and 11.00 kg/haul were recorded in HOBT with square mesh and diamond mesh codend respectively in October. On an average, total catch for the entire period of investigation was 10.56 kg/haul and 15.03 kg/haul respectively for HOBTs with square meshed and diamond meshed codends.

Group-wise monthly catch rates of HOBTs with 20, 30 and 40 mm mesh sizes are listed in Tables 33, 34 and 35. During the present investigation, about 14 different groups of fish/shellfish contributed to the catch composition. Among the most prominent groups were threadfin breams, ribbonfishes and cephalopods. Other groups, anchovies, pomfrets, Lactarius, mackerel, silver bellies and, clupeids also contributed to the catch. From the above listed tables it can be seen that. The total catches per haul in case of HOBTs with square meshed codends of 20, 30 and 40 mm were poorer than HOBTs with diamond meshed codends. The data from HOBTs with 20, 30 and 40 mm square meshed codends imply a decline of catch to the tunes of 2.62%, 17.59% and 29.75% respectively.

5.6.4.2. Escapement of juveniles

Selectivity data may be obtained by attaching a small-meshed (usually 15-30 mm stretched mesh) cover over codend or other parts of the trawl to retain animals escaping trough the trawl (Beverton and Ilolt, 1957; and Pope *et al.,* 1975). The use of such covers has been criticized on the grounds of its masking effect on codend meshes (Davis, 1934; Pope *et al.*, 1985). Investigation of Stewart and Robertson (1985) has indicated that a cover, which is 1.5 times the length and width of a codend is unlikely to obstruct the codend meshes (Fig. 6). Use of hoop to keep the cover separated from codend may improve the performance (DFO, 1995). Accordingly, for the present study, 10 mm nylon cover codend with hoop made out of steel was used. It is a simple procedure in which a commercially used trawl design was adapted. Maximum care was taken to avoid the masking effect during the study period.

The average weight and percentage of escapement of juveniles through square and diamond meshed codends of 20, 30 and 40 mm mesh size are presented in the Tables 36,37 and 38. The highest percentage of retention (94.63 %) was recorded in 20 mm square meshed codend. In the HOBT with diamond meshed codend the retention was full 100% in January. On an average, percent of retention was 93.13 % and 97.03 % in square and diamond meshed codends. The percentage of escapement through 20 mm square meshed codend varied from 5.21 to 9.26 %. Through diamond-meshed codend, the escapement of juveniles was none to 7.25 %. The highest percentage of escapement (9.26 %) was noticed in the month of November and the least during January. In case of HOBT with square meshed codend, an average 6.87% escapement of juveniles was discernible *vis a vis* 2.97% noticed in diamond meshed codend.

Escapement of juveniles through HOBTs with 30 and 40 mm square and diamond-meshed codends was higher (Table 5) than through their corresponding HOBTs with 20 mm mesh size. On an average, 15.18 % and 8.53 % escapement of juveniles and immature fishes was noticed in larger square and diamond meshed codends. Maximum catch of 23.25 kg/haul was recorded during January with square mesh codend. Out of this 76.34 % was found in the inner codend, which constituted the main catch and 23.66% of bycatch consisting of undersized and immature fishes in the outer codend. A highest quantity of 2.5 kg (10.99 %) escaped through the diamond mesh codend and minimum of 1.00 kg (4.76 %) was recorded.

The average total catch and percentages of escapement of juveniles through square and diamond meshed codends of 40 mm mesh size is presented in Table 38. It can be observed that the average total catch rate for both the codends are 13.86 kg/haul and 17.84 kg/haul respectively in square and diamond meshed codends. Among the two types of codends, the average total catch rate for diamond shaped codend was higher (17.3 kg) than that of the square meshed codend (13.86 kg/haul) regarding escapement of juveniles, the percentage of escapement varies from 27.50 % to 45.71 % in square meshed codend on other hand the same was ranged in between 8.33 to 17.11 % in diamond mesh codend. However, the comparison of escapement in square mesh codend is for superior than that of diamond-meshed codend. Among the different mesh size (20, 30 and 40 mm) square meshed codend,

Table 36. Escapement of juveniles through HOBT with square and diamond meshed codend of 20 mm mesh size during this investigation

Sampling month	Catch (Kg.) in HOBT with square mesh codend					Catch (Kg.) HOBT with diamond mesh codend				
	Total catch	Inner codend		Escapement of juveniles		Total catch	Inner Codend		Escapement of juveniles	
		catch	% of total catch	catch	% escapement		catch	% of total catch	Catch	% escapement
October	14.25	13.00	91.23	1.250	8.77	17.00	16.50	97.05	0.50	2.95
November	13.50	12.25	90.74	1.25	9.26	17.25	16.00	92.75	1.25	7.25
December	20.25	18.50	91.36	1.75	8.64	15.50	15.25	98.38	0.25	1.62
January	24.00	22.75	94.79	1.25	5.21	22.0	22.00	100.00	0.00	0.00
Febraury	24.75	22.75	91.92	2.00	8.08	27.75	27.25	98.18	0.50	1.82
March	16.50	15.50	93.94	1.00	6.04	26.75	26.00	97.19	0.75	2.81
April	23.00	21.75	94.56	1.25	5.44	22.50	21.50	95.55	1.00	4.45
May	22.75	21.50	94.63	1.25	5.37	18.50	17.75	95.94	0.75	4.06
Average	19.87	18.50	93.13	1.37	6.87	20.90	20.28	97.03	0.62	2.97

Table: 37. Escapement of juveniles through through square and diamond meshed codend of 30 mm mesh size during this investigation

Months	Catch (Kg.) in HOBT with square mesh codend					Catch (Kg.) HOBT with diamond mesh codend				
	Total average catch	Inner Codend		Escapement of juveniles		Total aver age catch	Inner Codend		Escapement of juveniles	
		Quantity	Percentage of catch	Quantity	Percentage of escapement		Quantity	Percentage of catch	Catch	Percentage of escapement
October	14.50	12.25	84.48	2.25	15.52	18.75	16.75	89.33	2.00	10.67
November	17.50	15.75	90.00	1.75	10.00	24.25	21.75	89.69	2.50	10.31
December	20.75	17.25	83.33	3.50	16.67	22.50	20.75	92.22	1.75	7.78
January	23.25	17.75	76.34	5.50	23.66	22.25	19.75	88.76	2.50	11.24
Febraury	22.50	19.75	87.78	2.75	12.22	21.00	20.00	95.24	1.00	4.76
March	21.50	18.25	84.88	3.25	15.12	22.75	20.25	89.01	2.50	10.99
April	19.75	18.75	94.94	1.00	5.06	24.75	23.25	93.93	1.50	6.07
May	22.00	17.50	79.54	4.50	20.46	23.0	21.75	94.56	1.25	5.44
Average	20.22	17.15	84.82	3.07	15.18	22.41	20.50	91.47	1.91	8.53

Table: 38. Escapement of juveniles through HOBT with square and diamond meshed codend of 40 mm mesh size during this investigation

Months	Catch (Kg.) in HOBT with square mesh codend					Catch (Kg.) HOBT with diamond square mesh codend				
	Total average catch	Inner Codend		Escapement of juveniles		Total average catch	Inner Codend		Escapement of juveniles	
		Quantity	Percentage of catch	Quantity	Percentage of escapement		Quantity	Percentage of catch	Quantity	Percentage of escapement
October	10.25	7.25	0.73	3.25	29.27	12.00	11.00	91.67	1.00	8.33
November	12.00	11.00	91.67	1.00	8.33	17.50	15.50	88.57	2.00	11.43
December	14.00	9.00	64.29	5.00	35.71	17.50	14.25	81.43	3.25	18.57
January	11.75	9.50	80.85	2.25	19.15	15.00	12.50	83.33	1.50	16.67
Febraury	17.50	12.50	71.43	5.00	28.57	18.75	16.00	85.33	2.75	14.67
March	14.75	10.00	67.79	4.75	32.21	19.00	15.75	82.89	3.25	17.11
April	15.25	12.75	83.61	2.50	16.39	18.75	16.75	89.33	2.00	10.67
May	15.50	12.50	80.65	3.00	19.35	20.25	18.50	91.36	1.75	8.64
Average	13.86	10.56	76.19	4.59	23.81	17.34	15.03	86.67	2.19	13.33

the total catch was found to be more (20.22 kg/haul) when compared to 20 mm (19.87 kg/haul) and 40 mm (13.86 kg/haul) codends. The percentage of escapement was maximum (35.50%) in case of 40 mm. followed by 30 mm (15.18%) and 20 mm (6.87%) square meshed codends. However the escapement of juveniles in 20,30 and 40 mm were said to be minimum 0.62, 1.91 and 2.19% respectively in diamond shaped codends.

The shape of mesh is known to affect the selectivity of codends (Pope, 1966; Robertson, 1986). As the central section of the diamond meshed codend stretches and closes preventing the escape of small fish, the percentage of escapement was smaller. As evidenced in the present study, more escapements could be achieved by using square mesh codends as the mesh will remain open while in operation. The superiority of square mesh over diamond mesh in facilitating escapement of juvenile fish has been reported by many workers (Robertson, 1982; 1983a, b; 1984 and 1986; Robertson and Polanski, 1984; Robertson *et al.* 1986; Robertson and Stewart, 1988; Varghese *et al.* (1989) and Kunjipalu *et al.* 1994). Varghese and Kunjipalu (1996) reported that the mean selection length was greater for square meshes indicating the superiority of the square mesh in releasing more juveniles. Further, Kunjipalu *et al.* (1996) reported that 27.3% of escapement of juveniles of fin-fish, shrimps and squids. Badami (2005) reported the escapement of over 19.19% juveniles in 30 mm square meshed codend, which also is, more than the one observed during the present investigation. The catch rates of reference gear was 1.7 times more than that of experimental gear and the average by catch landing of reference gear was about 35% higher than the experimental gear. However, the difference in by catch landing by these gears was not found to be statistically significant.

5.6.5. Threadfin bream

Threadfin bream is also called pink perch constitutes an important demersal finfish resource in the EEZ. These fishes are abundant beyond 50m with much higher concentration at 100-200 m depth-zone as revealed by the exploratory survey and experimental fishing (Sreeramchandramurthy *et al.*, 2003). After the introduction of stay-over fishing in late nineties, fishing operations up to 150 m depth increased landings of threadfin breams phenomenally. Landings of threadfin breams during 2002 amounted to 111051 tons and contributed to 4.2% of the total marine landings of the country (Sreeramchandra Murty *et al.*, 2003). The highest estimated landing of thread fin breams was along Gujarath and Maharastra coast followed by Mangalore, Malpe and Kochi. The total perch landings on Karnataka fluctuated from about 1900 ton in 1985 to 10,000 tons in 1988. There was an increasing trend in the perch landings till 1988 then landings dropped to 4600 tons on 1989 (Alagaraja *et al.*, 1994). Landing in the first quarter were always higher than those in other quarter. Major contributions come from the single day trawlers and multiday trawlers.

Length frequency studies revealed that dominant mode at Veraval was 110 mm. while off Mumbai and Mangalore the modes were 195 mm and 110 mm respectively (Sreeramchandramurthy *et al.*, 2003). Along the West coast, its spawning season is during October – November. In the present study the length range of pink perch caught in HOBT with square meshed codend was 7.00 to 21.00 cm and HOBT with diamond-meshed codend is 5.00 to 21.00 cm (Table 39). The peak frequencies caught in HOBT with diamond-meshed codend were higher than that with HOBT with square meshed codend. The median length of pink perch caught in HOBT with 20 mm square meshed codend is 10.50 cm, with 30 mm it is 14.00 cm and with 40 mm it is 16.10 cm In case of HOBT with diamond meshed codend the median length respectively is 9.5, 12 and 14.80 cm in 20, 30 and 40 mm mesh sizes (Fig. 38).

