STUDIES ON SOFT BYCATCH REDUCTION DEVICES FOR SELECTIVE TRAWLING

Thesis submitted to

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

in partial fulfillment of the requirements
for the award of the degree of

DOCTOR OF PHILOSOPHY

By

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2008

CERTIFICATE

This is to certify that this thesis titled ***Studies on Soft Bycatch Reduction Devices for Selective Trawling*** is an authentic record of the research work carried out by Mr. S. Sabu, M.Sc., under my guidance and supervision in the Fishing Technology Division of Central Institute of Fisheries Technology, Cochin, in partial fulfillment of the requirements for the degree of Doctor of Philosophy and that no part thereof has previously formed the basis for award of any degree, diploma, associateship, fellowship or any other similar titles of this or any other university or institution.

Cochin-29
August, 2008

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DECLARATION

I, S. Sabu hereby declare that the thesis titled ***Studies on Soft Bycatch Reduction Devices for Selective Trawling*** is an authentic record of the research work carried out by me under the supervision and guidance of Dr. M.R. Boopendranath, Principal Scientist, Fishing Technology Division, Central Institute of Fisheries Technology, Cochin, in partial fulfillment of the requirement for the Ph.D. degree in the Faculty of Marine Sciences and that no part thereof has previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title of any University or Institution.

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ACKNOWLEDGEMENTS

It is my pleasure to acknowledge:

Dr. K. Devadasan, Director, Central Institute of Fisheries Technology, Cochin for providing facilities for the study at the Institute and for his invaluable advice and words of encouragement;

Dr. M.R. Boopendranath, Principal Scientist, Fishing Technology Division, Central Institute of Fisheries Technology, for his invaluable guidance, sustained encouragement and critical assessment of the work;

Dr. B. Meenakumari, Head of Division, Fishing Technology, Central Institute of Fisheries Technology, for providing all facilities in the Fishing Technology Division, periodic assessment of progress, invaluable advise and encouragement;

Dr. Saleena Mathew, Director, School of Industrial Fisheries, Cochin University of Science and Technology, for the periodic assessment of the research work and words of encouragement;

Dr. P. Pravin, Senior Scientist, Fishing Technology Division, Central Institute of Fisheries Technology, for his wholehearted support, invaluable advice and encouragement, throughout the period of studies;

Dr. Leela Edwin, Principal Scientist; Dr. Saly N Thomas, Senior Scientist; Dr. M.P Remesan, Senior Scientist; Mr. P. Muhamed Ashraf, Scientist (SG), Dr. S.K. Panda, Scientist (SS), of Fishing Technology Division, Central Institute of Fisheries Technology, for their encouragement and goodwill, throughout the period of studies;

Mr. T.R Gibinkumar, Assistant Director, Marine Products Export Development Authority and former Senior Research Fellow, Central Institute of Fisheries Technology, for his valuable support, assistance and goodwill, during the period of studies;

Mr. K.J Francis Xavier, Skipper (T-9); Mr. P. Ferozkhan, Bosun (T-5) and the crew of research vessels *MFB Matsyakumari* and *MFV Sagar Shakthi*, Central Institute of Fisheries Technology, Cochin for their whole-hearted cooperation and assistance during field trials;

Mr. Gipson Edappazham, Mr. M. Ajith Peter, Ms. A. Sreeja, Mr. Baiju John, Mr. C. Kalidas, former Senior Research Fellows and Ms. Usha Bhagirathan, Senior Research Fellow, Fishing Technology Division, Central Institute of Fisheries Technology, Cochin, for their goodwill and assistance during the study period;

Sri. P.N. Sudhakaran, K.B. Bhaskaran and Mr. A.S. Kalangutkar, technical staff of Fishing Technology Division, Central Institute of Fisheries Technology, Cochin, for their assistance in fabrication of shrimp trawls and BRD prototypes and field data collection;

Scientific, technical, administrative, supporting staff and friends in Central Institute of Fisheries Technology, Cochin, fort their goodwill;

Dr. K.G. Ramachandran Nair, former Head of Division, Fish Processing Technology, Central Institute of Fisheries Technology, Cochin, for his words of encouragement and goodwill;

My dear friends, Mr. S. Abhilash, Mr. Anoop Krishna, Mr. P. Aneesh and Mr. T. Manoj for their constant support and goodwill;

My father, mother, brother, sister and close relatives for their support and encouragement;

My wife, Asha for her support and care during this period.

This thesis is dedicated to my family

CONTENTS

Chapter 1

Introduction

Fisheries is recognized as a strong and effective employment and income generator to large sections of the society. Fisheries provide cheap animal protein to the people, particularly to the poorer sections in the society. Fishing is an ancient occupation. A diverse range of fishing gears and practices from small-scale artisanal to large-scale industrial systems are used for fish capture. About 200 million people in the world directly or indirectly depend on the fisheries industry. Of this about 50 million people directly depends on fishing for their livelihood and the rest is involved in ancillary activities such as processing, marketing, and supporting activities (FAO, 1995). Development in craft technology, mechanization, introduction of synthetic materials, acoustic fish detection, electronic navigation, and remote sensing are the major developments that has taken place in the historical evolution of fishing methods and practices (Hameed and Boopendranath, 2000). The world capture fishery production raised from 25 million tonnes in 1955 to 133 million in 2002, of which 71.5 million was contributed by marine capture fisheries (FAO, 2004). The most important commercially used capture methods in the world are trawling and purse seining (Sainsbury, 1971).

The trawl net is a conical bag with two wings and a codend, operated by towing horizontally from one or two boats (Hameed and Boopendranath, 2000). Trawls are mainly operated from surface to bottom to harvest crustaceans, cephalopods, elasmobranchs, molluscs and finfishes, in different parts of the world (Boopendranath, 2000). Trawls are mainly classified into bottom trawl and midwater or pelagic trawl depending on the position in the water column, during operation. Bottom trawling, which is known to be the most effective method for shrimp capture, is widely accepted in the world. Bottom trawl is rather heavily rigged, with two otter boards provided to open the mouth horizontally and enough weight in the footrope to keep the trawl in contact with the bottom, during towing (Sainsbury, 1971; Hameed and Boopendranath, 2000; Misund *et al*., 2002). Incidental catching of non-target resources is a serious problem facing trawl fisheries in the world. Some part of the catch may be retained for sale or use, while others are discarded back into the sea because of a number of reasons like fish of wrong species, size, sex, damaged fish, lack of space for storage, prohibited species, etc. (Clucas, 1997). Discarding is a serious conservation problem because valuable living resources are wasted and populations of endangered and rare species are threatened (Harrington *et al*., 2005; Alverson and Hughes., 1996).

United Nations Convention on Law of the Sea adopted in 1982 provided a new framework for the effective management of marine resources. Exclusive Economic Zones (EEZs) of the coastal states provide 90% of the world's marine fisheries resources. In 1992, International Conference on Responsible Fishing in Cancun (Mexico), requested FAO to prepare Code of Conduct for Responsible Fisheries. The code was unanimously adopted on 31st October 1995 and it provides the principles and codes of practices for sustainable exploitation of aquatic resources, protection of aquatic environment, maintenance of biodiversity and conservation of energy (FAO, 1995).

1.1 Marine Fisheries of India

India is having a coastline of about 8128 km, an exclusive economic zone of 2.02 million sq. km and a continental shelf area of 0.5 million sq.km (Ayyappan and Diwan., 2007). The total fishermen population of India is about 3.57 million, with an active fishermen population of 0.81 million (CMFRI, 2006b). The fisheries sector contributed 1.08 % to the Gross Domestic Product (GDP) and 5.34% to the agricultural component during 2004 (GOI, 2006).

Fish production from India increased from 0.73 million tonnes in 1950 to 6.57 million tonnes in 2005-06. Marine capture fisheries production also increased from 0.5 million tonnes to 2.97 million tonnes during the above period (GOI, 2007). The number of trawlers operating in Indian waters has been recently estimated at 29,241 with maximum number operating in Gujarat (27.4%), followed by Tamil Nadu (18.1%), Maharashtra (14.4%), Kerala (13.6%), Karnataka (8.6%), Andhra Pradesh (6.2%), Orissa (4.6%), Goa (2.8%), West Bengal (2.1%), Pondicherry (1.1%) and Daman & Diu (1.1%). Of the total trawler fleet in India, 67.9% operates in the west coast and 32.1% in the east coast (CMFRI, 2006b). According to the recent estimate by CMFRI, the marine fish landing during the 2006-07 period is provisionally 2.71 million tonnes, of which 55% is contributed by pelagic species, 24% by demersal fishes, 16% by crustaceans and 5% by molluscs.

Major share (71%) of the total landings is contributed by mechanized sector, 24% by motorized sector and 5% by artisanal sector (CMFRI, 2006a).

1.2 Bycatch and Discards

1.2.1 Bycatch definitions

There are a number of definitions available regarding the term, bycatch. McCaughran (1992) defined bycatch as 'that portion of the catch returned to the sea as a result of economic, legal or personal considerations plus the retained catch of non-targeted species'. Hall (1996) defined bycatch as "that part of the catch that is discarded at sea dead (or injured to an extent that death is the result)". Gordon, (1991) defined bycatch as "non-target species caught with and incidentally to the target species". Clucas, (1997) defined bycatch as "that part of the catch which is not the primary target of the fishing effort which includes fish which is retained, marketed (incidental catch) and that which is discarded or released". Pillai, (1998) defined the term bycatch as "the portion of catch other than the target species caught while fishing for a particular species". Hameed and Boopendranath (2000) stated that "bycatch includes undersized fish, non-targeted fish species, birds, mammals and other organisms encountered during fishing operations".

Alverson *et al*. (1994) reviewed the literature on bycatch and concluded that there are mainly three accepted definitions of bycatch. In some areas, bycatch is the catch, which is retained and sold, that is not target species. In some other areas, bycatch means species or sizes and sexes of fish which are discarded. The term bycatch is also known to include all non-target fish species retained, sold or discarded.

Alverson *et al.* (1994) defined bycatch, based on recommendations of the Newport Workshop, Oregon (USA), as discarded catch plus incidental catch. Discarded catch means catch returned to the sea due to economic, legal, or personal considerations. Incidental catch means retained catch of non-targeted species. Definition of bycatch as advocated by Alverson *et al.* (1994) is followed, in this study, and includes both discarded catch and incidental catch.

1.2.2 Bycatch and discards - World scenario

A preliminary assessment of bycatch in world fisheries was made by Saila (1983). According to Saila (1983), the discards were 6.72 million tonnes in shrimp fisheries. Later, Andrew and Pepperell (1992) estimated global bycatch in shrimp fisheries at 16.7 million tonnes. In the year 1994, Alverson *et al*. (1994) estimated that annual bycatch in the world fisheries as 28.7 million tonnes of which an estimated 27.0 million tonnes were discarded. Shrimp trawling accounted for 37.2% (9.5 million tonnes) of the total world bycatch. According to this data, much of the discard in shrimp fisheries is comprised of small tropical fishes. In temperate and sub-arctic waters, main portion of the discards are juveniles and adults of fishes of commercial value. Shrimp fisheries of India and Pakistan were contributing major share of discards in West Indian ocean (Alverson *et al*., 1994). In 1998, FAO estimated a global discard level of 20 million tonnes (FAO 1999). Average annual global discards, has been re-estimated to be 7.3 million tonnes, based on a weighted discard rate of 8%, during 1992-2001 period (Kelleher, 2004). Decline in discards, may be due to a number of reasons such as stock depletion, strict regulations in some fisheries in the form of improved fishing selectivity, anti-discard regulations and increased use of bycatch reduction devices. Globally, shrimp trawling contributes to the highest level of discard/catch ratios of any fisheries, ranging from about 3:1 to 15:1, and the amount of bycatch varies in relation to target species, seasons and areas (EJF, 2003). Trawl fisheries for shrimp and demersal finfish account for over 50% of the total estimated global discards (Kelleher, 2004).