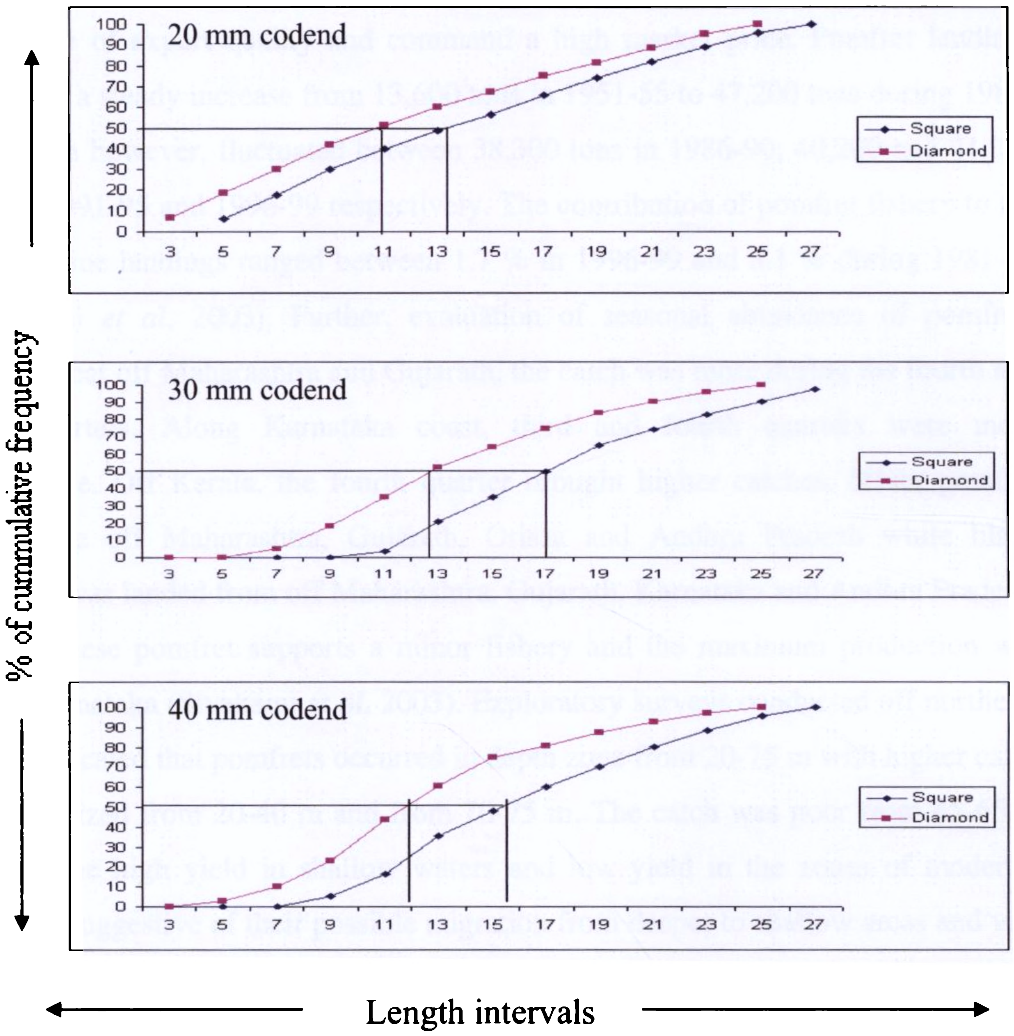
According to Vivekanandan and James (1986) the fish measuring a length of 14.50 cm are matured ones and all the fish below the size are regarded as juveniles. Earlier, Acharya and Dwivedi (1981) reported that the size at first maturity of pink perch is 15.50 cm in males and 11.50 cm in females. It is therefore apparent that both the gears with 30 mm and 40 mm meshes caught matured fishes. HOBT with 20 mm and 30 mm diamond meshed codend retained respectively the immature individuals and size range close to first maturity. Length frequency of pink perch is a maximum of 1141 for HOBT with square meshed codend and 1322 in case of HOBT with diamond-meshed codend. Higher contribution indicates that higher sized commercially valuable species contributed a higher number of the total catch in all HOBT with square mesh codends when compared to HOBT with diamond mesh codends. Results from this investigation compare very closely to those of

Table: 39. Length frequency distribution of threadfin bream caught in HOBT with different mesh sizes and shapes of codend

Mid class Interval (cm)	Square meshed		Diamond meshed	
	F	% of CF	F	% of CF
20 mm mesh				
1	0		171	6.59
3	148	6.43	315	18.72
5	261	17.76	300	30.28
7	287	30.22	297	41.72
9	219	39.73	242	51.04
11	203	48.54	237	60.17
13	182	56.44	188	67.41
15	214	65.73	206	75.35
17	193	74.11	160	81.57
19	180	81.92	185	88.70
21	163	89.20	176	95.48
23	157	95.82	117	100
25	91	100		
30 mm mesh				
5	0		57	2.96
7	98	5.11	133	9.87
9	213	16.22	254	23.06
11	371	35.57	403	43.98
13	241	48.14	315	60.34
15	230	60.14	278	74.77
17	201	70.03	119	80.95
19	189	80.49	122	87.28
21	155	88.57	107	92.84
23	138	95.77	85	97.25
25	83	1	53	100
40 mm mesh				
7	38	3.37	78	4.88
9	196	20.75	214	18.29
11	257	43.53	269	35.15
13	129	55.00	271	52.13
15	113	65.02	189	63.97
17	100	73.89	168	74.50
19	98	82.58	145	83.58
21	85	90.12	107	90.29
23	83	97.48	91	95.99
25	29	100	64	100

F = Frequency of distribution and, CF = cumulative frequency of distribution

Fig 38: Median lengths of 50% threadfin bream caught in different sized, square or diamond meshed codends on HOBT



Talwar (1997) and Badami (2005). These authors had reported higher quantity of catch in diamond meshed codend and bigger sized and more valued fishes in the square mesh codend.

5.6.6. Pomfrets:

Pomfrets are delicious food fish available along the Indian coast. These fishes are of export quality and command a high market price. Pomfret landings indicated a steady increase from 13,600 tons in 1951-55 to 47,200 tons during 1981-85, which however, fluctuated between 38,300 tons in 1986-90; 40,200 and 41,000 during 1991-95 and 1996-99 respectively. The contribution of pomfret fishery to the total marine landings ranged between 1.7 % in 1996-99 and 3.1 % during 1981-85 (Sivakami *et al*, 2003). Further, evaluation of seasonal abundance of pomfrets showed that off Maharashtra and Gujarath, the catch was more during the fourth and first quarters. Along Karnataka coast, third and fourth quarters were more productive. Off Kerala, the fourth quarter brought higher catches. Silver pomfret was more off Maharashtra, Gujarath, Orissa and Andhra Pradesh while black pomfret was landed from off Maharashtra, Gujarath, Karnataka and Andhra Pradesh. The Chinese pomfret supports a minor fishery and the maximum production was from Karnataka (Sivakami *et al*, 2003). Exploratory surveys conducted off northeast coast indicated that pomfrets occurred in depth zone from 20-75 m with higher catch rates realized from 20-40 m and from 70-75 m. The catch was poor from 45-65 m depth. The high yield in shallow waters and low yield in the zones of moderate depth is suggestive of their possible migration from deeper to shallow areas and vice versa (Sivakami *et al.*2003).

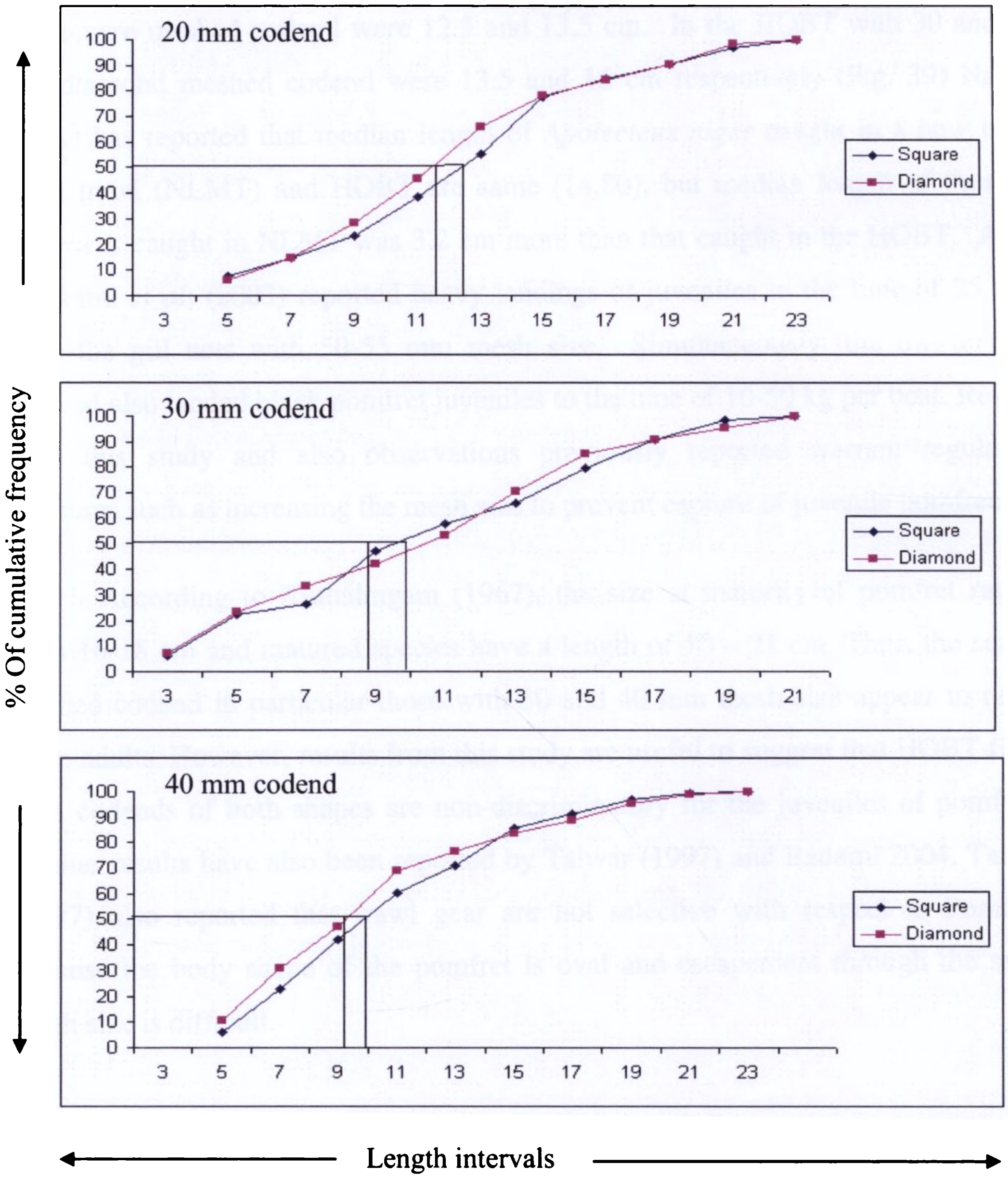
Length frequency distribution of pomfrets caught in HOBT with square meshed codend and HOBT with diamond-meshed codend are presented in the Table 40. Individuals of pomfrets caught in HOBT with square meshed codends of 20, 30 and 40mm mesh sizes were in the length ranges of 5 to 23 cm. In case of diamond meshed codends, also they were in the same range. More numbers of pomfrets were caught in diamond mesh codends during the course of the study. However, Talwar (1997) reported that pomfrets caught in experimental gear were higher than those caught in experimental gear of 30 mm square meshed codend.

Table: 40. Length frequency distribution of pomfrets caught in HOBT with different mesh sizes and shapes of codend

Mid class Interval (cm)	Square meshed		Diamond meshed	
	F	% of CF	F	% of CF
20 mm mesh				
5	25	7.81	21	6.14
7	22	14.69	30	14.91
9	28	23.44	47	28.65
11	49	38.75	58	45.61
13	53	55.31	69	65.78
15	71	77.50	42	78.06
17	24	85.00	21	84.20
19	17	90.31	21	90.34
21	22	97.19	28	98.53
23	9	100	5	100
30 mm mesh				
5	14	5.98	20	7.14
7	38	22.20	45	23.21
9	10	26.47	29	33.57
11	48	46.98	24	42.14
13	25	57.66	31	53.21
15	19	65.78	48	70.35
17	33	79.88	42	85.30
19	26	90.99	16	91.01
21	17	98.25	13	95.65
23	4	100	8	100
40 mm mesh				
5	17	6.09	28	10.89
7	47	22.94	51	30.73
9	54	42.29	42	47.07
11	50	60.21	56	68.86
13	30	70.96	20	76.64
15	42	86.01	18	83.64
17	15	91.39	16	88.87
19	16	97.12	14	95.32
21	7	99.60	10	99.21
23	1	100	2	100

F = Frequency of distribution and, CF = cumulative frequency of distribution

Fig 39: Median lengths of 50% pomfret caught in different sized, square or diamond meshed codends on HOBT



Among the square meshed codends, the highest numbers of individuals were caught in 20 mm meshed ones followed by those of 40 mm and 30n mm. In case of 30 mm codend similar results were also reported by Badami (2005). In the present study, the median length of pomfrets caught using HOBT with 20 mm square meshed codend was 11.50 cm and in HOBT with diamond meshed codend it is 11.50 cm (Fig. 39). The length ranges of pomfrets caught in HOBT with 30 and 40 mm square meshed codend were 12.5 and 13.5 cm. In the HOBT with 30 and 40 mm diamond meshed codend were 13.5 and 16 cm respectively (Fig. 39) Nayak (1991) has reported that median length of *Apolecteus niger* caught in a new large mesh trawl (NLMT) and HOBT are same (14.80), but median length of *Pampus argenteus* caught in NLMT was 3.2 cm more than that caught in the HOBT. Also, Sivakami *et al*, (2003) reported heavy landings of juveniles to the tune of 25 tons from the gill nets with 50-55 mm mesh size. Simultaneously, the trawlers off Veraval also landed black pomfret juveniles to the tune of 10-50 kg per boat. Results from this study and also observations previously reported warrant regulatory measures such as increasing the mesh size to prevent capture of juvenile pomfrets.

According to Kuthalingam (1967), the size at maturity of pomfret ranges from 16-18 cm and matured species have a length of 10 – 21 cm. Thus, the square meshed codend in particular those with 30 and 40 mm mesh size appear to retain more adults. However, results from this study are useful to suggest that HOBT fitted with codends of both shapes are non-discriminatory for the juveniles of pomfrets. Similar results have also been reported by Talwar (1997) and Badami 2004. Talwar (1997) also reported that trawl gear are not selective with respect to Pomfrets because the body shape of the pomfret is oval and escapement through the small mesh size is difficult.

5.6.7. Ribbon fish

The ribbonfish forms major and abundant fishery resources among marine pelagic finfishes of Indian seas. They are essentially marine, but occur in estuarine too. They are distributed all along the Indian coasts with abundance in the northwest and central east coasts. Large fishes are consumed fresh and even transported to the interior markets, but the smaller ones, in excess of the local requirements, are usually sun-dried. In recent years, the marketing scenario of ribbonfish has undergone drastic change as it has gained a position in the export market. Currently, large quantities of ribbon fishes are exported in the frozen form to China, Japan and other south-east Asian countries. The frozen ribbonfish exported accounted for 62,942 tons in 1999- 2000 and 1,33,536 tons in 2000-2001, which realized Rs. 161.94 crores and Rs. 363.37 crores respectively (Anon, 2003b). This shows that the ribbon fish resource plays a key role in India's marine products export.

Accounting 91% of the total fish landings (Balan *et al.* 2005), the average annual ribbonfish production from the west coast is estimated at 1.31 lakh tons. All the five maritime states along the west coast have a share of this resource. The landings peaked in 2000 (1.8 lakh tons) and were the lowest in 1995. Their landings from Karnataka coast saw increases from 34.66% to 46.7% of the national total during 2000 (Radhakrishan *et al.*, 2001). Trawl net has been the dominant gear contributing 94% of their total landings. Of the five ribbonfish species, *Trichiurus lepturus* and *Lepturaconthus savala* contribute to the bulk of the fishery in Karnataka. The peak season for *T. lepturus* is between June and September in Kerala and, between October and December in Karnataka. These species are caught mainly from 4 – 50m depth zone by trawl net and gill net in Karnataka. Many ribbon fish species are known to perform diurnal vertical migration and, found close to the bottom during day time and ascend to the vertical water column and disperse at night (Rao *et al.,* 1977).

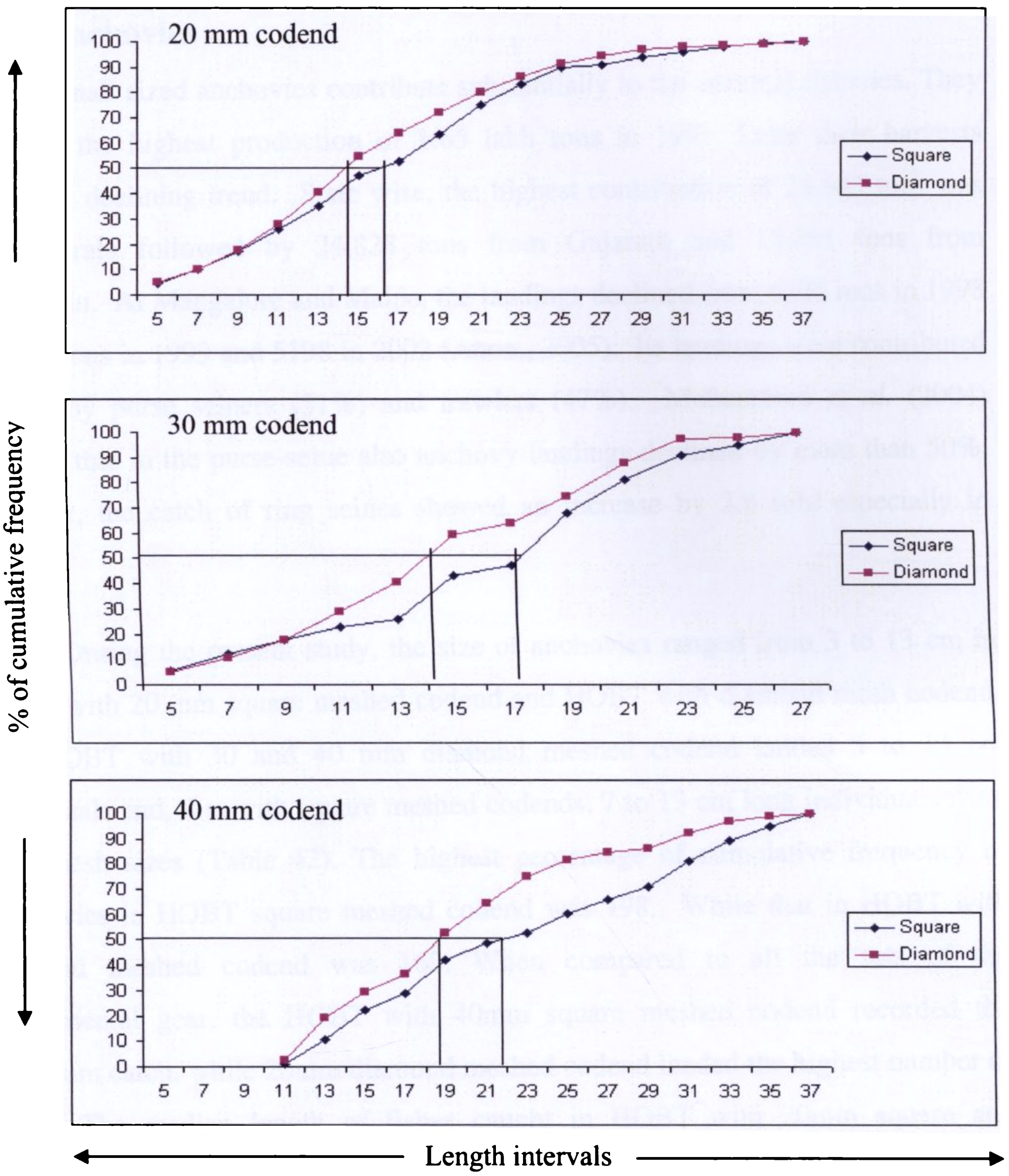
With a known prolonged spawning all through the year, the length frequency data from fishes collected off Mangalore suggest that the ribbon fishes attain 39.1, 58.7, 70.8 and 82.8cm respectively at the end of I, II, III and IV year of their life (Anon., 2006). Rao *et al.* (1977) have also reported similar condition for this species from other regions along the west coast. Maximum size of *Trichiurus sp.* caught during the study period was 37 cm, and minimum size was 5.0 cm. (Table 41). In general, the number of larger sized *Trichiurus sp.* caught in HOBT with diamond meshed codends is higher than that caught in the HOBT with square meshed codends. The median lengths of fishes caught in 20, 30 and 40 mm square meshed codends are 12, 15.80 and 19cm and, in diamond meshed codends, 14.20, 17 and 22 cm (Fig. 40) respectively. From the much smaller sized individuals caught during the study, it is clear that they are all in their immature stage as Bal and Rao

Table: 41. Length frequency distribution of ribbon fishes caught in the HOBT with different mesh sizes and shapes of codend

Mid class Intervals (cm)	Square meshed		Diamond meshed	
	F	% of CF	F	% of CF
		20 mm mesh		
5	62	4.36	81	5.13
7	85	10.33	80	10.20
9	98	17.22	114	17.62
11	121	25.73	169	28.13
13	135	35.22	200	40.80
15	173	47.39	218	54.61
17	80	53.02	151	64.18
19	145	63.43	128	72.29
21	167	75.17	127	80.34
23	117	83.40	94	86.30
25	91	89.80	80	91.37
27	18	91.07	49	94.48
29	41	93.95	36	96.76
31	30	96.06	19	97.96
33	30	98.17	8	98.47
35	18	99.30	10	99.10
37	11	100	14	100
		30 mm mesh		
5	40	5.41	49	4.85
7	50	12.17	57	10.49
9	40	17.58	72	17.61
11	40	22.99	114	29.00
13	20	25.69	120	40.80
15	130	43.26	190	59.61
17	30	47.31	44	63.97
19	150	67.88	110	74.87
21	100	81.29	131	87.84
23	80	91	95	97.25
25	30	95.10	28	98.02
27	30	100	12	100
		40 mm mesh		
11	8	1.09	30	2.77
13	72	10.86	181	19.46
15	86	22.53	109	29.51
17	48	29.04	74	36.34
19	97	42.20	180	52.95
21	49	48.85	124	64.39
23	30	52.92	119	75.37
25	56	60.52	70	81.82
27	40	65.94	32	84.77
29	37	70.96	14	86.06
31	76	81.27	70	92.52
33	58	89.14	50	97.12
35	41	94.70	19	98.87
37	39	100	12	100

F = Frequency of distribution and, CF = cumulative frequency of distribution

Fig 40: Median lengths of 50% ribbonfish caught in different sized, square or diamond meshed codends on HOBT



(1990) reported the minimum size at maturity to be 47 to 48 cm for *Trichiurus sp.* However, a few bigger sized fishes were caught in 40 mm square meshed codend. Talwar (1997) have also concluded that 28 mm square mesh codend is not selective for *Trichiurus* spp.

5.6.8. Anchovies

Small sized anchovies contribute substantially to the national fisheries. They recorded the highest production of 1.65 lakh tons in 1991. Later their harvests showed a declining trend. State wise, the highest contribution of 25,643 tons was from Kerala followed by 24,828 tons from Gujarath and 18,391 tons from Tamilnadu. At Mangalore and Malpe, the landings declined from 6225 tons in 1998 to 5213 tons in 1999 and 5198 in 2002 (Anon., 2005). Its landings were contributed equally by purse seiners (51%) and trawlers (47%). Mohammad *et al.* (2004) reported that in the purse-seine also anchovy landings declined by more than 50%. However, the catch of ring seines showed an increase by 3.8 fold especially in Kerala.