1.2.3 Bycatch and discards - Indian scenario

In India, the bycatch problem is more due to the multi-species nature of the tropical fisheries. During shrimp trawling large quantities of finfish bycatch including significant amount of juveniles are also landed. The preliminary assessment of bycatch and discards in India by Central Marine Fisheries Research Institute, Cochin in 1979, has given 79.18% (3,15,902 tonnes) of total shrimp trawl landings as bycatch in India, maximum being in Gujarat (92.58%), followed by Tamil Nadu (91.04%) and Pondicherry (86.52%) and was utilized either for human consumption or as fish meal and fish manure (George *et al*., 1981). During 1980-82, trawl bycatch was estimated at 85% of the trawl landings off Mangalore and Malpe in Karnataka (Sukumaran *et al.*, 1982). According to Gordon (1981), bycatch landing in east coast of India was 90,000 to 130,000 tonnes per annum. Gordon (1991) estimated that juvenile discards from trawling operations, off Visakhapatnam was 25 to 30%. Rao (1998) re-assessed the estimate of bycatch by the fleet based at Visakhapatnam at 40,410 tonnes, of which 32,421 tonnes was discarded and 8258 tonnes was retained.

A study conducted along the states of Kerala, Karnataka and Tamil Nadu by Menon in 1996 observed that target groups such as shrimp (16%) and cephalopods (4%) together constituted only 20% and others such as finfishes (65%) and benthic organisms 15% constituted the rest of the trawl landings. The quantity of bycatch landed by trawlers in the above states during 1985-90, was estimated as 43,000 t, of which 81% was constituted by stomatopods, and another 87,000 t of unmarketable benthic organisms is estimated to be discarded (Menon, 1996). Bycatch landings along Cochin, Visakhapatnam and in Saurashtra region (Gujarat), was about 70 to 90% and average discards was 15 to 20% from shrimp trawling (Pillai, 1998). Bycatch landing was maximum in Gujarat (90 to 95%), followed by Tamil Nadu (80 to 90%), Andhra pradhesh (80 to 85%), Karnataka (80 to 85%), Orrisa (75 to 80%), Mahahrashtra (70 to 75%) and Kerala (65 to 70%). It is significant to note that among the bycatch, about 40% consisted of juveniles (Pillai, 1998).

A recent study conducted in Karnataka (India) revealed that bycatch quantity from trawlers is 56,083 tonnes in 2001 and 52,380 tonnes in 2002, forming 54.4% and 47.9% of total trawl catch, respectively. The quantity of discards was 34,958 tonnes (33.9%) in 2001 and 38.318 tonnes (35.1% of total catch) in 2002. Discards were more in post-monsoon months. During single day fishing, stomatopods formed the most dominant component among discards (over 52%) but in multi-day fishing various finfishes dominated the discards. In Karnataka, juveniles contributed 36% of discards (15.9% of total catch) in single day fishing and 78% (23.5% of total catch) in multi-day fishing (Zacharia *et al*., 2005).

The characterization and quantification of bycatch and discards along Kerala coast, during 2000-2002, was done by Kurup *et al.* (2003). The discarded quantity estimated during 2000-2001 was 2,62,000 tonnes and during 2001-2002 it was 2,25,000 tonnes. The dominant varieties among the discards were finfishes, crabs and stomatopods. The group wise average discards during the study period were finfishes (95,000 tonnes), crabs (68,000 tonnes), stomatopods (40,000 tonnes), gastropods (22,000 tonnes), juvenile shrimps (5,000 tonnes), soles (3,000 tonnes), jelly fishes (3,000 t), cephalopods (2,900 tonnes), echinoderms (1,800 tonnes), sea snakes (1000 tonnes), and eggs (890 tonnes) (Kurup *et al*., 2003; 2004).

Kelleher (2004) has estimated total bycatch discards in Indian fisheries at 57917 t, which formed 2.03% of the total landings. Kumar and Deepthi (2006) have discussed the implications of trawl bycatch on marine ecosystem.

1.3 Bycatch Reduction Devices

Several approaches have been proposed and undertaken for bycatch reduction in trawling (Hall, 1996; Hall *et al*., 2000; EJF, 2003). Bycatch reduction has been attempted in several areas by reduction in the overall fishing effort, reduction in bycatch per unit effort by technological interventions and management actions like setting bycatch limits for individual vessels. Bycatch reduction through technological intervention (modification of fishing gears, installing Bycatch Reduction Devices and Turtle Excluder Devices) is considered as the prime approach for shrimp trawling industry around the world.

Bycatch Reduction Devices (BRDs) is defined as any device that can be incorporated in a fishing gear in order to exclude or reduce non targeted and unwanted catch in a fishing system and there by making it more selective. Bycatch Reduction Devices are physical modifications to trawls designed to reduce the catches of unwanted organisms, while maintaining catches of prawns (Broadhurst, 2000; Mitchell *et al*., 1995). BRDs are also known as trawl efficiency devices or trash excluder devices (Robins-Toeger., 1994). TED or turtle excluder devices are a specific type of BRD design designed to exclude large animals such as sea turtles, sting rays, sharks, sponges, etc. There is a widespread and increasing requirement for using bycatch reduction devices in trawl fisheries throughout the world. Efforts towards reducing bycatch take advantage of the variation in size of the species and their differential behaviour within and in the proximity of fishing gear.

There are several advantages in using BRDs in shrimp trawling (Brewer *et al*., 1998). BRDs reduce the negative impacts of shrimp trawling on marine community. Fishers could benefit economically from higher catch value due to improved catch quality, shorter sorting time, lower fuel costs, and longer tow duration. Adoption of BRDs by fishers would forestall any criticism by conservation groups against trawling. Recreational and non-shrimp commercial fisheries would also benefit due to a reduced impact on the species targeted by them.

1.3.1 Classification of Bycatch Reduction Devices

BRDs have been developed based on the differential behavior patterns such as differences in swimming speed, vertical distribution or size of shrimp and fish inside the net and size selectivity. The fish are active and capable of swimming against the water flow inside the net and may escape at any time when the required facilities are provided. Shrimp is unable to swim against the water flow and carried away with the flow of water up to the cod end. (Broadhurst and Kennely, 1994; 1996; Brewer *et al*., 1998; Pillai, 1998; Broadhurst, 2000; Hameed and Boopendranath, 2000). A standard classification for BRDs is found unavailable while a generalized categorization was observed in some literature (Mitchell *et al.,* 1995; Talavera, 1997; Pillai, 1998; Broadhurst, 2000). BRDs can be broadly classified into three categories based on the type of materials used for their construction, *viz*., Soft BRDs, Hard BRDs, and Combination BRDs. Soft BRDs make use of soft materials like netting and rope frames for separating and excluding bycatch. Hard BRDs are those, which use hard or semi-flexible grids and structures for separating and excluding bycatch (Mitchell *et al*.,1995). Combination BRDs use more than one BRD, usually hard BRD in combination with soft BRD, integrated to a single system (Boopendranath *et al.,* 2006; Boopendranath, 2007).

1.3.2 Soft Bycatch Reduction Devices

The soft Bycatch Reduction Devices use soft structures made of netting and rope frames instead of rigid grids, prevalent in hard BRDs, for separating and excluding bycatch. Based on the structure and principles of operation they are classified into five categories *viz*., (i) Escape windows, (ii) Radial Escapement Section without Funnel, (iii) Radial Escapement Section with Funnel, (iv) BRDs with differently shaped slits and (v) BRDs with guiding/separator panel. Soft BRDs have advantages such as ease of handling, low weight, simplicity in construction and low cost, compared to hard BRDs.

1.4 Review of Literature

One of the greatest challenges before modern fisheries, in recent times, is to develop and implement selective fishing, in order to minimize ecological and environmental impacts of fishing. The importance of reducing bycatch and minimizing ecological impacts of fishing operations have been emphasized by a number of authors in the world (Andrew and Pepperell, 1992; Alverson *et al*., 1994, FAO, 1995; FAO, 1996; Kennelly, 1995; Mitchell *et al*., 1995; Hall, 1996; Clucas, 1997; Kaiser and de Groot., 2000; Broadhurst, 2000; Hameed and Boopendranath, 2000; Boopendranath *et al.,* 2006; Boopendranath, 2007). FAO code of conduct for responsible fisheries has given priority status to development and for improvement of fishing technology that eliminates bycatch or selectively target fish in a way promotes long-term sustainability and protection of biodiversity (FAO, 1995). One of the approaches in the responsible fishing practices is to reduce the negative impacts of a fishing gear by improving the selectivity and incorporation of bycatch reduction devices.

1.4.1 Historical evolution

Good fisheries management and responsible fishing regimes requires that fishing gear should preferentially catch the adult fish at a particular age, which would maximize yield while permitting the juveniles and sub-adults to escape. Earlier works on gear selectivity are by Todd (1911), Davis (1929; 1934), Clark (1952), Graham (1954) and others. Mesh size of the netting has the greatest influence on selectivity. Among other intrinsic design features which influence selectivity of trawls are mesh configuration, 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; Briggs, 1986). Most of the size selection occurs in the codend and escape of fish also takes place through forward net panels (Ellis, 1963; Clark, 1963; Bennett, 1984). Shrimp mesh selectivity studies have been carried out with the objective of allowing greater escapement of undersized shrimps (Valdemarsen, 1989).

From the history, fishery managers attempted to minimize pre-recruit mortality through the use of mesh sizes in trawls (Armstrong *et al*., 1990). The first separator trawls were developed in France and the Netherlands in 1964 (FAO, 1973). Selective trawls were used in Belgium, Norway, Iceland and in the Northwestern United States on *crangonid* and *pandalid* shrimp in the 1960’s (Watson *et al*., 1986). Selective shrimp trawl experiments were conducted in Europe during the mid 1960s followed by experiments in West coast of US (FAO, 1973; Alverson *et al*., 1994). The need for selective shrimp trawling gear was first discussed by Seidel in 1975. The earlier method for the reduction of bycatch from shrimp trawl begins with the incorporation square mesh in codends (Averill and Carr 1987; Averill 1990; Isaksen and Valdemarsen 1986; Walsh *et al*. 1989). Greater efforts have been directed towards reducing bycatch by taking advantage of the differential behaviour of species in the fishing gear employed (Watson, 1989; Laevestu and Alverson 1992).

Species behaviour in trawls nets leads to the introduction of separator panels. The separator trawl designs used panels of webbing placed in the mouth, throat or along the wings of the trawl to lead the fish toward escape openings, allowing shrimp to pass through panel meshes into the codends. Other designs divided the trawl into upper and lower halves with separate codends (FAO, 1973; Watson and Taylor, 1986; Andrew and Pepperell, 1992; Prado, 1993). During 1980s experiments using sorting trawls spread world wide (Valdemarsen, 1986; Isaksen and Valdemarsen, 1986) and as a result, number of panel separators and funnel excluders and other soft devices for sorting catch from top to bottom or bottom to top or having vertical separating qualities emerged for use in different waters and for different species (FAO, 1973; Watson *et al*., 1986). Based on the separation concept, development of Radial Escapement Section took place in 1980s in Norway (West *et al*., 1984; Watson *et al*., 1986; Valdemarsen,1986). After the series of experiments and evaluation with earlier soft devices, hard turtle excluder device was developed in United States of America in 1980s (Watson and Taylor, 1986, Harrington, 1992).

Linnane *et al*. (2000) reviewed potential gear modifications in beam and otter trawl nets and they discussed the importance of mesh size, square mesh codends, separator panels and the incorporation of sieve net in the demersal trawls. Van Marlen (2000) discussed the importance of technical modifications in trawl such as square mesh codends, square mesh panels and windows, separator panels, escape openings in trawl and optimum mesh size for codends to reduce the capture of undersized fish and discards. Glass (2000) reviewed methods like square mesh codends, square mesh window, separator panels, composite codends and escape panels in trawl net for the conservation of fish stock. He described the methods of bycatch reduction based on the differential behavioral principle and mechanical sorting principle. Need for responsible fishing through the effective use of selectivity devices in ASEAN member countries were discussed by Chokesanguan (2002).

1.4.2 Development of hard BRDs

Research has been done on concepts or devices for shrimp trawling all over the world (Prado, 1993). Research on hard bycatch reduction device started only after 1980s, after the innovation of hard Turtle Excluder Device by National Marine Fisheries Service, US (Watson *et al*., 1986; Harrington, 1992; Isaksen *et al*., 1992; Prado, 1993). The important hard TEDs like NMFS hooped TED, Fixed angle TED and Cameron TED (Oravetz and Grant, 1986; Prado, 1993; Mitchell *et al*., 1995; Talavera, 1997, Rogers *et al*., 1997), Matagorda TED, Georgia-Jumper, Super Shooter, Anthony Weedless, Jones TED and Flounder TED (Talavera, 1997; Mitchell *et al*., 1995; Dawson, 2000; Belcher *et al.*, 2001; CIFT, 2003) were developed under the category of hard TEDs for the conservation of Sea turtles.

Various designs of hard BRDs are in operation either experimentally or commercially around the world which includes (i) Oval grids, oval shaped metallic grid with exit opening like Georgia-Jumper (Mitchell *et al.,* 1995), Galvanisada (Talavera, 1997), Saunders grid (Talavera, 1997), Thai Turtle Free Device (TTFD) (Chokesanguan, 1996); Oregon grate (Hannah *et al*., 2003), CIFT-TED (Dawson and Boopendranath, 2001), Seal Excluder Device (AFMA, 2008) and Halibut Excluder Grate (Rose, 2000); (ii) Slotted grid BRDs which provide slots for the passage of non-targeted organisms such as Hinged grid (Eigaard and Holst, 2004) and Anthony Weedless (Talavera, 1997); (iii) Bent grids in which grid bars and grid frame are bent at one end near the opening such as Juvenile and Trash Excluder Device (JTED) (Chokesanguan *et al*., 2000), NAFTED (Brewer *et al*., 1998; Eayrs, 2004); (iv) Flat grid BRDs such as Nordmore grid (Isaksen *et al*., 1992), Wicks TED (Robins *et al*., 1999), Kelly-Girourard grid (Morris, 2001), and EX-it grid (Maartens *et al*., 2002). Fisheye BRD is considered as an important hard BRD around the world (Pillai, 1998; Brewer *et al*., 1998; Hannah *et al*., 2003; Burrage, 2004). There are several design variations of fisheye BRD such as Florida Fish Eye (FFE) used in the Southeast US Atlantic (NCDMF, 1997) and in the Gulf of Mexico (Wallace and Robinson, 1994). Other designs in this categories are Snake-eye BRD used in North Carolina Bay (Fuls and McEachron, 1997), Fish slot (Morris, 2001), Sea eagle BRD (NCDMF, 1997) and Popeye Fish excluder or Fishbox BRD (Anon, 2004c).

1.4.3 Development of Semi-flexible BRDs

Semi-flexible BRDs made of semi-flexible or flexible materials such as polyethylene, polyamide and FRP are used in the North Sea brown shrimp fishery (Polet, 2002), Polyamide grid devices provided with hinges to facilitates operation from net drums have been used in the Danish experiments in the North Sea shrimp fishery (Madsen and Hanson, 2001) and Polyamide-rubber grid design are used in Denmark (Anon, 2002a).

1.4.4 Development of Soft BRDs

Based on the structure and principles of operation soft BRDs are classified into five categories *viz*., (i) Escape windows, (ii) Radial Escapement Section without Funnel, (iii) Radial Escapement Section with

Funnel, (iv) BRDs with differently shaped slits and (v) BRDs with guiding/separator panel.

1.4.4.1 Escape windows

Escape windows function based on the differential behaviour of fishes and shrimps. Fishes that have entered the codend tend to swim back and escape when suitable escape windows provided, at the top in the front section of the codend. Square mesh window, square mesh panels and rope BRD are the examples of this category (Broadhurst and Kennely, 1994; 1996; Brewer *et al*., 1998; Eayrs and Prado., 1998;1998b; Pillai, 1998; Pillai *et al*., 2004). Studies carried out using square mesh windows have indicated their effectiveness in reducing bycatch by 30 to 40% in Northern prawn trawl fisheries (Broadhurst and Kennely, 1994; 1996; Brewer *et al*., 1998). Square mesh has the advantage that the mesh opening is not distorted while under operation, unlike diamond meshes (Broadhurst and Kennely, 1994; 1996; Brewer *et al*., 1998; FAO, 1997; Robins *et al*., 1999; Kunjipalu *et al*., 1994). Experiments conducted in Persian Gulf waters has shown that Rope BRD is effective in excluding 25% of the bycatch with no loss of shrimp or commercial fish species (Eayrs and Prado., 1998). Use of square mesh panels has been found to reduce the bycatch, particularly juveniles and young ones, by about 20% in Indian waters (Kunjipalu *et al*., 1994; 1997; Pillai, 1998; Pillai *et al*., 2004).

1.4.4.2 Radial Escapement Section without Funnel

In Radial Escapement Section without Funnel, a radial section of netting with large meshes is provided between hind belly and codend. Small sized fishes, jellyfish and other bycatch components, which have low swimming ability, are expelled due to enhanced water flow through large mesh section. Based on this principle Fuwa *et al*. (2002) described a Trawl flow Regulative Ecological Friendly Netting Device (TREND). Experiments in Japanese waters, using TREND has been shown to give safe escapement to juvenile fish, with better opportunity for survival (Fuwa *et al*., 2002).

1.4.4.3 Radial Escapement Section with Funnel

Radial Escapement Devices with funnel (Watson and Taylor.,1988) positioned between hind belly and codend of the trawl. A small meshed funnel accelerates the water flow inside the trawl and carries the catch towards the codend. Actively swimming fishes swim back and escape through the large mesh netting section surrounding the funnel, where the water flow rate is weak, while the shrimps are retained in the codend. Studies using Radial Escapement Device have shown 20-40% reduction in the fish bycatch in Australia’s Northern Prawn Fishery (Brewer *et al*., 1998). Studies in India have indicated of 18% reduction in fish bycatch by using a variation of Radial Escapement Device with 80 mm square meshes, surrounding the funnel (Pillai *et al*., 2004). Experiments in Louisiana have shown that Extended Funnel BRD and Skirted Extended Funnel BRDs caught less bycatch than the control nets (Rogers *et al*., 1997). The Extended Funnel BRD has provided 44% fish reduction with 5% shrimp loss. The Monofilament BRD, which is used in commercial trawling, has been reported to give 25-51% reduction in bycatch, without problems of clogging. Bycatch reduction by Neil-Olsen BRD has been reported to be 27-45%, in tropical coastal waters (Robins *et al*., 1999).

1.4.4.4 BRDs with differently shaped slits

BRDs with differently shaped slits utilized the behaviour of fish and shrimp. Fishes that entered the codend are given opportunity to swim back and escape by providing slits in the netting on the topside of the codend or hind belly, while shrimps are retained in the codend (Robins *et al*., 1999; Morris, 2001). Average bycatch reduction from V-cut BRD, operated in Queensland east coast trawl fishery has been reported to be 16%, with very low or no shrimp loss (DPI-QLD, 2004). The Lake Arthur BRD, widely used in shrimp trawling in Lake Arthur area of Western Louisiana, is one of the earliest BRDs. Lake Arthur BRD is reported to reduce the bycatch up to 34% (Morris, 2001). Big eye BRD reduce bycatch by 30 to 40%, in tropical coastal waters, commercially used by shrimp fleet in Queensland east coast waters. During 1998, 30% of the Queensland east coast trawl fleet used Big eye BRD in their penaeid fishery (Robins *et al*., 1996).

1.4.4.5 BRDs with guiding or separator panel

Guiding or separator panels are used to achieve separation of the bycatch by using differences in their behaviour or size. BRDs with guiding panels lead the fishes to escape openings, making use of the herding effect of the netting panels on finfishes. The shrimps are not subjected to herding effect and hence pass through the meshes towards the codend. BRDs with separator panels physically separate the catch according to the size, with the use of appropriate mesh size. Shrimps pass through the panels to the codend while bycatch such as fishes and sea turtles are directed towards the exit opening (Christian *et al*., 1988; Rogers *et al*., 1997; Polet *et al*., 2004). Separator panel BRD operations in New South Wales shrimp trawl fisheries have indicated a shrimp loss of 2-30% and fish exclusion of 30-80% (Anon, 2004a). However, there is a chance for debris clogging the separator panel. Authement-Ledet BRD with bottom opening has been reported to give better exclusion of fishes, while top opening BRD entailed in minimum shrimp loss (Rogers *et al*., 1997).

The Morrison TED, Parker TED and Andrews TED are efficient soft TEDs, which are used to exclude sea turtles and large marine animals in many countries. Proper installation of the soft TEDs is essential in order to ensure their efficient performance. Morrison soft TED has been used successfully to exclude sea turtles in Gulf of Mexico. In addition to sea turtles, it reduced other bycatch species, particularly fish. The biggest drawback regarding this category of BRDs is the possibility of clogging with debris (Christian *et al*., 1988; Kendall, 1990). Studies in Moreton Bay, Queensland, Australia using Morrison soft TED has given reduction in bycatch by an average of 32% (Andrew *et al*., 1993; Robins-Troeger, 1994). Results of studies conducted in the Gulf of Mexico and South Atlantic shrimp fisheries has shown that Andrews soft TED is very effective in excluding the red snapper bycatch up to 77% with a shrimp loss of 16% and Morrison soft TED excluded 20 to 40% of fish bycatch with a shrimp loss of 13%. Andrews soft TED is successfully used in West Florida shelf area without excessive clogging (Anon, 2002b). Turtle exclusion rate from Parker soft TED, which is approved for use in US waters, has been reported to be 97% (Anon, 1998). Experiments using Sieve net in Belgium fishery has been bycatch exclusion rates of 29-50% in different seasons, with less than 15% loss of shrimps (Polet *et al*., 2004).

1.4.5 Development of Combination BRDs

Researchers has proposed different combinations of sorting grids, slotted BRDs such as fisheye and soft BRDs such a square mesh window and bigeye BRD in order to obtain higher bycatch exclusion efficiencies (Mounsey *et al*., 1995; Robins-Troeger *et al*., 1995; Brewer *et al*., 1998; McGilvray *et al*., 1999; Robins *et al*., 1999; Robins and McGilvray, 1999; Ramirez, 2001; Steele *et al*., 2002; Eayrs, 2004). Broadhurst *et al*., 2002 described a combination of square mesh panel with Nordmore grid.