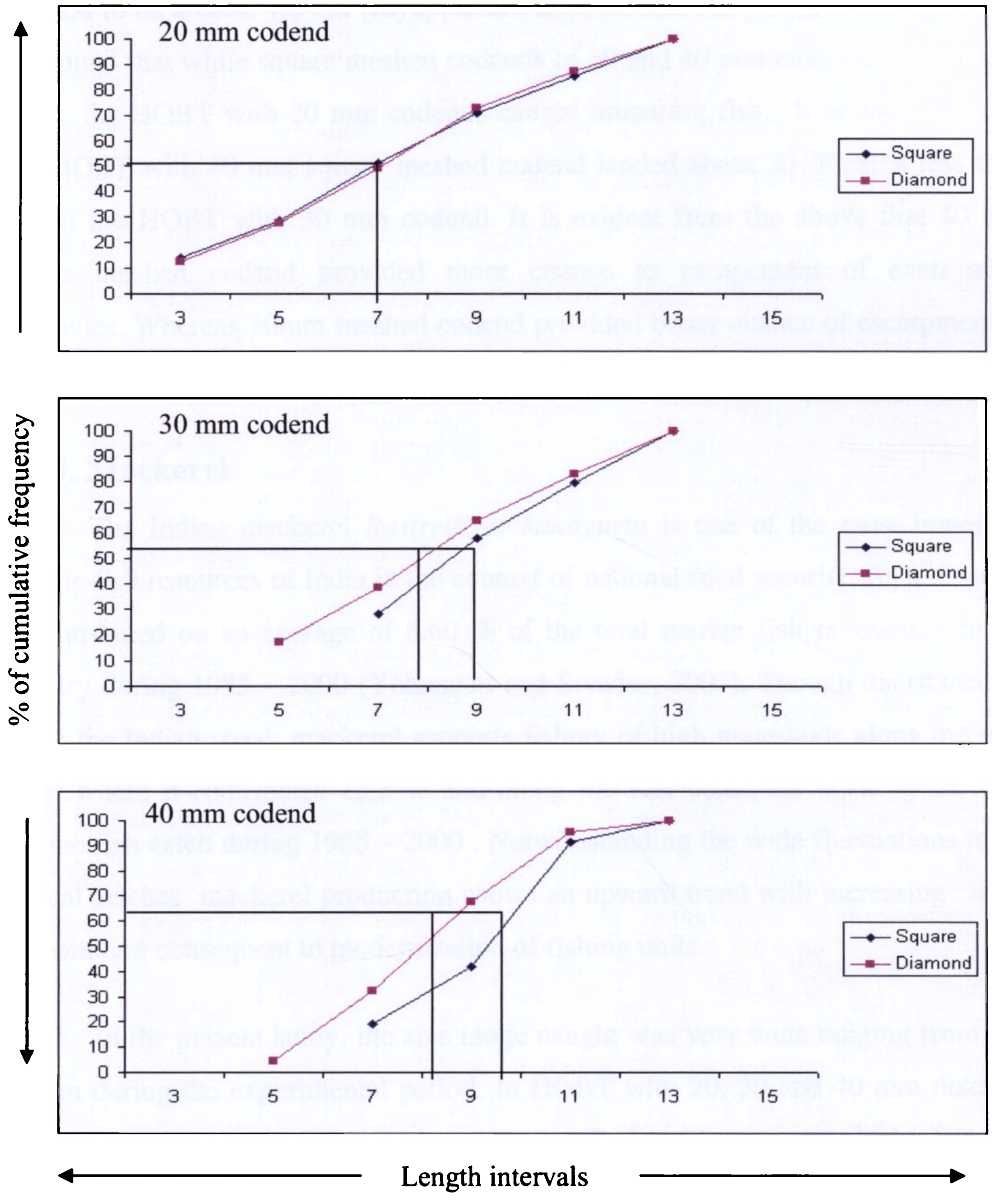
During the present study, the size of anchovies ranged from 3 to 13 cm in HOBT with 20 mm square meshed codend and HOBT with diamond mesh codend. The HOBT with 30 and 40 mm diamond meshed codend landed 5 to 13 cm individuals and, that with square meshed codends, 7 to 13 cm long individuals from both mesh sizes (Table 42). The highest percentage of cumulative frequency of Anchovies in HOBT square meshed codend was 198. While that in HOBT with diamond meshed codend was 160. When compared to all the sets of the experimental gear, the HOBT with 40mm square meshed codend recorded the minimum catch, while 20mm diamond meshed codend landed the highest number of fishes. The median length of fishes caught in HOBT with 20mm square and diamond meshed codend respectively are 6.8 and 7.1cm, with 30mm mesh size: 7.5 and 7.8 and, with 40 mm mesh size: 7.5 and 9.8 cm (Fig. 41). Kunjipalu *et a.l* (2001) reported almost 100% escapement of juveniles and sub-adults of 20 to 60 mm was found to be in the 20 to 40 mm mesh sizes. During this study, the escapement of juveniles of increased length showed 0.00, 22.54, 4.92 and 75 % in 20, 30 and 40 mm meshed respectively.

Table: 42. Length frequency distribution of anchovies caught in the HOBT with different mesh sizes and shapes of codend

Mid class Interval (cm)	Square meshed		Diamond meshed	
	F	% of CF		F
20 mm mesh				
3	110	14.23	I08	12.81
5	113	28.85	126	27.76
7	173	51.23	185	49.35
9	150	70.75	198	72.84
11	117	85.63	123	87.43
13	110	100	106	100
30 mm mesh				
5	0		115	17.45
7	150	27.99	138	38.39
9	160	57.85	173	64.65
11	118	79.86	121	83.00
13	108	100	112	100
40 mm mesh				
5	0		18	4.35
7	38	19.19	115	32.13
9	45	41.92	148	67.88
11	98	91.42	114	95.42
13	17	100	19	100

F = Frequency of distribution and, CF = cumulative frequency of distribution

Fig 41: Median lengths of 50% anchoves caught in different sized, square or diamond meshed codends on HOBT



In the present study, the catch of Anchoviella was restricted to the size group <10 cm length. Badami (2005) recorded the size group of 4.3 –10 cm in the square meshed codend while 3 – 9.80 cm size range were recorded in diamond meshed codend. The median lengths of the fishes were 6.20 and 5.30 cm in square meshed codend and diamond-meshed codend respectively. In the present study higher median lengths were recorded (Fig. 41) The length at first maturity of Anchovy is reported to be around 7.5 cm (Jayaprakash, 2003). From the present investigation it was found that while square meshed codends of 30 and 40 mm retained the matured fishes, the HOBT with 20 mm codends caught immature fish. It is was also seen that HOBT with 40 mm square meshed codend landed about 50 % catch less than that of the HOBT with 30 mm codend. It is evident from the above that 40 mm square meshed codend provided more chance to escapement of even adult anchovies. Whereas 30mm meshed codend provided better chance of escarpment to juveniles and sub adults.

5.6.9. Mackerel

The Indian mackerel *Rastrelliger kanagurta* is one of the most important pelagic fish resources of India in the context of national food security. As a resource it contributed on an average of 8.60 % of the total marine fish production in the country during 1985 – 2000 (Yohannan and Sivadas, 2003). Though distributed all along the Indian coast, mackerel supports fishery of high magnitude along the west coast where it contributes 10.2 % and along the east coast, ca. 4.9% of the total marine fish catch during 1985 – 2000 . Notwithstanding the wide fluctuations in the annual catches mackerel production shows an upward trend with increasing rate of exploitation consequent to modernization of fishing units.

In the present study, the size range caught was very wide ranging from 7 to 25 cm during the experimental period. In HOBT with 20, 30 and 40 mm diamond meshed codend, the smallest sizes caught were 7, 9 and 9 cm respectively. Whereas minimum sizes of 9, 11 and 13cm mackerels were landed in 20, 30 and 40mm square meshed codends respectively (Table 43). In the diamond meshed codends, the cumulative frequency distribution values were the highest (748) in 20 mm followed by 30mm diamond (575) and , 40 mm (413). In the square meshed codends, these values were the highest (344) in 20 mm followed by 30 mm diamond

(210) and, 40mm (Table 43). It is thus evedient that higher number of mackerel were landed in all the diamond shaped codends than the square meshed codends. The median values (Fig.42) for the fishes caught in each gear with diamond shaped codend were 13, 14, and 14.60 cm and HOBT with square meshed codends: 14, 16 and 16.80 cm respectively in 20, 30 and 40mm mesh sizes.

The size range of mackerel varied widely and Ogive curve (Fig.42) indicates that its median length caught in square meshed codend was higher (16.50 cm) than that caught in diamond meshed codend (14.70 cm). Bal and Rao (1990) have reported that the size of Indian mackerel is 22.40 cm at first sexual maturity and all individuals below this size are to be regarded as juveniles. Talwar (1997) also felt that juveniles mostly support the mackerel fishery. From the present study it is clearly evident that both square meshed and diamond meshed codends mostly caught juveniles of mackerel. Hence trawl gear with smaller meshed codends is not a suitable gear for catching mackerel, which is apparently shifting from pelagic to demersal habitats owing to changing temperature regimes as a consequence of climate change. According to Yohannan and Shivadas (2003) bulk of the catch from west coast is constituted by juveniles of age below one year, of size between 11 and 16 cm when they are around four months old. They appear in the fishery during July/August at a size of 6.0 cm when they are less than two months old. Along the west coast, they are heavily exploited when they are just three months old indicating the high fish mortality (2.5). Thus total mortality is around 5.14. On an average, the annual total stock along the Karnataka coast is estimated as 4.0 lakh tons of which 1.90 lakh tons are exploited. Exploitation beyond this level may not be economical under the present fishing efficiency. Moreover, the vulnerability of the stocks to the existing fishing fluctuates from year to year due to variation in stock density, which is related to fishery independent and fishery dependent factors. Under the present age at capture, the maximum sustainable yield from the resource is 2.20 lakh tons. The important factor that limits the yield of mackerel stock is the large-scale exploitation of the juveniles along the west coast. Fishes below the size of the 150 mm form almost 42% of the catch from the west coast. Increasing the size at first capture from 140 to 160 mm by controlling the exploitation during the recruitment or increasing the mesh size can resolve both these problems.

Table: 43. Length frequency distribution of mackerel caught in the HOBT with different mesh sizes and shapes of codend

Mid class Interval (cm)	Square meshed		Diamond meshed	
	F	% of CF	F	% of CF
20 mm mesh				
9	35	6.09	48	6.42
11	87	21.22	67	15.38
13	165	49.92	205	42.79
15	90	65.57	140	61.34
17	85	80.35	122	77.65
19	71	92.70	80	88.35
21	19	96.00	55	95.86
23	8	97.91	17	97.97
25	15	100	14	100
30 mm mesh				
9	0		21	5.08
11	14	4.22	26	12.61
13	29	12.95	50	24.72
15	46	26.80	65	40.56
17	91	54.21	92	62.83
19	85	79.81	88	84.14
21	49	94.55	25	90.19
23	10	97.60	28	96.07
25	8	100	18	100
40 mm mesh				
9	0		30	8.72
11	0		39	20.06
13	32	15.24	58	36.92
15	39	33.81	60	54.36
17	48	56.67	57	70.93
19	51	80.96	48	84.88
21	22	91.44	25	92.15
23	9	95.73	12	95.64
25	9	100	15	100

F = Frequency of distribution and, CF = cumulative frequency of distribution

5.7. Cephalopods

Edible cephalopods fall under three groups: cuttle fishes, squids and octopuses. Amongst squids there are two important species viz. *Loligo duvaucelli* and *Sepioteuthis lessoniana.* Due to flourishing export market, cephalopods are now highly priced and are in great demand. Mohamed *et al.* (2004) have reported that trawl units undertaking daily and multi-days voyages contribute more than 90% of the cephalopod catch. With the all India production estimated at 1,27,000 tons, their landing along the west coast accounts for the bulk. The increase in national production was mainly due to steep increase in landings at Mumbai, Mangalore, Malpe, Mandapam and Vizhinjam. Peak abundance of cephalopods during May, June, August, September and October was observed in Karnataka (Meiyappan and Mohamed). At Mangalore, the size ranges vary from 60 – 370 mm Large modal lengths were observed during post monsoon coinciding with the peak-breeding season. The annual mean length of *L. duvaucelli* was 149 mm at Mangalore. With heavy exploitation pressure in this region, the juvenile catch of cephalopods is to the tune of 51.40 tons aong Karnataka coast (Zacharia et al., 2006).