1.4.6 Development of bycatch reduction technologies in India

In India, Kunjipalu *et al*. (1994a;1994b; 2001), Varghese and Kunjipalu (1996), Varghese (1999) have reported results of trawl selectivity studies conducted using square mesh codends and panels. Their studies indicated that mesh size below 25 mm in square mesh codend provided very little chance of escapement for juveniles and sub-adults. Pillai *et al*. (1999) developed a new separator device with horizontally divided codend for separation of shrimp and fish during trawling. Pillai *et al*. (1998; 2004) has made preliminary observations on the bycatch and discards of shrimp trawls in India and described certain selective devices with potential for reduction of bycatch in trawls. This includes square mesh window attachment, Radial Escapement Devices, Fisheye, Grid devices in shrimp trawling. Varghese *et al*. (2000) has reported a method of separating jellyfish from target species in shrimp trawls, using inner square mesh filter. Shrimp trawling and bycatch issues associated with mini trawling along the coastal waters of Kerala and the need to reduce bycatch in mini-trawl nets were discussed by Thomas (2000). Regulation in mesh size for trawl nets and use of square mesh in mini-trawl and other trawl nets used in inshore areas was proposed by Vijayan and Edwin (2001). Varghese *et al.* (2004) compared the selection pattern of diamond and square mesh codends in trawl. The effects of separator panel for bycatch separation in trawl codend were discussed by Vijayan *et al*. (2004). An indigenous Turtle Excluder Device (Hard TED) for use by the commercial trawling industry in order to prevent fishing induced mortality of sea turtles with minimum catch loss was developed by Central Institute of Fisheries Technology (CIFT) (Dawson & Boopendranath, 2001; CIFT, 2003).

1.5 Rationale and Objectives of the Study

Though trawling is an efficient method of fishing, it is known to be one of the most non-selective methods of fish capture. The bulk of the wild caught penaeid shrimps landed in India are caught by trawling. In addition to shrimps, the trawler fleet also catches considerable amount of non-shrimp resources. Bycatch discards is a serious problem leading to the depletion of the resources and biodiversity. In order to minimize these problems, trawling has to be made more selective by incorporating Bycatch Reduction Devices (BRDs). The soft BRDs use soft structures made of netting and rope frames instead of rigid grids prevalent in hard BRDs, for separating and excluding bycatch.

Studies regarding the technologies to reduce bycatch have been conducted in various fisheries in different parts of the world. In India not much work has been done in this regard even though the bycatch in the landings by shrimp trawlers in India is very significant. Under the Code of

Conduct for Responsible Fisheries (FAO, 1995) stress have been given to the design and development of fishing gear that are environment friendly which minimize negative impacts of fishing on long term sustainability and biodiversity. The present study aims to develop simple, efficient, cost-effective bycatch reduction devices using soft structures for the mechanized shrimp trawl fisheries sector of India.

The main objectives of the study have been:

- To design and develop soft bycatch reduction devices, incorporating flexible materials for selective trawling;
- To study the existing trawl systems (vessel, gear and accessories) and bycatch issues off south Kerala; and
- Comparative field evaluation using prototype BRDs and statistical analysis of data, in order to evolve the most appropriate BRD for the small-scale mechanized trawl sector.

Chapter 2

Materials and Methods

The objectives of the study included design and development of soft bycatch reduction devices incorporating flexible materials for selective trawling, comparative field evaluation of soft BRDs for selective shrimp trawling and investigations on the status of existing trawl systems (vessel, gear and other accessories) and bycatch issues off south Kerala.

2.1 Soft BRDs used for the study

A wide variety of soft BRDs are used in experimental or commercial basis in different fishing areas, in order to reduce bycatch from shrimp trawls with promising results. It is important to take the characteristics of the fishery and their geographical peculiarities into consideration before designing BRDs.

The selection of BRDs for this study was based on (i) their applicability to bycatch issues prevailing in the Indian waters (ii) their record of success in reducing bycatch while maintaining the shrimp catch and (iii) their potential for acceptance by the industry. Soft BRDs selected for the study were (i) Radial Escapement Device, (ii) Bigeye Bycatch Reduction Device, (iii) Sieve net Bycatch Reduction Device, (iv) Separator panel Bycatch Reduction Device.

2.1.1 Radial Escapement Device

Radial Escapement Device consists of a small mesh funnel surrounded by a radial section of large square mesh netting (Watson and Taylor, 1988). Mesh size of the netting in the square mesh section is so regulated as to exclude the fishes constituting the bycatch (Brewer *et al*., 1998).

2.1.1.1 Radial Escapement Device with 150 mm square meshes

Escapement section of this radial escapement device consists of a netting cylinder of 150 mm square mesh (20 mesh depth and 38 mesh circumference) fabricated of 3 mm dia twine attached to 900 mm dia hoops made of 6 mm dia stainless steel rod at both ends. The total length of the BRD is 1.5 m. A 25 mm small mesh funnel with 211 meshes in the leading edge and 69 meshes in the hind edge with a depth of 98 meshes (cutting rate:1P2B) is fixed inside the netting cylinder by attaching the wider part of the funnel to the leading edge of the cylinder (Fig 2.1). A 8 mm rope is attached along the sides of the device for strengthening. The device is fixed in between the hind belly and the codend of the shrimp trawl. A 20 mm diamond mesh codend 200 meshes in length (4.0 m in hung length) and 280 meshes in circumference was used for the experiments. A cover made of polyamide netting (210Dx1x2) of 15 mm mesh size and 7.0 m in hung length was attached to the front hoop for retaining the excluded catch.

A modified version of this 150 mm Radial Escapement Device was constructed after the initial field trials. In the latter version, the front hoop was modified by attaching a 1200 mm dia outer frame for attaching the cover, in order to minimize the masking effect of the cover (Fig 2.2).

Fig 2.1 Radial Escapement Device with 150 mm square mesh escapement section

Fig 2.2 Radial Escapement Device-150 mm modified for reducing masking effect of the cover

2.1.1.2 Radial Escapement Device with 100 mm square meshes

Escapement section of this radial escapement device consists of a netting cylinder of 100 mm square mesh (30 meshes in depth and 56 meshes in circumference) fabricated of 2.5 mm dia twine attached to 900 mm dia hoops made of 6 mm dia stainless steel rod at both ends. The total length of the BRD is 1.5 m. A 25 mm small mesh funnel with 211 meshes in the leading edge and 69 meshes in the hind edge with a depth of 98 meshes (cutting rate:1P2B) is fixed inside the netting cylinder by attaching the wider part of the funnel to the leading edge of the cylinder (Fig 2.3). A 8 mm rope is attached along the sides of the device for strengthening. The device is fixed in between the hind belly and the codend of the shrimp trawl. A 20 mm diamond mesh codend 200 meshes in length (4.0 m in hung length) and 280 meshes in circumference was used for the experiments. A cover made of polyamide netting (210Dx1x2) of15 mm mesh size and 7.0 m in hung length was attached to the front hoop for retaining the excluded catch.

A modified version of this 100 mm Radial Escapement Device was constructed after the initial field trials. In the latter version, the front hoop was modified by attaching a 1200 mm dia outer frame for attaching the cover, in order to minimize the masking effect of the cover (Fig 2.4).

Fig 2.3 Radial Escapement Device with 100 mm square mesh escapement section

Fig 2.4 Radial Escapement Device-100 mm modified for reducing masking effect of the cover

2.1.2 Bigeye BRD

Bigeye BRD consists of a simple horizontal slit in the upper part of codend or hind belly, where the opening is maintained by means of floats and sinkers. Differences in the behaviour of fish and shrimps are utilized in the design of this category of BRDs. Fishes that have entered the codend are given opportunity to swim back and escape by providing slits in the netting on the topside of the codend or hind belly, while shrimps are retained in the codend (Fig 2.5). Two designs of Bigeye BRDs were used for the study.

2.1.2.1 Bigeye BRD positioned at 0.5 m from the leading edge of the codend (Big eye-0.5 m)

A slit is provided in top of the codend by cutting 15 meshes in the twine-wise direction across the net section. The slit is positioned 0.5 m from the leading edge of the codend. The Bigeye BRD was used in a commercial type codend of 5 m long constructed of 20 mm netting. Four sinkers (2x30 g and 2x125 g) and four floats with sufficient extra-buoyancy were used to keep the slit vertically open (Fig 2.6).

2.1.2.2 Bigeye BRD positioned at 1.5 m from the distal end of the codend (Bigeye-1.5 m)

A slit is provided in top of the codend by cutting 15 meshes in the twine-wise direction across the net section. The slit is positioned 1.5 m from the distal end of the codend. The Bigeye BRD was used in a commercial type codend of 5 m long constructed of 20 mm netting. Four sinkers (2x30 g and 2x125 g) and four floats with sufficient extra-buoyancy were used to keep the slit vertically open (Fig 2.7).

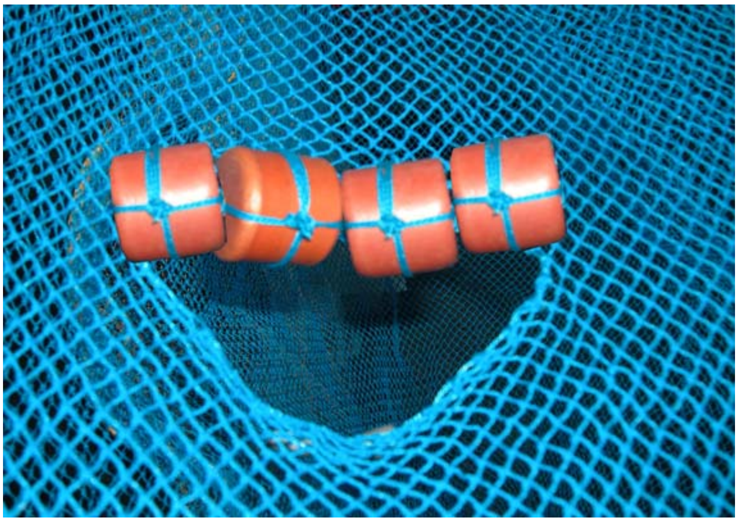


Fig 2.5 Bigeye BRD in the trawl codend, kept open by means of floats and sinkers

Fig 2.6 Positioning of the Bigeye-0.5m BRD

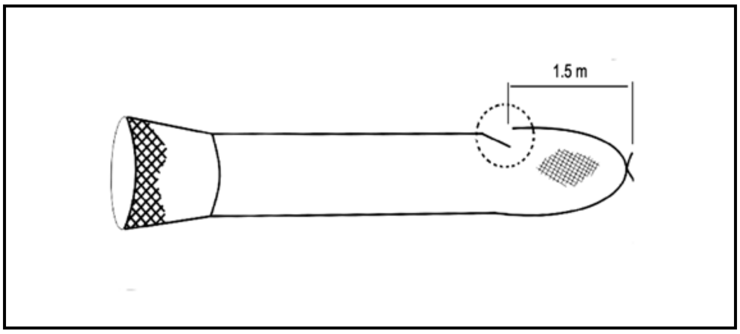


Fig 2.7 Positioning of the Bigeye-1.5 m BRD

2.1.3 Sieve Net BRD

In Sieve net BRD, a large mesh funnel positioned inside the net is used to separate shrimps from other non-target organisms (Fig 2.8 and 2.9). Three design variations were used for performance evaluation.

2.1.3.1 Sieve net with 60 mm diamond mesh funnel and 80 mm diamond mesh outlet codend (Sieve net-60 mm)

In the first design of sieve net, a funnel made of 60 mm mesh netting (135 mesh circumference in the leading edge, 19 meshes circumference in the hind edge and 70 meshes in depth, with a cutting rate of 1N10B) is used for separation of shrimps. The hind end of the funnel is opening to an outlet codend with 80 mm mesh size, of 4 m length and 60 meshes in circumference. The throat section with sieve net is attached to the codend of 5 m length (mesh size: 20 mm).

2.1.3.2 Sieve net with 40 mm square mesh funnel and 60 mm square mesh outlet codend (Sieve net-40 mm)

In the second design, the sieve net was made of 40 mm square mesh netting (203 bar circumference in the leading edge, 57 bar circumference in the hind edge and 190 bar in depth). The tapering edge leads to an outlet codend of 4 m in length and 74 bar in circumference, fabricated of 60 mm square mesh netting.

2.1.3.3 Sieve net with 50 mm diamond mesh funnel and 60 mm diamond mesh outlet codend (Sieve net-50 mm)

In the third version, a 50 mm mesh funnel (162 meshes in circumference in the leading edge, 22 meshes in circumference in the hind edge and 84 meshes in depth) was used. The hind end of the funnel is opening to outlet codend of 4 m length and 70 meshes in circumference, fabricated of 60 mm mesh netting. The second codend is surrounded by small mesh (12 mm) cover which is 2.5 times the dimensions of the codend.

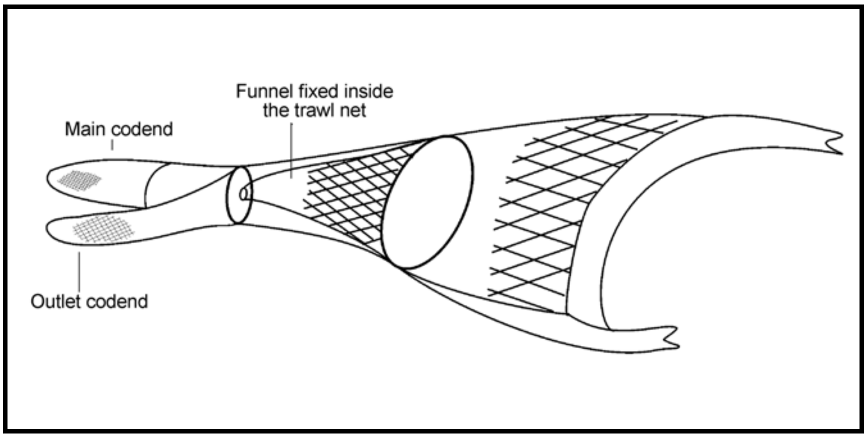


Fig 2.8 Perspective view of Sieve net BRD installed in the trawl net

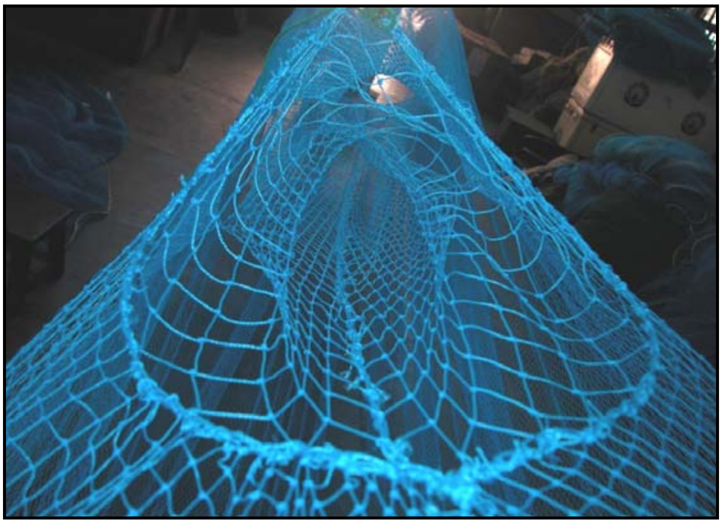


Fig 2.9 A view of the funnel exit opening of the Sieve net-40 mm BRD

2.1.4 Separator panel BRD

Separator panels physically separate the catch according to the size, with the use of appropriate mesh size. Shrimps pass through the panels to the codend while bycatch such as fishes and sea turtles are directed towards the exit opening. Two design variations of separator panel were used for experiments. In this BRD, an oval shaped netting panel is placed at 45-55° angle from the horizontal, leading to a opening in the top and is used to separate shrimps from fish in shrimp trawls (Fig. 2.10). The following are two different types of separator panels used for the study.

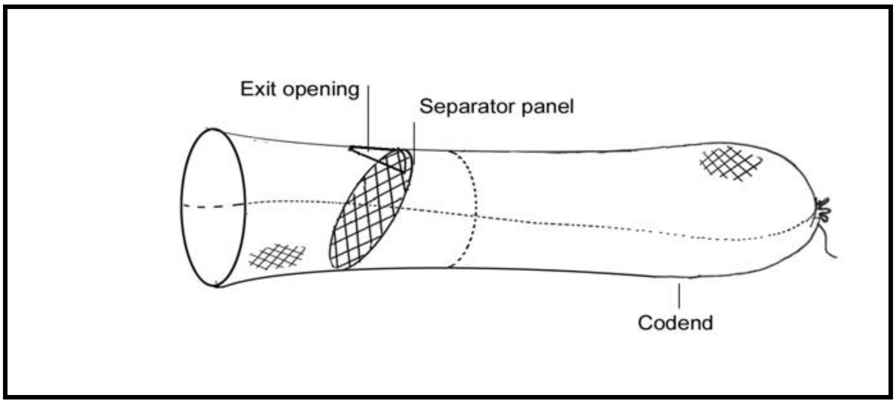


Fig. 2.10 Perspective view of Separator panel BRD

2.1.4.1 Separator panel with 40 mm diamond mesh netting

In the first design, an oval shaped separator panel of 1000x800 meshes in size constructed of square mesh netting of 40 mm mesh size and 1.25 mm twine dia with an outer rope frame (8 mm dia polypropylene) was used (Fig 2.11)

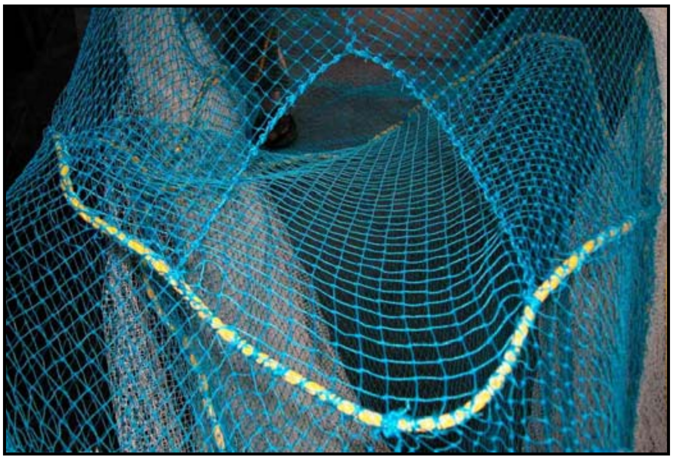


Fig 2.11 A view of Separator panel made of 40 mm square mesh netting

2.1.4.2 Separator panel with 60 mm square mesh netting

In the second design, an oval shaped separator panel of 1000x800 meshes in size constructed of square mesh netting of 60 mm mesh size and 1.25 mm twine dia with an outer rope frame (8 mm dia polypropylene) was used. The oval shaped panel was fixed in the throat section of the net in front of the codend to assume an angle of about 45° from the horizontal and a 15 mesh bar opening was provided in the top panel in order to facilitate the escapement of fishes (Fig 2.12).

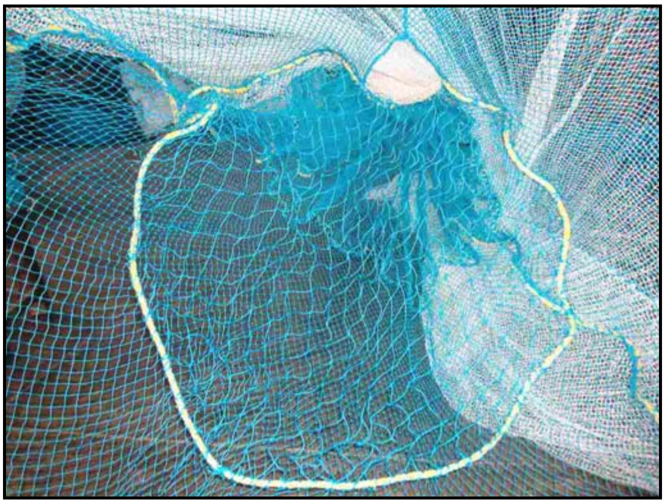


Fig 2.12 Separator panel BRD made of 60 mm diamond mesh netting

2.2 Fishing Gear

Three commercial shrimp trawl designs used widely off Kollam, South Kerala were deployed for the experiments. The trawls were fabricated in the fishing gear laboratory of Central Institute of Fisheries Technology, Cochin. The shrimp trawl designs used for the experiments were 28.8 m shrimp trawl (*Karikkadi vala*) (Fig. 2.13), 29.0 m shrimp trawl (*Poovalan vala*) (Fig. 2.14) and 32.4 m shrimp trawl (*Naran vala*) (Fig. 2.15). The trawls were fabricated of HDPE netting.

The shrimp trawl was rigged with V-type steel otter boards of size 1420x790 mm size (80 kg each) (Fig. 2.16) and 20 m double bridles (Fig. 2.17).

2.3 Research vessels

Field trials were conducted from two research vessels of Central Institute of Fisheries Technology *viz*., MFB Matsyakumari (17.5 m LOA, 57.17 GRT; 277 bhp @ 1000 rpm Kirloskar Mann engine) (Fig. 2.18) and MFV Sagar Shakti (wooden trawler 15.24 m LOA, 30 GRT, 223 bhp @ 1800 rpm Ruston MWM engine) (Fig. 2.19).