In the present study, the HOBT with square meshed codends landed squids ranging in size from 5.00 to 25.00 cm, 7.0 to 25, and 9.0 to 25 cm respectively in 20, 30 and 40 mm mesh sizes (Table 44). Where as in HOBT with diamond meshed codends squids landed were in the size ranges of 3-27 mm in 20mm, 30mm and incase of 40mm it was 9.0 to 27mm The median lengths of cephalopods caught in HOBT with square meshed codends were 8.5, 10.5, and 13.5cm (Fig. 43) respectively. In the HOBT with diamond-meshed codend, the respective median lengths were 7.0, 13.5 and 13.5 cm (Fig. 43). The contribution of cephalopods is considerably high during the present investigation. Silas (1985) reported that females of cephalopods mature at a length of 19 cm and the male at 28.50 cm length. From the present investigation it can be concluded that majority of catch consisted matured ones in square meshed codend while more number of juveniles were present in diamond meshed codend. Similar results are also reported by Kunjipalu *et al.* (2001). Further, these authors observed 100% escapement of juveniles of 2 -6 cm through 40 mm meshed codends and up to 67.58% in 20, 25 and 30 mm mesh sized codends respectively. Also, 34.78% of 80 – 90 mm size and 76.40% of 60 – 79 mm sized *Loligo sp.* escaped from 40 mm square meshed codend. It is evident from the

Table: 44. Length frequency distribution of cephalopods caught in the HOBT with different mesh sizes and shapes of codend

Mid class Interval (cm)	Square meshed		Diamond meshed	
	F	% of CF	F	% of CF
20 mm mesh				
3	17	1.0	59	3.34
5	52	4.04	112	9.67
7	176	14.59	193	20.59
9	217	27.31	208	32.36
11	218	40.09	240	46.26
13	250	54.74	236	59.60
15	170	64.70	1622	68.76
17	110	71.14	126	75.88
19	132	78.88	193	86.79
21	116	85.68	59	90.13
23	78	90.25	102	93.47
25	69	94.29	36	96.81
27	91	100	41	100
30 mm mesh				
5			12	0.76
7	27	1.96	29	2.59
9	63	6.54	59	6.31
11	290	27.63	138	15.01
13	253	46.03	281	32.72
15	197	60.36	352	54.90
17	183	73.66	263	72.73
19	172	86.17	94	78.65
21	90	92.72	149	88.04
23	49	96.28	85	93.40
25	28	98.32	68	97.68
27	23	100	31	98.66
29			26	100
40 mm mesh				
9	59	6.20	82	6.04
11	197	26.89	239	23.64
13	165	44.22	209	39.03
15	126	57.46	203	53.98
17	103	68.28	159	65.69
19	82	76.91	162	77.62
21	93	86.76	129	87.12
23	49	91.90	64	91.83
25	41	95.49	80	97.72
27	37	100	31	100

F = Frequency of distribution and, CF = cumulative frequency of distribution

present analyses that the mesh size of 20 mm provides very little chance of escapement for juveniles. Whereas, mesh sizes of 30 and 40 mm codend provided better chance of escapement of juveniles. Since there is no target fishery for the cephalopods in India except along the Vizhinjam - Kanyakumari coast, it is difficult to set any management option exclusively for cephalopods. However, indiscriminate bottom trawling severely disrupts the habitats, which facilitate the cephalopods to lay their egg-masses (mohan Joseph and Jayaprakash, 2003). It also affects their food availability. Closure of trawling during peak spawning period and increase in codend mesh size are recommended for sustaining the cephalopods production along Indian coast.

5.7.1. Penaeid shrimps

India is one of the major contributors to the world production of marine crustaceans. The penaeid shrimp constitutes the backbone of seafood export industry as the major foreign exchange earner as well as a source of livelihood of millions of fish workers. Frozen shrimps contribute about 70 % (4480 crores) of the total export value of our country with the share of capture fisheries being 59 % by volume.

Landings of penaeid shrimps show a phenomenal growth from 32,000 tons in 1960 to 2,07,080 tons in 2000. This was mainly achieved by intense combing operations of inshore waters, increase in effort, and extension of trawlers in to deeper waters, introduction of multi-day fishing operations, night trawling and introduction of innovative gears. During 1991-2000, penaeid shrimps formed 47% of the total crustacean landings along both the coasts. The all India annual shrimps production during this period varied between 1,73,443 and 2,24,902 tons with an annual average catch of 1,95,059 tons. About three fourths (75.5%) of the catch was harvested along the west coast and the rest (24.5%) from east coast. Kerala, Maharashtra, Gujarath, Tamilnadu, Andhra Pradesh and Karnataka are the important contributors to penaeid landings in the descending order of abundance.

In Karnataka trawling is the most important method of commercial fishing and, aimed at harvesting chiefly the demersal fish and shrimp resources. As a result of intensive and indiscriminative trawling, the most of the demersal fishery resources have started showing over-exploitation. Further, some of individual fish stocks appear to be presently fished intensively or over-fished. This is particularly so as there are no controls as to the type of fishing gear, size of fishing vessels and the quantum of fishing efforts to be employed for a given resource. Recent survey showed that commercial trawlers, which are using small mesh in their codend, resulted in landing of large quantity of by-catch along the Karnataka coast (Jayanaik, 2002). This unregulated activity is causing large scale destruction of natural resources and increasing the level of by-catch and juveniles. Talwar (1997) investigated the catching efficiency and the selectivity of the conventional HOBT with square meshed panel in the forward part of upper belly and codend. His results had shown that the average by-catch landing in conventional trawl was about 35% higher than the experimental gear. Nandakumar and Maheswarudu (2003) have estimated the maximum sustainable yield based on the data on the fishery and population characteristics of the species collected different fish landing centers. Their results implicitly suggest that the average annual yield of all commercial shrimps had reached the MSY and yield per recruit analyses further confirmed that there may not be any significant improvement in the harvests with increase in fishing effort. An increased level of by-catch, juveniles and depletion of shrimps has attracted the attention of all those concerned for evolving effective methods to stop this dangerous onslaught of both finfishes and shrimps.

5.7.2. *Metapenaeus sp.*

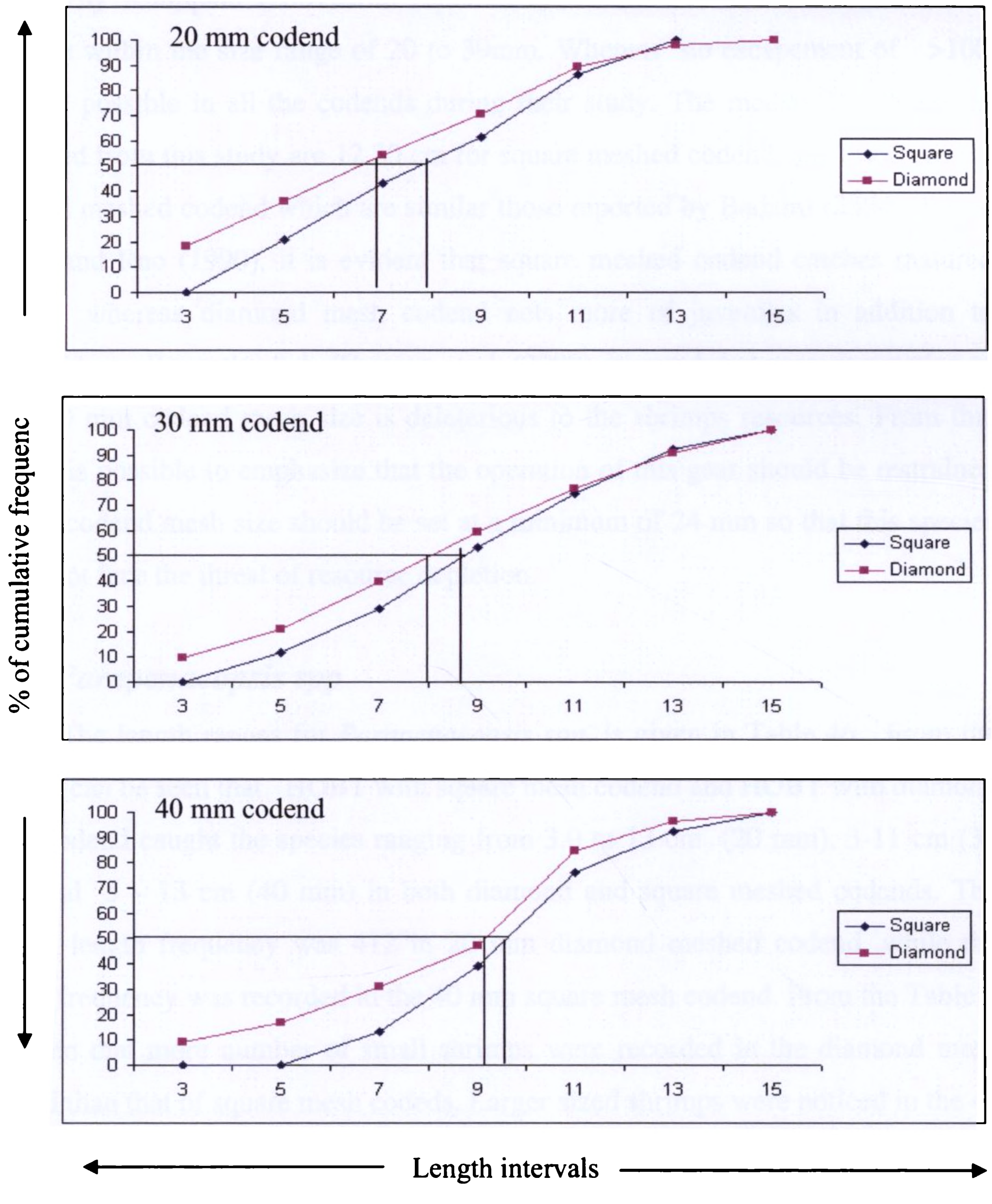
From the selectivity trawl gears with different mesh size and shapes of codend operations were carried out during the experiments, a total of 1858 numbers of *M. dobsoni* were caught. The length ranges of *Metapenaeus spp.* are presented in Table 45. Its size ranged from 5 to 15cm and 3-to15 cm in HOBT with square meshed codends and diamond meshed codend respectively. The median lengths calculated for *Metapenaeus* spp. caught in HOBT with square meshed codend and diamond meshed codend were 8.60 and 7.80 cm (20 mm), 10.60 and 9.00 (30 mm) and 10.80 and 10.00 (40 mm) respectively (Fig.44) Comparatively more number of larger sized shrimps of this species were caught in HOBT with 40 mm square meshed codend followed by 30 mm. and 20 mm. than in the HOBT with diamond meshed codends. Bal and Rao (1990) reported that the minimum size at sexual maturity is 8.80 cm for *Metapenaeus* spp. The general size of the individual shrimp in the catch is ca 10– 15cm off Mangalore (Jayanayak, 2002). In the present

Table: 16. Length frequency distribution of *M dobsoni* cephalopods caught in the HOBT with different mesh sizes and shapes of codend

Mid class Interval (cm)	Square meshed		Diamond meshed	
	F	% of CF	F	% of CF
20 mm mesh				
3	0		171	18.21
5	151	20.89	168	36.10
7	160	43.02	173	54.52
9	132	61.28	149	70.39
11	180	86.18	178	89.35
13	100	100	80	97.88
15			20	100
30 mm mesh				
3	0		212	9.69
5	119	11.59	140	20.90
7	180	29.12	231	39.39
9	250	53.46	247	59.17
11	218	74.69	220	76.78
13	180	92.22	175	90.80
15	80	100	115	100
40 mm mesh				
3	0		12	9.02
5	0		10	16.54
7	14	12.96	19	30.88
9	28	38.88	22	47.37
11	40	75.92	50	84.96
13	18	92.59	15	96.24
15	8	100	5	100

F = Frequency of distribution and, CF = cumulative frequency of distribution

Fig 44: Median lengths of 50% *M dobsoni* caught in different sized, square or diamond meshed codends on HOBT



investigation, comparatively more number of large sized shrimps were caught in square meshed codend than in the diamond meshed codend. Talwar (1997) reported the length range of *Metapenaeus* species caught in square meshed codend (28 mm) was in the range of 9.30 –16 cm, while for diamond meshed codend it was in the range of 7.20 – 16.60 cm. The effect of mesh size on the selective escapement of length class of *M. dobsoni* was studied using 20, 25, 30 and 40 mm square mesh codends by Kunjipalu (2001).who reported that there was 100% escapement of juveniles within the size range of 20 to 39mm. Whereas no escapement of >100 mm was possible in all the codends during their study. The median length values calculated from this study are 12.30 cm for square meshed codend and 11.60 cm for diamond meshed codend which are similar those reported by Badami (2004). Based on Bal and Rao (1990), it is evident that square meshed codend catches matured shrimps, whereas diamond mesh codend nets more of juveniles in addition to matured ones. Recently, Saly Thomas *et al.* (2008) reported that present practice of using 10 mm codend mesh size is deleterious to the shrimps resources. From this study it is possible to emphasize that the operation of this gear should be restrained and the codend mesh size should be set at a minimum of 24 mm so that this species would not face the threat of resource depletion.