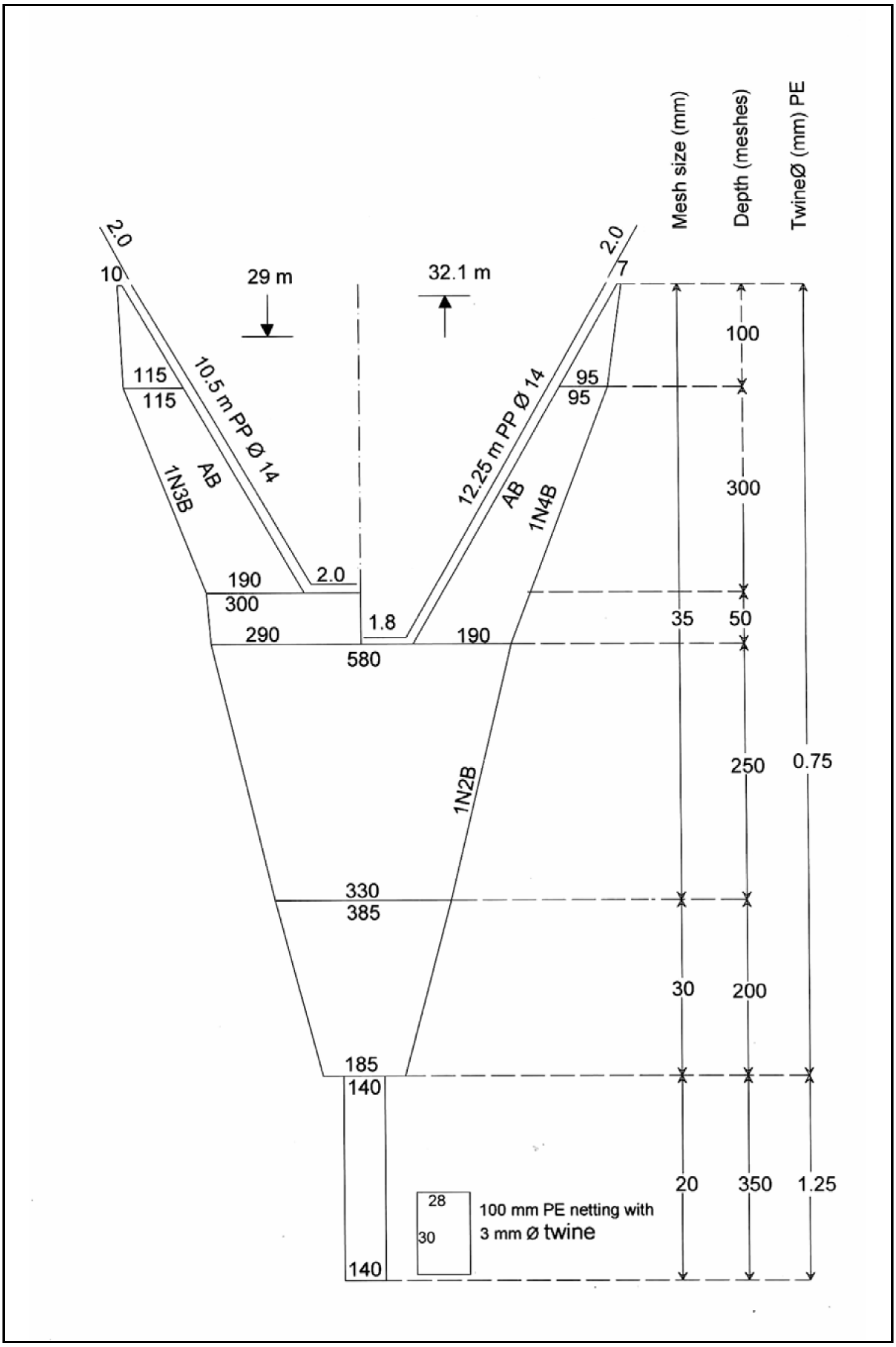


Fig. 2.13 Design of 28.8 m shrimp trawl (*Karikkadi vala*)

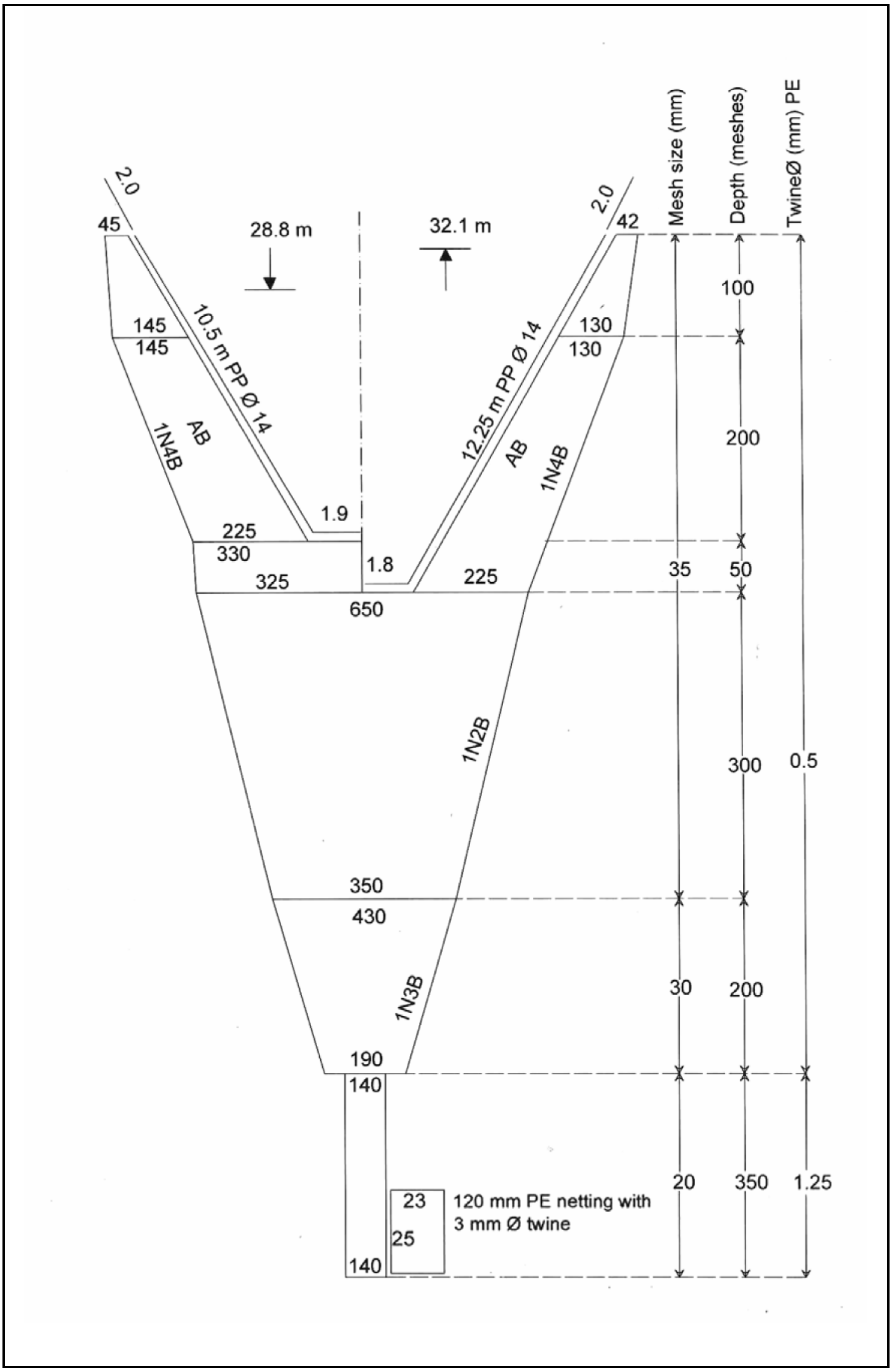


Fig. 2.14 Design of 29.0 m shrimp trawl (*Poovalan vala*)

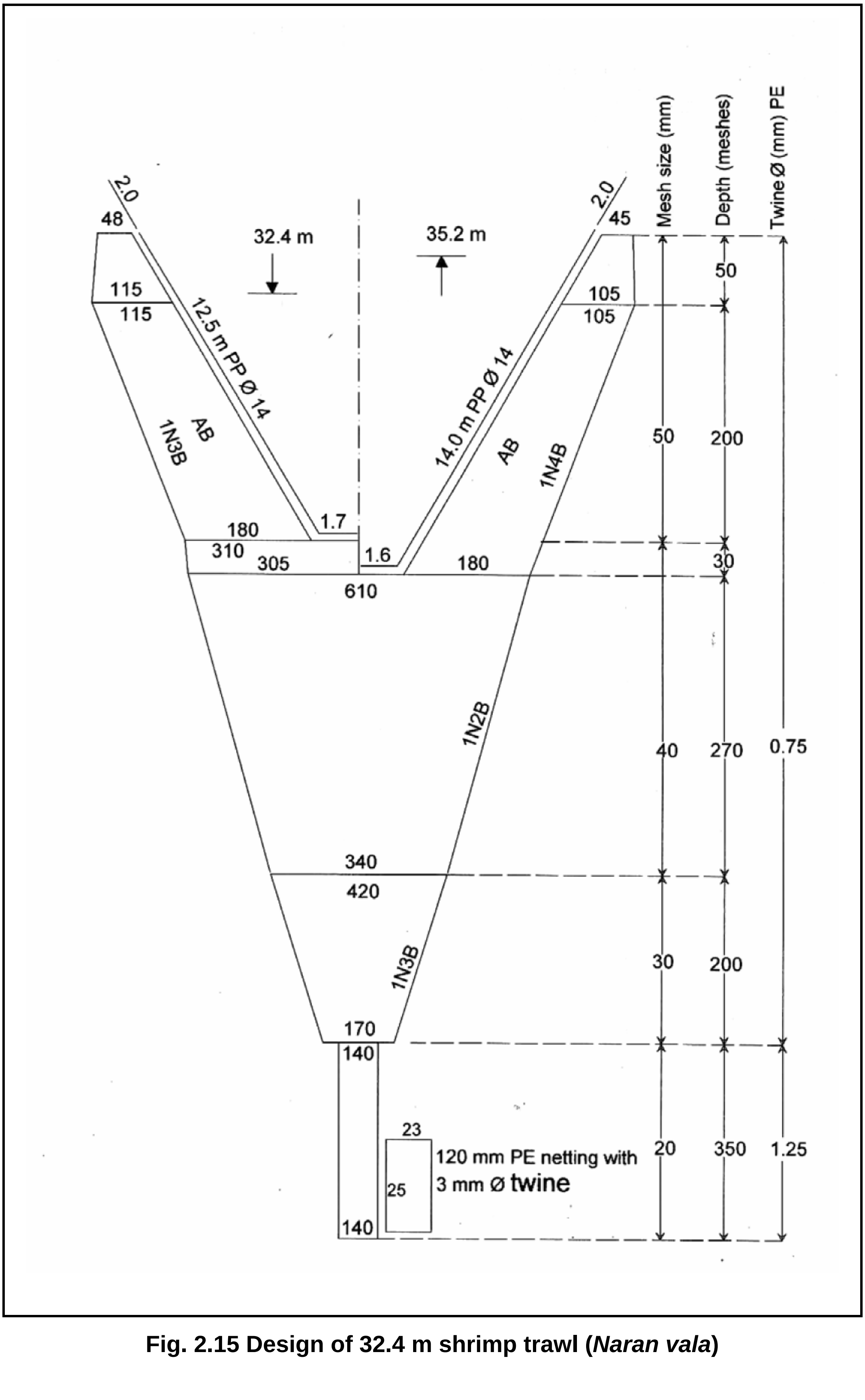


Fig. 2.15 Design of 32.4 m shrimp trawl (*Naran vala*)

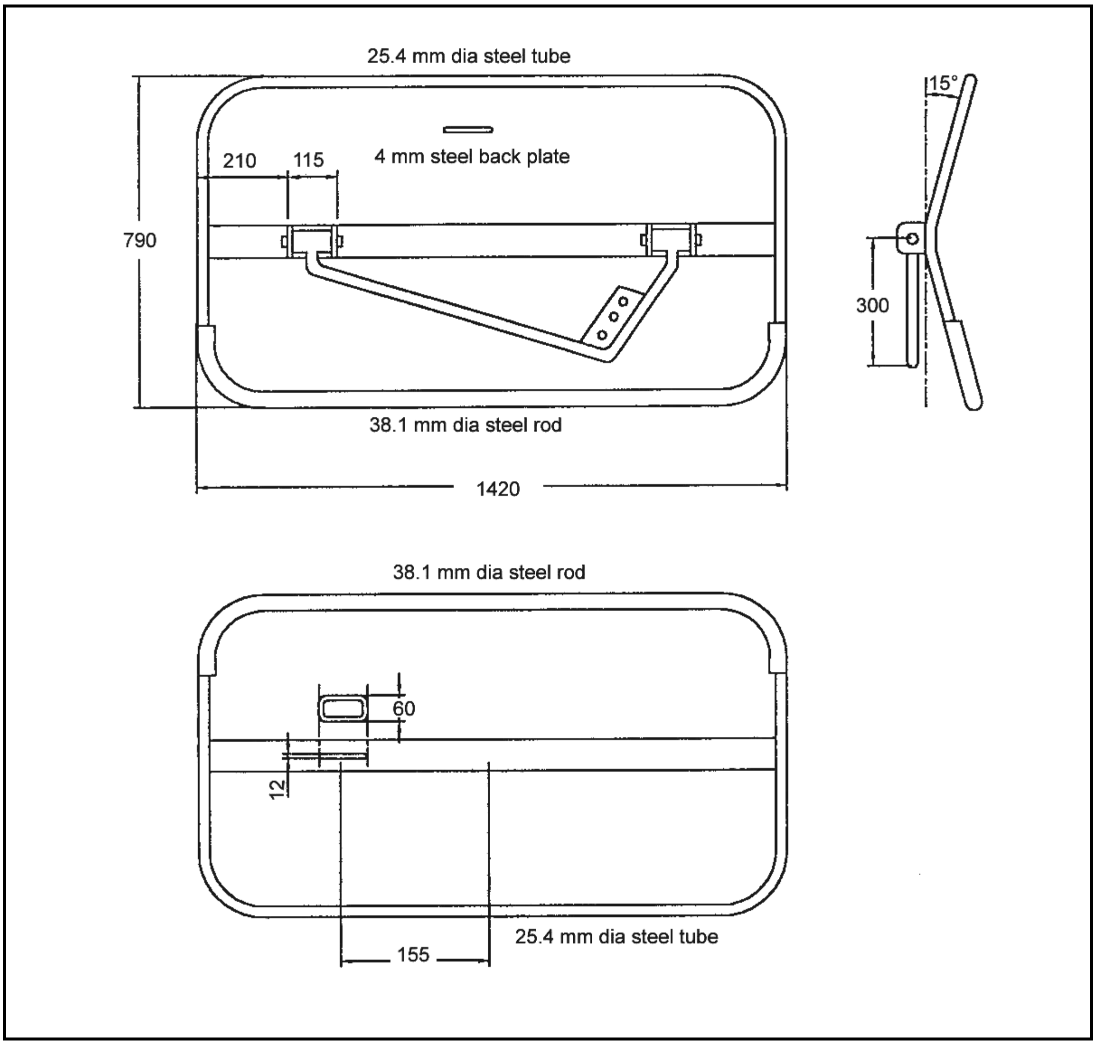


Fig. 2.16 Design details of V-type otter boards (1420x790 mm; 80 kg each)

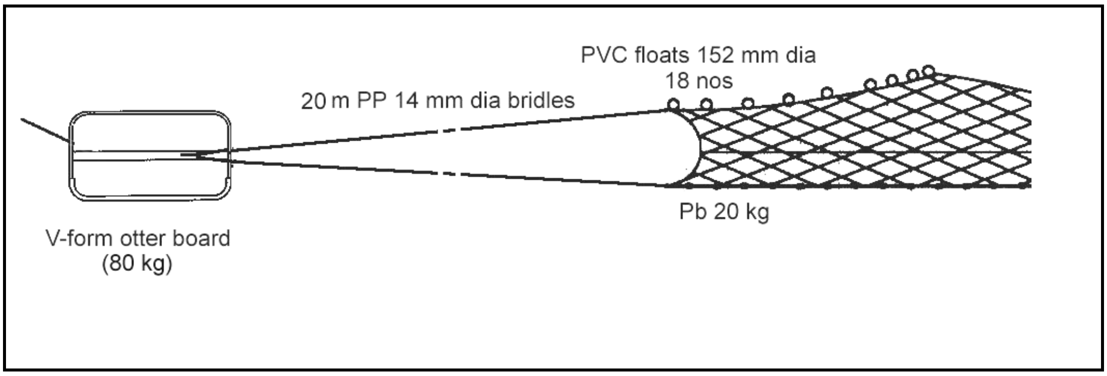


Fig. 2.17 Rigging of a typical shrimp trawl

Fig. 2.18 MFB Matsyakumari

Fig. 2.19 MFV Sagar Shakthi

2.4 Fishing area

The experimental fishing operations were conducted during daytime, in the traditional shrimp fishing grounds at a depth ranging between 9-32 m off Cochin (Fig. 2.20).

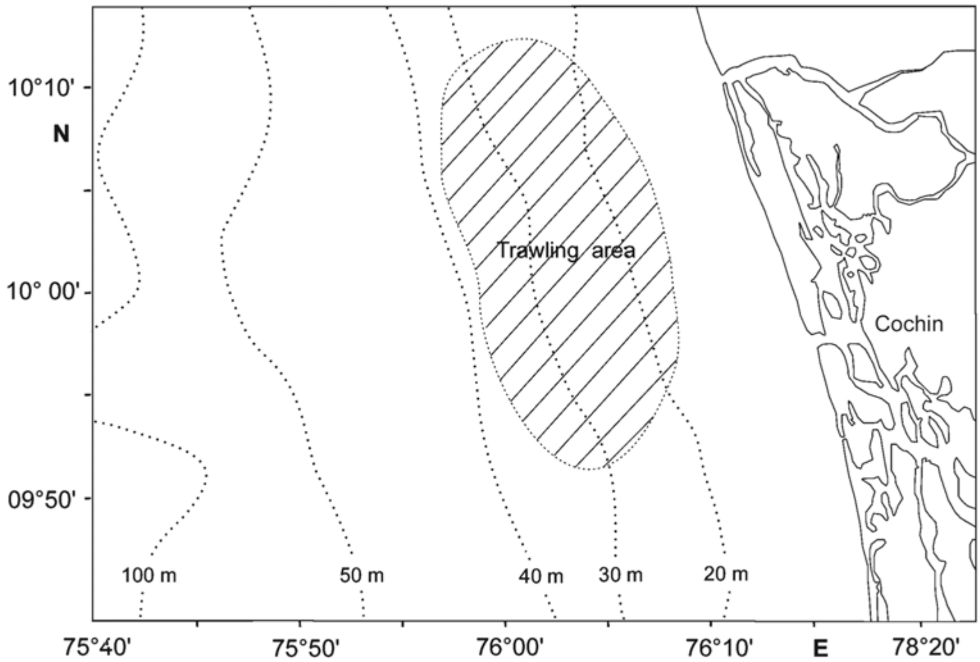


Fig. 2.20 Fishing area

2.5 Field trials, data collection and analysis

Statistically designed comparative fishing experiments were used for evaluation of comparative performance of BRDs. About 10 to 20 hauls each of 1 to 1.5 h duration were conducted for each set of experiments. Covered codend method (adapted from Sparre *et al*., 1989; and Wileman *et al*., 1996) and small meshed covers over BRD exit opening (CIFT, 2003) were used to retain the excluded catch, during BRD installed trawling operations. Both retained and excluded catches were sorted and identified up to species level, in order to determine selectivity parameters such as selection lengths (L_{50}, L_{25} and L_{75}), selection range and selection ogive and bycatch exclusion characteristics of the BRDs. In the case of large volumes of catch, sub-samples were taken for analysis. In the case of fishes and shrimps total length was taken and for cephalopods the mantle length was measured.

Format used for onboard data collection is given in Annexure 1. Student's *t*-test was used to evaluate the significance of the difference in performance of the soft BRDs.

Catch diversity analysis is useful in the assessment of the impact of trawling on the resources and in the development of eco-friendly trawl systems which minimize impact on non-target resources. PRIMER software package (Version 5.2.9; Plymouth Marine Laboratory, Plymouth, UK) (Clark and Warwick, 2001) was used for SIMPER analysis, k-dominance curves, diversity indices such as total number of species (S), Margalef richness (d), Pielou's evenness (J'), Brillouin index (H), Shannon index (H'), Simpson's dominance index (λ'). Simpson's evenness measure ($E_{1/D}$) was determined using MS Excel by dividing reciprocal of Simpson's dominance index with total number of species (S) in the excluded catch (Clark and Warwick, 2001).

2.6 Survey of trawl systems and bycatch issues off South Kerala

Information on trawlers, trawl nets and accessories, bycatch issues were collected using pre-tested structured schedules prepared for the purpose (Annexures 2 and 3), from important trawl fishing centres off south Kerala. Sakthikulangara, Neendakara, Chavara, Anandavalleswaram and Kavanad in Quilon district were selected for study (Fig. 2.21).

Field visits were conducted during May 2004 - February 2005, in order to collect the details of trawlers, gear and equipment and bycatch issues. Structured questionnaires were used to collect the data from boat owners and operators, boat yard operators, net makers, gear and gear accessories suppliers and agents. Details were collected regarding craft materials; L_{OA}, engine make, model and horsepower; crew size; area and depth of operation; number and duration of hauls; fish hold capacity; quantity of ice and water; diesel consumption; type of otter boards; and electronic navigation and fish finding equipment; operational details and bycatch, for different size classes.

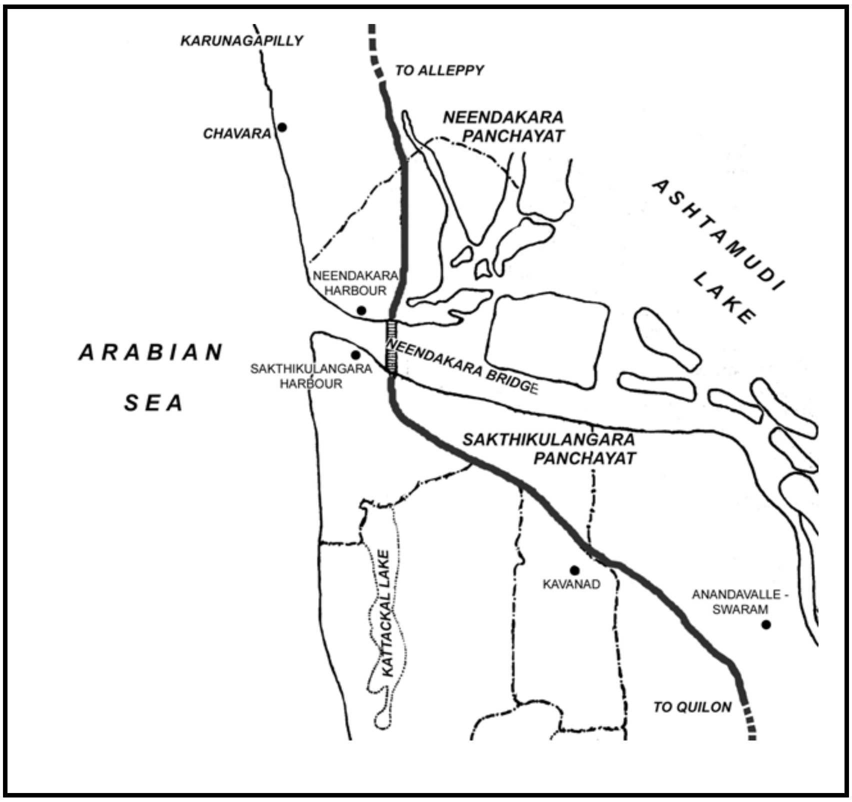


Fig.2.21 Map showing the study area in Quilon

A design template (Annexure 4) was used to collect the details of existing trawl net designs. Details were collected regarding dimensions, construction, material, accessories such as floats and sinkers, seasons of operation and number and types of nets stowed onboard, for different size classes of trawlers. Design drawings and specifications were prepared as per conventions of FAO (1975, 1978) and recommendations of ISO (1975).