5.7.3. *Parapenaeopsis spp*

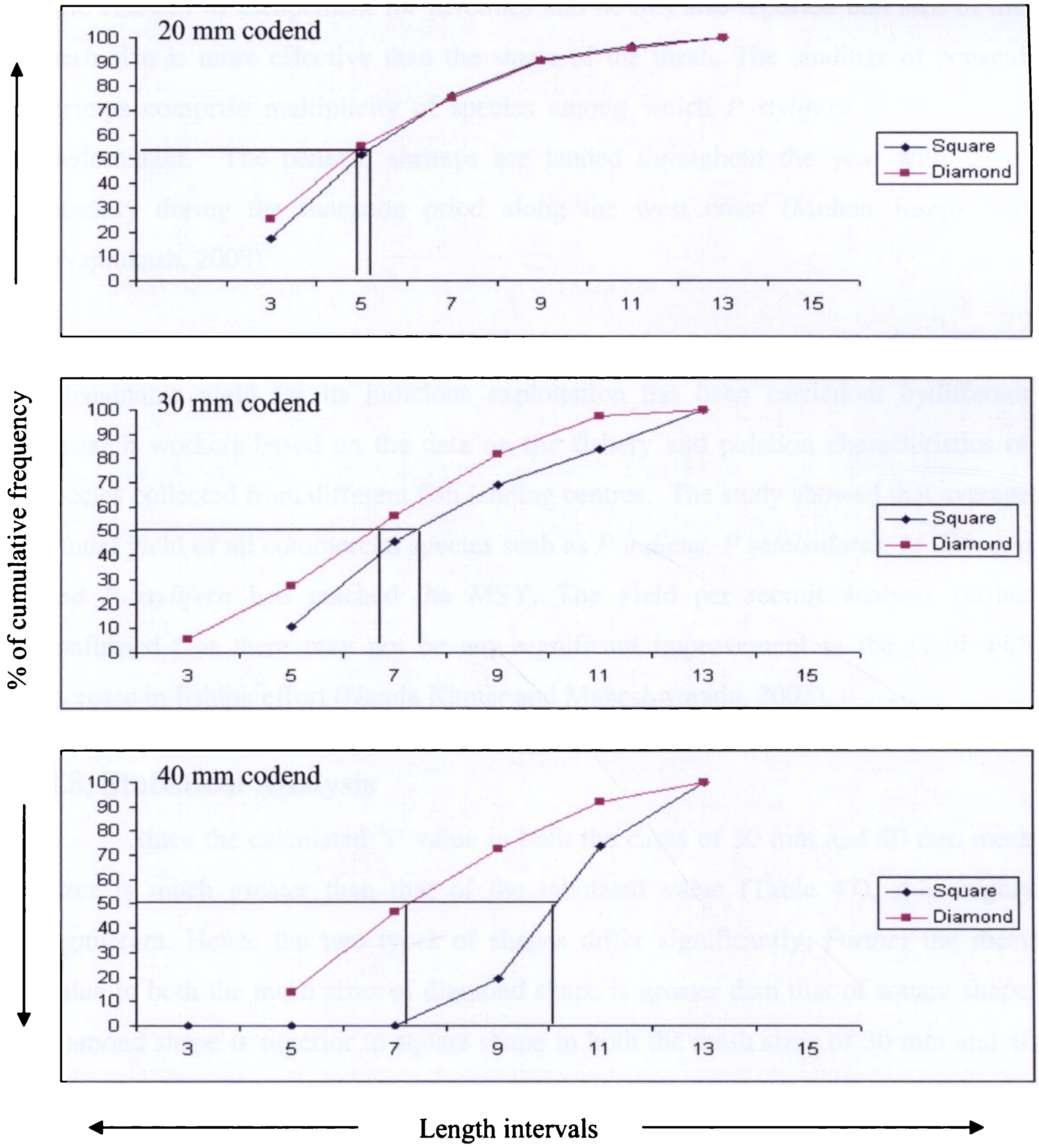
The length ranges for *Parapenaeopsis spp.* is given in Table 46. From the Table it can be seen that HOBT with square mesh codend and HOBT with diamond mesh codend caught the species ranging from 3.0 to 13 cm (20 mm), 3-11 cm (30 mm) and 5 – 13 cm (40 mm) in both diamond and square meshed codends. The highest length frequency was 412 in 20 mm diamond meshed codend, while the lowest frequency was recorded in the 40 mm square mesh codend. From the Table it can seen that more number of small shrimps were recorded in the diamond mesh codend than that of square mesh codeds. Larger sized shrimps were noticed in the 40 mm square meshed codend. From the Fig. 45 it can be noted that the median values for *Parapenaeopsis sp.* caught in HOBT with square mesh codends were 5.0, 7.2 and 10.2 in 20, 30 and 40 mm mesh size codend. With regard to diamond mesh codends the median values were 3.8, 5.8 and 7.2 mm in 20, 30 and 40 mm codends respectively. The median values are higher incase of square mesh codends than that

Table: 46. Length frequency distribution of *Parapeneopsis stylifera* caught in the HOBT with different mesh sizes and shapes of codend

Mid class Interval (cm)	Square meshed		Diamond meshed	
	F	% of CF	F	% of CF
		20 mm mesh		
3	180	17.51	346	25.19
5	351	51.65	412	55.09
7	253	76.26	276	75.12
9	148	90.66	210	90.36
11	62	96.69	73	95.66
13	34	100	61	100
		30 mm mesh		
3	0		59	5.33
3	100	10.66	246	27.57
5	330	45.84	319	56.41
7	218	69.08	280	81.73
9	139	83.90	172	97.28
11	151	100	30	100
		40 mm mesh		
5	0		34	13.88
7	0		80	46.53
9	19	19.38	64	72.65
11	53	73.46	47	91.83
13	26	100	20	100

F = Frequency of distribution and, CF = cumulative frequency of distribution

Fig 45: Median lengths of 50% *P stylifera* caught in different sized, square or diamond meshed codends on HOBT



of the diamond meshed codends. Bal and Rao (1990) have reported that the minimum size at sexual maturity is 6.50 cm in male and 7.00 cm in females. Hence it is clear that the square mesh codend catches matured and maximum sized shrimp while the diamond mesh codend catches more percentage of juveniles than the adult ones. Therefore square mesh codend has good selectivity for *Parapenaeopsis* species. Kunjipalu (2001) reported that mesh size below 25 mm provides a very little chances of escapement for juveniles and he has also reported that size of the mesh size is more effective than the shape of the mesh. The landings of penacid shrimps comprise multiplicity of species among which *P stylifera* is one of the predominant. The penacid shrimps are landed throughout the year with lesser intensity during the monsoon priod along the west coast (Mohan Joseph and Jayaprakash, 2003).

Estimation of stock for individual penacid species to find out maximum substainable yield for its judicious exploitation has been carriedout bydifferent research workers based on the data on the fishery and pulation characteristics of species collected from different fish landing centres. The study showed that average annual yield of all commercial species such as *P indicus, P semisulatus, M dobsomi and P stylifera* had reached the MSY. The yield per recruit analysis further confirmed that there may not be any significant improvement in the yield with increase in fishing effort (Nanda Kumar and Maheshwaradu, 2003).

5.8. Statistical Analysis

Since the calculated 't' value in both the cases of 30 mm and 40 mm mesh sizes is much greater than that of the tabulated value (Table 47), it is highly significant. Hence the two types of shapes differ significantly. Further the mean value in both the mesh sizes of diamond shape is greater than that of square shape, diamond shape is superior to square shape in both the mesh sizes of 30 mm and 40 mm. However, there is no significant difference between the two shapes in case of 20 mm mesh size.

5.9. TRAWL GEAR PERFORMANCE:

The catch assembled in the codend has to enter first in mouth of trawl so that the large the area of the mouth of the net, the more chance of catching fish. The

Table: 47a "t" Values for three different mesh-sizes and two different shapes(Ref : Table32)

Mesh Size		
20 mm	30mm	40mm
0.798 NS	3.185 **	4.197 **
Tabulated 't' ------ 2.145(0.05) **2.977(0.01)**		

NS: Not Significant ** : Highly Significant

Table:47b Correlation coefficients between total catch and different mesh sizes with different shapes (Ref : Table-36 Table-37 Table-38)

Mesh Size	Type of Mesh	Inner codend	Escapement
20 mm	Square	0.998**	0.453 NS
	Diamond	0.996**	-0.022NS
30 mm	Square	0.870**	0.631NS
	Diamond	0.951**	0.098NS
40 mm	Square	0.788*	0.524NS
	Diamond	0.958**	0.598NS

NS: Not Significant

* Significant at 5% level ** Significant at 1% level

mouth opening of trawl depends on various parameters like design details, rigging of trawl nets, sinkers, otter boards, scope ratio, towing speed, engine speed etc. In addition to the above some of the hydrographical parameters may also influence mouth opening of a trawl.

5.9.1. Drag of the trawl net

The drag of the gear is the resistance offered by various gear components such as netting panels, sweep lines, bridles, floats, sinkers, otter boards and warps. In the present study, same length of warp released for both the gears since the fishing is done at equal depths by the same vessel running at given rpm. Further, the otter boards used were also the same for both the gears. In the present investigation it can be seen from Tables 48 and 49 that among the various components contributing to the total drag, the drag due to net constitutes major fraction. From the above table it can be inferred that total drag increases with increased towing speed. The average drag of 1469.50 Kgf and 1083.41 Kgf at 3.0 and 2.48 Knots was recorded in HOBT with square mesh codend and diamond mesh codend respectively. Stewart and Maclennan (1987) suggested that total net alone accounts for 75% of the total drag of a single boat otter trawl. Reduction of total drag by increasing the mesh size is also reported by several authors (Dickson 1964; Anon., 1973; Dehmel, 1973; Gorman, 1975; Plado, 1977; Lan, 1980; Fujishi, 1985; Naidu *et al.,* 1987; Kunjipalu *et al* ., 1989 and Nayak (1991).Total towing surface area of the net influences the net drag. The total surface area of the nets found to be same as there is no difference in the design features except in cod mesh configuration. Though both the nets have same twine surface area, the HOBT with square mesh codend develops resistance of 1469.50 kgf at 3.00 knots whereas HOBT with diamond mesh codend develops 1083.41 kgf at 2.48 knots. This is attributed to the more opening in the square mesh codend opening and easy flow of water helps in increase in the towing speed in the same rpm besides oceanographical and metrological parameters like currents and winds. This difference may be due to practical aspects such as the difficulty of keeping the thrust out put by the vessel exactly the same in view of the difficulty in maintaining the same rpm while operating the two gears (Nayak, 1991). Further, the method adopted for drag determination required to use lot of assumptions of coefficient values while calculating the resistance of foot rope, sinkers, floats, otter boards and net. In the

Table 48: Total drag of hobt with square mesh codend

Towing Speed (Knots)	$Q=\frac{\rho V^2}{2}$	Drag of the net (Kgf) Rn	Drag due to floats (Kgf) Rf	Drag due to sinkers (Kgf) Rs	Drag due to Lines & ropes (Kgf) Rl	Drag due To Bridles (Kgf) Rb	Drag due to otter boards (Kgf) Rob	Total Drag (Kgf) D
2.50	84.68	804.37	5.92	29.46	85.86	12.19	137.18	1074.98
2.70	102.45	923.99	7.17	35.65	103.89	14.75	175.55	1261.00
2.90	113.94	1009.32	7.97	39.65	115.53	16.40	184.58	1373.45
3.00	121.94	1064.22	8.53	42.43	129.64	17.55	197.54	1459.91
3.20	138.74	1178.25	9.71	48.28	140.68	20.60	224.75	1622.27
3.50	165.97	1359.55	11.61	57.75	168.29	23.89	268.87	1889.96
Arerage 2.95	121.29	1056.62	8.49	42.20	123.98	17.56	190.07	1446.92
%	-	73.03	0.58	2.90	8.60	1.23	13.14	

Table 49: Total drag of HOBT with diamond mesh codend

Towing Speed (Knots)	$Q=\frac{\rho V^2}{2}$	Drag of the net (Kgf) Rn	Drag due to floats (Kgf) Rf	Drag due to sinkers (Kgf) Rs	Drag due to Lines & ropes (Kgf) Rl	Drag due To Bridles (Kgf) Rb	Drag due to otter boards (Kgf) Rob	Total Drag (Kgf) D
2.20	65.57	666.75	4.59	22.81	66.48	12.74	106.22	879.60
2.30	71.67	711.04	5.01	24.94	72.67	10.32	116.10	940.08
2.50	84.67	804.37	9.52	29.46	85.85	12.19	137.16	1078.55
2.70	98.46	903.87	6.91	34.36	100.14	14.22	160.00	1219.50
3.00	121.93	1064.22	8.54	42.43	123.63	17.55	197.52	1453.88
Average 2.54	88.66	830.05	6.91	30.80	89.75	13.40	143.40	1114.32
Percentage	7.97	74.50	0.62	2.76	8.06	1.18	12.88	100

present calculation the foot rope and head rope were assumed to be normal to the tow direction while bridle rope was assumed to be parallel to tow direction. However, in reality they are not exactly so (Nayak, 1991).

5.9.2 Vertical opening

Vertical opening of a trawl gear is more important than the horizontal opening for fast swimming fishes. The vertical opening of the gear was calculated for both the nets. The vertical opening of a HOBT with square mesh codend varies between 3.72 to 4.57 m. Higher vertical opening (3.92 to 5.09 m) was registered in HOBT with diamond mesh codend. It can be observed from the Tables and that as the speed increases, the vertical opening of a net decreases. Similar results were also reported (Hanumanthappa and Clivea, 1998). Higher vertical opening of large mesh trawls were reported by many workers (Pillai *et al.* 1979; Anon., 1980 and Anon., 1990d). The height of the trawl mouth is directly proportional to the circumference of the mouth whereas it is inversely proportional to the speed of the trawl. In the present investigation, the vertical opening of the trawls for the average speed (3.00 Knots) of tow gives 3.92 m in HOBT with square mesh codend. However, the vertical opening of the HOBT with diamond mesh codend registered 4.6 m at 2.48 Knots (Table 50 and 51). This indicates that though both the nets are having similar circumference the influence of towing is more in determining its vertical opening. Contrary to this Nayak (1991) found that influence of towing speed is much less than the influence of trawl mouth circumference in determining the vertical mouth opening. Further reported that new large mesh trawl (NLMT) being a four saem trawl and having large mesh in the body has greater circumfence than that of HOBT. Thus it is obvious that NLMT has higher mouth vertical mouth opening than HOBT. On the other hand, NLMT always registered higher towing speed, which will decrease the vertical opening to certain extent. In the present study, the square shaped mesh codend shows the similar effect. However, a much better way to obtain more vertical opening is to increase the head line floatation rather than adjusting the bridle lengths (Hanumananthappa and Clive, 1998).

5.9.3 Horizontal opening:

Horizontal opening of a trawl mouth is an important parameter to determine the catching efficiency. It can be seen from Table 50 and 51 that the average horizontal opening of HOBT square mesh codend is 18.47 m at a towing speed of 3.00 knots, while that of of HOBT with diamond mesh codend is 17.35 m at 2.48 knots. From the horizontal spread decreases in both the nets. Similar results were recorded by earlier workers (Pillai *et al.,* 1979; Kunjipal *etal.* 1989; Anon., 1973; Naidu *et al.*, 1978; Nayak, 1991and Hanumanthappa and Clive, 1999). The average horizontal spread of the gear was 64. 25% of the head rope at 2.5 knots. Nair *et al.* (1996) reported that for a net to get efficient performance the horizontal spread should be about 60% of the length of head rope. Other earlier investigators (Mukundan, 1970 and Sathyanarayan and Nair 1964) are of the opinion that horizontal spread should be 50 to 60% for better performance of the gear.

In the present investigation nets were rigged directly to the otter board with 30 meter bridle length from wing tips. Results showed that with increase in the towing speedthere is an increase in the spread of otter board. Flume tanks studies showed that two bridles and three bridles with sweep line rigging gives better horizontal spread to trawl net (Hanumanthappa and clive, 1998). In addition the tow and rigging arrangements, several external factors like current velocity, wind velocity etc. have some influence on the otter boards opening.

Table 50: Speed otter board spread, Horizontal spread and vertical height of HOBT with square mesh codend

Sl No.	Towing Speed	Vertical opening of the net (m)	Horizontal spread of Otter boards (m)
1	2.50	4.30	13.85
2	2.70	4.40	14.30
3	2.90	4.30	14.20
4	3.00	3.70	15.50
5	3.2	3.50	15. 80
6	3.5	3.60	16.40
Average	3.0	3.96	15.50

Table:51 Horizontal spread and vertical height of HOBT with diamond mesh codend

Sl No.	Towing speed	Vertical opening of the net (m)	Horizontal spread of Otter boards (m)
1	2.2	4.80	11.80
2	2.30	4.50	12.70
3	2.50	4.90	12.50
4	2.70	4.60	13.30
5	3.0	3.90	13.60
Average	2.54	4.54	12.78

CHAPTER VI

SUMMARY/RECOMMENDATIONS

The HOBT developed is to be used by a 50 feet wooden mechanized trawler RTV Nethravathi fitted with 98 bhp water-cooled engine. The fishing grounds were selected at random with the depth range of 31-86 m. off Mangalore based on the fishing operation of commercial trawlers in the area. The duration of towing was fixed at 2-3 hours for each haul excluding the period of shooting and hauling of the gear. The towing was done parallel to the coast to maintain a constant depth. The warp-scope ratio was kept varying between 1:5 and 1:6 depending upon the depth of fishing ground in order to ensure that foot rope sweeps the sea bed. Towing speed was directly recorded with the help of Global Positioning System (G.P.S.). In addition to positions (latitudes & longitudes) GPS was also used to know the towing & cruising speed and compass course.

The details of the exploratory fishing trips, such as location of the fishing ground, fishing effort, depth of operation during the fishing season 2003-2004 are recorded. This study involves the listing of different commercially important fishes of the faunal complex in the overall area and depth zones of investigation. Hence the data, when discussed, would give an idea of the distribution pattern of fishery resources. Length and weight analyses have been conducted to know the size composition of various types of commercially important fishes caught during the period of survey and also to judge the percentage of juveniles captured by the trawler. Therefore, fish caught were grouped into 4 different groups measuring lengths less than 5 cm, 5-10 cm, 10-15 cm and more than 15cm.

Depth range of 41-50m. It can be noted that catch of thread fin breams was highest (3730 kg) followed by cephalopods (1902 kg), shrimp (230 kg) and lizard fish (111kg). It is also seen that in the finfish group, threadfin breams constituted the highest total catch during the month of March followed by bull's eye, pomfret and rock cod.

Depth range of 51-60 m. The distributions of catch of different groups are recorded. In this depth range the trawling operation was conduced during the months of September and October months only and found that the threadfin bream constituted the highest catch followed by lizard fish and rock cod.

Depth range of 81-90m. At this depth zone the catch of thread fin breams was highest (4052 kg) followed by lizard fish (427 kg), rock cod (350 kg), bull's eye (275 kg), cephalopods (270 kg) and shrimp (158 kg). There was no catch of pomfret at this depth zone. Here again the contribution of threadfin breams was highest with 4052 kg per month when compared to all the other depths.

The thread fin breams measuring 10 to 15 cm contributed 37.6% during the post monsoon month of October 2003, while, in the same month fishes measuring less than 5 cm did not represent the catch. An over view of the total period of study revealed that fish measuring more than 15 cm contributed to the highest percentage of total catch (40%) followed by 10-15 cm group (33.2%) and 15.3% of the size group of 5-10 cm Fishes measuring less than 5 cm contributed to an average of 11.5% to the total catch. Considering the size range of 10-15 cm. as immature fishes as stated by Vivekanandan and James (1986), the catch of immature fish thus contributed 60% to its total.

The Bull's eye fish catch formed with the good representation of the size groups of 10-15 cm and above only. An average percentage contribution larger than this group was represented by 43.9%. Further, fish size group of more than 15 cm ranged from 33.1% in January to 61.1% in May. The size range of 10-15 cm represents the catch in good quantities with as high as 66.9% in January to as low as 38.9% in May 2004.

From the data obtained during the period of study it can be seen that lizard fishes measuring between 10-15 cm contributed to the highest percentage of total catch (45.7%) followed by fishes measuring more than 15 cm (44.5%). However, the total contribution of the individual species to the sum of total of the entire group is only 5.1%.

Flat fishes measuring more than 15 cm contributed to the highest percentage of total catch (45.9%) and the less than 5 cm. On an average (45.9%) of the Flat fish landed were of the size group of 15 cm group (33.90 %) and 12.7% of the size group of 5-10 cm. Flat dishes did not represent the fishery during the month of November and January.

Ribbon fish of 15 cm and above represented the total annual catch in all the months except in the month of September. The highest catch (450 kg) was recorded during the month of December followed by November (442 kg), while minimum catch (10 kg) was recorded in the month of October.

On an average, 78.9% of the Pomfret caught were of the size group of 15 cm and above followed by 10-15 cm group (19.0%). Fishes measuring 5-10 cm. contributed to an average of 2.1% of total catch only. In the present study showed that about 21.1% of the fishes landed represented the juveniles that are less than 15cm.

The White fishes that were landed during the study period were of size less than 15 cm. In the present study, considering the size range of 5-10 cm as immature fishes, 35.5% of this fishes landed could be declared as juveniles.

It can be clearly indicated that a gradual increase in rock co fish catch was seen in the fishes measuring more than 15 cm form December till March with the highest percentage of total catch during March (80.8%). Rock cod size more than 15 cm comprised 61.2% followed by 10-15 cm group (27.70 %) and 5-10 cm group (8.4 %) Fish measuring less than 5 cm comprised as an average 2.7% of whole catch during the fishery.

On an average, 40.20 % of the croaker fishes caught were of the size group 5-10 cm followed by 10-15 cm (35.70 %) and 24 % of the size group of 5 cm and below. Somashekar Nair (1977) has reported that minimum size at first maturity is 11.5 cm for females and 12.5 cm for males.

On an average 54.3 % of the Cephalopods caught were of the size group of 15 cm and above, followed by 5-10 cm (23.0 %) and 10-15cm groups (22.7 %). Therefore, it can be noted that the 45.7% of the Cephalopods landed during the study period represented the juveniles with less than 15 cm.

On an average, 72.5% of the shrimps caught were of the size group of 5-10 cms followed by 10-15 cm (27.5%). The total contribution of this individual species of the sum of the total of all the groups is only 2.7%. It can be noted that 100% of the shrimps landed during the study period represents the mature shrimp.

Selectivity studies in trawl fishing: Data collected from trawl fishing with codend mesh sizes of 20, 30 and 40 mm of diamond and square are being analyzed and tabulated for individual species.

The total catch per haul in case of square mesh codends of 20, 30, 40 mm. are 18.50 kg, 17.15 kg and 10.56 kg respectively. While in case of diamond mesh codend catches were 20.28 kg , 20.53 kg and 15.03 kg in respective codends.

The catch was highest in 20 mm. diamond mesh codend in the month of February, and lowest catch was 7.25 kg. in 40 mm square mesh codend.

The highest averages catch of 20.53 kg. recoded in 30 mm diamond mesh codend and 18.5 kg in 20 mm square codend. A lowest catch of 10.56 kg and 15.03 kg per haul were recorded from HOBT with 40 mm square and diamond mesh codend.

40mm square mesh codend permitted the escapement of some quantity of commercial size groups of economically important fishes. This could be due to the fact that mesh opening of the square mesh codend has more area of opening and it is more stable. Hence, the possibilities of escapement of under sized fishes through these openings are greater.

Whereas the diamond shaped mesh has lesser opening and not stable and therefore retaining of fish from escaping is more. Percentage of different length classes cumulative frequency tables of finfish and shrimps for 20, 30 and 40 mm mesh size are tabulated.

Further, Selectivity curves in respect of *Lactarius sp Leiognathus sp., Stolephrous sp., Cynoglosses sp.,* Mackerel, Threadfin bream., *Pompfrets* and three shell fish resources *Metapenaeus sp., Parapenaeopsis s.p and Loligo sp* for square mesh codends are drawn.

High opening bottom trawls (HOBT) with square and diamond meshed codends of 20, 30 and 40 mm were designed and fabricated. Their efficiency for catching demersal fishes was tested through fishing trails conducted in the fishing grounds off Mangalore coast during October 2004 to May 2005. In order to study the the benefits of the square mesh and diamond shaped meshes of different mesh size, comparative fishing trails were conducted.

During the study period both codends were fitted with a small meshed nylon cover codend to study the extent of escapement. The ring was fabricated with steel material and fitted in the front part of the codend with 10 mm nylon webbing cover transversely and it was longer than the codend. There was plenty of lateral slack in the cover after fitting. To maintain the space in side the cover codend floats were provided along the central line of the upper portion of the cover codend.

Fishing cruise were carried out randomly in the inshore waters off-Mangalore at a depth range of 40-45 m 50 feet Wooden trawler RTV Nethravathi fitted with 98 bhp water cooled engine belonging to College of Fisheries, Mangalore was used. Alternative hauling technique was adopted to nullify the effects current speed, direction of water current and wind on the towing speed. The gears were operated in the same depth, direction and engine rpm to maintain the similarity between them.

Total weight of the species groups caught during the study period were recorded and and analysed to determine the relative catching efficiency.

Length of individuals of different species groups were recorded and studied to determine the escapement of juveniles of commercially important species.

The highest percentage of retention (94.63 %) was recorded in 20 mm square meshed codend. In the HOBT with diamond meshed codend the retention was full 100% in January.

On an average, percent of retention was 93.13 % and 97.03 % in square and diamond meshed codends.

The percentage of escapement through 20 mm square meshed codend varied from 5.21 to 9.26 %. Through diamond meshed codend, the escapement of juveniles was none to 7.25 %. The highest percentage of escapement (9.26 %) was noticed in the month of November and the least during January.

Escapement of juveniles through HOBTs with 30 and 40 mm square and diamond-meshed codends was higher than through their corresponding HOBTs with 20 mm mesh size. On an average, 15.18 % and 8.53 % escapement of juveniles and immature fishes was noticed in larger square and diamond meshed codends.

The peak frequencies caught in HOBT with diamond-meshed codend were higher than that with HOBT with square meshed codends. The median length of pink perch caught in HOBT with 20 mm square meshed codend is 10.50 cm, with 30 mm it is 14.00 cm and with 40 mm it is 16.10 cm

It is therefore apparent that both the gears with 30 mm and 40 mm meshes caught matured fishes. HOBT with 20 mm and 30 mm diamond meshed codend retained respectively the immature individuals and size range close to first maturity. When compare the catches, the bigger sized and more valued fishes are retained in the square mesh codend.

Individuals of pomfrets caught in HOBT with square meshed codends of 20, 30 and 40 mm mesh sizes were in the length ranges of 5 to 23 cm. In case of diamond meshed codends, also were in the same range. More numbers of pomfrets were caught in diamond mesh codends during the course of the study.

Among the square meshed codends, the highest numbers of individuals were caught in 20 mm meshed ones followed by those of 40 mm and 30 mm. In the present study, the median length of pomfrets caught using HOBT with 20 mm square meshed codend was 11.50 cm and in HOBT with diamond meshed codend it is 11.50 cm. The length ranges of pomfrets caught in HOBT with 30 and 40 mm square meshed codend were 12.5 and 13.5 cm. In the HOBT with 30 and 40 mm diamond meshed codend were 13.5 cm and 16 cm respectively.

Trawl gear are not selective with respect to Pomfret because the body shape of the pomfret is oval and escapement through the small mesh size is difficult.

Maximum size of *Trichiurus* sp. caught during the study period was 37 cm, and minimum size was 5.0 cm. In general, the number of larger sized *Trichiurus* sp. caught in HOBT with diamond meshed codends is higher than that caught in the HOBT with square meshed codends.

The median lengths of fishes caught in 20, 30 and 40 mm square meshed codends are 12, 15.80 and 19 cm and, in diamond meshed codends, 14.20 cm, 17 cm and 22 cm respectively.

Maximum lengths recorded during the study are much lower than those reported and much smaller sized individuals caught during the study, it is clear that they are all in their immature stage as Bal and Rao (1990).

From the present investigation it was found that while square meshed codends of 30 and 40 mm retained the matured fishes, the HOBT with 20 mm codends caught immature fish.

It is was also seen that HOBT with 40 mm square meshed codend landed about 50 % catch less than that of the HOBT with 30 mm codend. It is evident from the above that 40 mm square meshed codend provided more chance to escapement of even adult anchovies. Whereas 30 mm meshed codend provided better chance of escarpment to juveniles and sub adults.

It is thus evident that higher number of mackerel was landed in all the diamond shaped codends than the square meshed codends. The median values for the fishes caught in each gear with diamond shaped codend were 13 cm, 14 cm, and 14.60 cm and HOBT with square meshed codends: 14 cm, 16 cm and 16.80 cm respectively in 20, 30 and 40 mm mesh sizes. It is clearly evident that both square meshed and diamond meshed codends mostly caught juveniles of mackerel.

Hence trawl gear with smaller meshed codends is not a suitable gear for catching mackerel, which is apparently shifting from pelagic to demersal habitats owing to changing temperature regimes as a consequence of climate change.

In the present study, the HOBT with square meshed codends landed squids ranging in size from 3.00 to 27 cm, 7.0 to 27, and 9.0 to 27 respectively in 20, 30 and 40 mm mesh sizes. While in HOBT with diamond meshed codends squids landed were in the size ranges of 3-27 mm in 20 mm, 30 mm and incase of 40 mm it was 9.0 to 27 mm.

The median lengths of cephalopods caught in HOBT with square meshed codends were 8.5, 10.5, and 13.5 cm and -------cm respectively. In the HOBT with diamond meshed codend, the respective median lengths were 7.0, 13.

It is evident from the present analyses that the mesh size 20 mm provides very little chance of escapement for juveniles. Whereas, mesh sizes of 30 and 40 mm codend provided better chance of escapement of juveniles.

The results of the present study showed highest total catch was got during the month November and the lowest was during January. The threadfin bream and cephalopods were the two major groups represent the catch through out the study period. In the fins groups, 20 to 30.5 % of juveniles were recorded. In shellfish group 45.70% landed represented the juvenile catch. Depth zone of 41-50 m was found to be the most productive zone. It is an evident from the selectivity investigation that more number of sub adults and juveniles can escape through square meshed codends than the diamond-meshed codend. Hence 30 mm square mesh codend is recommended as the square meshes are more open and there is no distortion and gives more chance to escape juveniles and sub adults which will help in conservation of fishery resources for sustainable fishing activity.

CHAPTER VII

EXTENSION ACTIVITIES

The trawlers of Karnataka use nets with different mesh sizes dependin upon the time of trawling. The codend mesh size varies from 10 to 22 mm, which is small and could harvest the large quantity of juveniles. Hence it is essential to conduct the awarness program on responsible fishing. Fishermen's responsibility in the utilization of selective fishing is becoming is an important subject. Although responsible exploitation of the natural resources of the sea through more selective fishing operations is now being realized as a necessity, the recommendations for more selective fishing have not proven easy to put into practice. Many research Institutions have conducted research on the selectivity of fishing methods involving various fish species. However, communications and exchange of information among the fishery industries and communication and exchange of information among the fishery industries and the research sector in the country are in general, very limited. An overall lack of available research data related to the subject is still persists. As problem related to the selectivity of fishing gears are in general common to many of the countries.

The importance of Training of fishers in concepts of selective fishing is recognized and in this regard, consultation with the fishermen is required in order to design appropriate education/extension programmes.(taking into consideration time constraints of vessels operators and when necessary income compensation during the training period). Effort should be made for the dissemination of information to small scale fishermen to explain fisheries management issues. Further to convince and encourage the fishing communities to behave responsibly in harvesting resources. This can be best achieved by showing that it is to their advantage to do so. In many cases, it is advisable to first demonstrate the results of the selective fishing techniques to key fishermen. Allow them to test and examine the results for their acceptance. In certain situations financial incentive may be provided. The information contained in this data sheet is based on work carried out during this study to evaluate the use of square mesh selector panels as a means of releasing juvenile round fish from demersal towed fishing gears in an attempt to reduce levels of discarded fish.

To understand how the panels work it is necessary to study the behavior of fish as they pass form the trawl mouth to the codend. This has been done through the video films on underwater observations. Over a number of trials, the results obtained with the panels have shown consistent reductions in discard levels of species like threadfin breams, rock cods, pomfrets, bull's eye, cephalopods and shrimps from nets fitted with square mesh codend when compared with conventional nets made from diamond mesh. As a technical conservation measure, the use of square mesh panels is simple, effective, practical and relatively inexpensive to undertake.

7.1. The use of square mesh netting

With conventional diamond mesh netting have a natural tendency to close-up once the netting comes under tension applied along the direction of tow. In components of the trawl such as the extension and codends, the increased tension caused by the build-up of catch tends to cause a closing of the meshes in these areas resulting in a reduced area of escape for undersized fish. Since size selection is dependant on the mesh opening, the process is vulnerable to changes in the shape of the netting within the codend and extension. One way of improving the selection is to use square mesh netting panels incorporated into the extension. In this way the meshes can be kept more open over a larger area and the positioning of these panels can be varied to optimize the escape of juvenile fish.

To produce this square mesh effect with conventional diamond mesh the netting is turned so that half of the mesh bars are parallel and half at right-angles to the direction of tow of the net. This is achieved by cutting the panels out of conventional sheet netting "on the bar". Then the netting is not stretched or constricted by water pressure or affected by any other tensions. All the meshes maintain their square shape thus increasing the potential escape area for juvenile fish. Conventional knotted diamond mesh netting can be used for these panels but as per Sea fish authority report, the use of knotless material is preferred. This material has a number of advantages over knotted netting amongst which are: it maintains a more regular 'square' mesh shape, the absence of knots presents an improved escape area and abrasion damage to the fish is minimized as they pass through the meshes. Finally, panel distortion is reduced as the possibility of knot slippage is eliminated. It should be noted that although it is described as square mesh knotless netting it is sold as "diamond" knotless netting and cut on the square. If knotless netting is damaged it is repaired by cutting out the damaged area and replacing it with a 'patch' which is 'laced in' along the four sides of the resulting hole. If this is well done it is not a disadvantage and is probably easier for the less skilled fisherman.

7.2. Designing the panels

Based on the result obtained during this study period, 30 mm square mesh netting panels was used to demonstrate the construction of 30 mm square meshed codend. The selector panels are constructed as a complete section of codend to allow more flexibility with their use and simplify their fitting. Each panel section is made up with the square mesh top panel and laced on to lower panel then it is ready for insertion into the desired position within the nets existing extension configuration.

7.3. Fitting the Panels

All the panels described use a diamond mesh: square mesh joining rate of 2:1 when fitted into the extension/codend section of a net. The bottom panels are joined at a normal 1:1 rate. Once the panel width has been determined it is cut out from sheet netting. It is an advantage to selvedge the square mesh section separately before lacing together. Since it has been cut from diamond mesh sheet netting, it has a tendency to try and pull back into diamond mesh configuration. By selvedging the panel prior to lacing together, the section maintains its square mesh shape more easily.

If the netting section to which the square mesh panel is to be attached has a four-mesh selvedge, then the square mesh panel should have two mesh selvedges. This is achieved by lacing the first three vertical bars together over the full length of the selvedge edge of the panel. It is also important to strengthen the horizontal joining edges of the panel to prevent the meshes parting on the first row of the panel.

This is best achieved by lacing the first two horizontal bars together in a similar way to the selvedge edge.

The joining of the square mesh selector panel section to the existing net can also be simplified by braiding a row of diamond meshes onto the first row of square meshes. This facilitates a conventional diamond mesh join with a simple 2:1 baiting rate. Alternatively, the meshes of this first row can be joined onto the middle of the horizontal bar of the square mesh directly by clove hitching.

Based on the results found during this study and to prevent the onslaught of juveniles, six training programmes were conducted in the coastal districts conducted on "Awareness of responsible fishing and conservation of fishery resources for the fisher folk of coastal Karnataka viz. Mangalore, Malpe, Gangolli, Honnavar, Thadadi and Karwar. Each programme was participated by more than fifty local fishermen, Fishermen associations and officer of the Department of Fisheries.

Fig 46: Inauguration of the training program at Thadadi
(North canara)

Fig 47: Training on awareness of responsible fishing being held

Fig 48: Interaction between fishermen and the trainer

Fig 49: Training program held at Karavar

Fig 50: A view of square mesh codend

CHAPTER VIII

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