Annexure **1**

DATA COLLECTION LOG FOR BRD INCORPORATED TRAWL OPERATIONS

Date:	Vessel:	Voyage no.	Departure:	Particulars of gear and BRD:
Base:			Arrival:	
Operational details	Haul 1	Haul 2	Haul 3	
Fishing Ground				Sea state:
Longitude				
Latitude				Weather:
Depth of ground				
Length of warp				Remarks:
Time of shooting				
Time of hauling				
Towing duration				
Trawling speed				
Course				

Length data

Species	**Sample wt/ total wt.**	**Length (mm)**

Annexure 2

DETAILS OF TRAWLER

1	Name of the vessel		
2	Type of vessel		
3	OAL		
4	Engine	BHP	
		Make	
		Model No	
5	Type of gear		
6	No. of gears on board		
7	Crew size		
8	Area		
9a	Operation	Depth	
		Area	
		Time	
9b	Duration	No.of hauls	
		Duration of hauls	
10	GPS	Model	
		Make	
11	Echo sounder	Model	
		Make	
12	Wireless	Model	
		Make	
13	Mobile		
14	No. of Fishing Days (Avg)		
15	Oil consumption/day (Avg)		
16	Type of otter board		
17	Winch	Type	
		Make	
		Rope length	
18	Fish hold capacity		
19	Qty. of Ice		
20	Qty. of water		
21	Avg. monthly expenditure		
22	Avg. monthly income		
23	Catch details		
24	Bycatch details	Retained	
		Discards	

Annexure 3

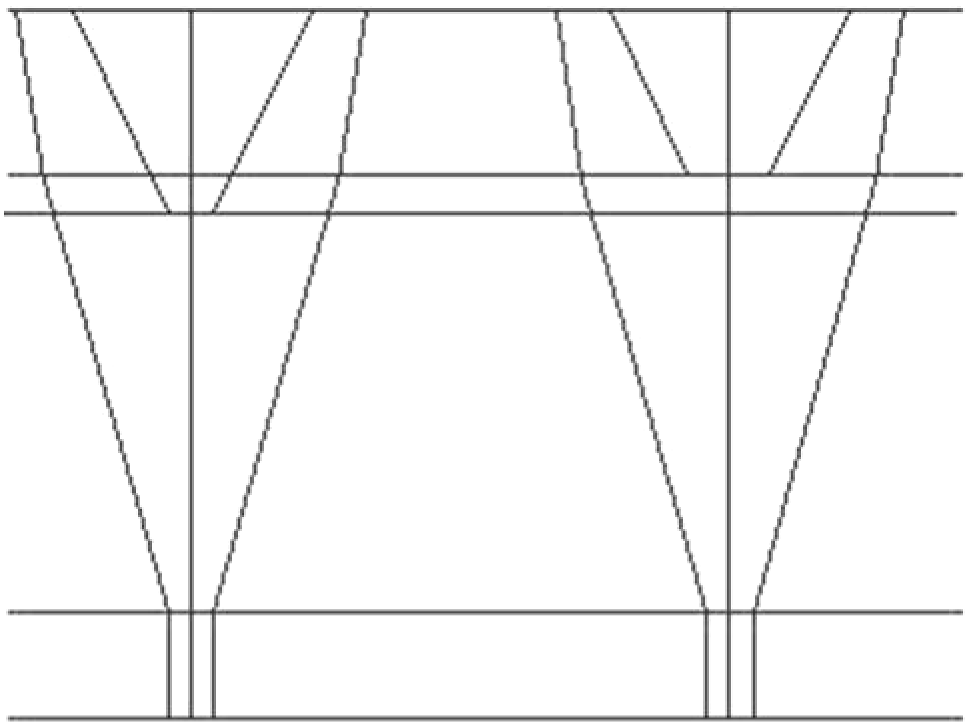
GEAR DETAILS

1	Type of vessel	OAL					
		BHP					
2	Type of net						
3	Head rope length						
4	Foot rope length						
5	No. of floats						
6	Weight of sinkers						
7	Qty. of Netting						
8	Cost	Netting		Float		Labour	
		Rope		Sinkers		Total	
9	Panel sections						

	Mesh size	Twine size Ø	Meshes in the leading edge	Meshes in the tailing edge	Depth of meshes
9.1					
9.2					
9.3					
9.4					
9.5					
9.6					
9.7					
9.8					
9.9					
9.10					

Annexure 4

TRAWL DESIGN TEMPLATE



Chapter 3

Trawling Systems and Bycatch Issues, off South Kerala

3.1 Introduction

In Kerala mechanized fishing was first introduced in 1956 at Sakthikulangara-Neendakara in the Quilon coast, which is by far the most important landing centre of the state and it had extensive effect on the socio-economic aspects of this area. (Devaraj and Smita, 1988; Sathiadhas and Venkataraman, 1981). Currently there are about 850 trawlers operating from Quilon and their number increases to more than 1200 during peak season. The importance of Quilon as a fishing centre is mainly due to its geographic proximity to the Quilon bank which is a highly productive fishing area between 275 and 375 m well-suited for bottom trawling (Rajan *et al*., 2001). Moreover, Sakthikulangara is a major landing centre for penaeid shrimps especially *Parapenaeopsis stylifera* (*karikkadi*) and deep sea shrimps. About 70-75% of *Parapenaeopsis stylifera* and more than 70% of deep-sea shrimp catch of Kerala are landed at Sakthikulangara and Neendakara (Suseelan *et al*., 1989; Rajan *et al*., 2001; Joseph and Jayaprakash, 2003). About 20% of the seafood processing units in Kerala are located here (Ramachandran *et al*., 1993; MPEDA 2004). All these factors make Quilon an ideal area for conducting the study regarding the trawl systems that contributes 97% of the total catch contributed by the mechanized sector of Kerala (Yohannan *et al*., 1999).

The design and performance of trawl system have progressed significantly since its introduction during 1950s (George, 1980; Mukundan and Hameed, 1993; Verghese, 1998; Thankappan, 2000). A wide range of designs of small mechanized boats from 7.62 m to 17.52 m fit for commercial trawling were introduced and popularized by the erstwhile Indo–Norwegian Project (INP) and Central Institute of Fisheries Technology (CIFT) (Gnanadoss, 1977; Gulbrandsen, 1984; Gulbrandsen and Anderson, 1992; Verghese, 1998 and Ravindran and Baiju, 1998; Pillai *et al*., 2000). The trawl nets have also undergone significant changes in course of time in terms of dimensions and design parameters. Over the years, CIFT has introduced several designs of bottom trawls such as two–seam trawl, four–seam trawl, six–seam trawl, long wing trawl, bulged belly trawl and energy saving concepts in trawl design such as large mesh trawl and rope trawl and sheer devices for bottom trawling (George, 1998; Mukundan and Radhalakshmy, 1998; CIFT, 1998; CIFT, 2003).

In this chapter, an attempt is made to assess the present status of trawlers, various trawl net designs and other accessories used for trawling along with bycatch issues in trawl fisheries existing in southern Kerala.

3.2 Materials and Methods

Information on trawlers, trawl nets and accessories, bycatch issues were collected using pre-tested structured schedules prepared for the purpose (Annexures 1 and 2), from important trawl fishing centres off south Kerala. Sakthikulangara, Neendakara, Chavara, Anandavalleswaram and

Kavanad in Quilon district were selected for study (Fig. 2.21). Detailed methodology for the study is given Chapter section 2.6.

3.3 Results and Discussion

3.3.1 Trawler details

3.3.1.1 Vessel classes

Trawlers of both wood and steel construction are prevalent in Quilon. Most of the large vessels are constructed in steel. The trawlers are categorized into four groups, as below, based on size, horsepower, resale value and year of construction.

i. Small-sized trawlers: They are of wooden construction ranging in size from 8.5 m to 9.7 m L_{OA}. They are more than 20 years old and have a resale value of Rs. 0.1 to 0.15 million and are deployed for shrimp trawling in peak season.

ii. Medium-sized trawlers-I: They are of both wood and steel construction and range in size from 9.7 m to 12.1 m L_{OA}. They are 3-4 years old and have a resale value of Rs. 0.2 to 0.5 million.

iii. Medium-sized trawlers-II: They are mostly of steel construction and range in size from 12.1 m to 16.7 m L_{OA}. Most of them are 3-4 years old and have a resale value of Rs. 0.4 to 0.7 million.

iv. Large trawlers: They constitute most of the recent constructions with an investment of Rs. 2.0 to 2.5 million, range in size from 16.7 to 18.2 m L_{OA} and are equipped multi-day deep sea fishing.

3.3.1.2 Engine details

Nearly 100% of the engines of trawlers used in this area is Ashok Leyland marine diesel engine. This engine is preferred over other engines by the fishermen and owners, because of its reliable performance and easy availability of spares. Details of the engines widely used in trawlers, operated off south-west coast of India are given in Table 3.1.

3.3.1.3 Crew size and earnings

Crew size in smaller vessels is 5 and for larger vessels 6 to 7, consisting of one skipper (*serang*), one engine driver and 3 – 5 deckhands. Crew is paid a share of the returns and an allowance (*bata*) ranging between Rs. 50 and 100 per fishing day. 65% of the net returns goes to the boat owner and the balance 35% is divided among the crew members. Of the crew share, 10% goes to skipper, 7% to engine driver and the balance is equally divided among deckhands.

Table 3.1: Details of engine models, their power and vessel type

Engine model	hp @ 2000 rpm	Vessel size L_{OA}
ALM 370	90	< 9.7 m
ALM 400	100	< 12.1 m
ALM 402	107.5	< 12.1 m
ALM 412 (turbo-charged)	124	12.1 m-16.7 m
ALM 680	158	12.1 m-16.7 m
ALM 680 (turbo-charged)	177	>16.7 m

3.3.1.4 Fishing area

Area of operation depends upon the season and size of the vessel. Smaller vessels (8.5-9.7 m L_{OA}) restrict their operation in and around Quilon area and operate up to a depth of 20-30 m. Medium size vessels - I (9.7-

12.1 m L_{OA}) operate up to 60-70 m. Medium size vessels–II (12.1-16.7 L_{OA}) operate up to 250 m depth. Medium vessels operate up to Varkala in south and up to Cochin in north. Larger vessels (>16.7 m L_{OA}) operate up to 300 m depth and fishing grounds range from Thoothukudy in the east coast to Mangalore in the west coast. Most of the vessels particularly larger ones operate from Quilon during August-January and from Kannur or Thalassery during February-April and again from Quilon during May-June.

3.3.1.5 Duration of fishing

Duration of fishing ranges from 9 h to 10 days depending on the size and endurance of the fishing vessel and the species targeted. Small vessels up to 9.7 m L_{OA} conduct daily fishing from 3:00 AM to 12:00 PM, during peak season only. Number of hauls of these vessels range between 3 and 4 and duration of haul is 1.5 h. Small vessels mainly target shrimps and anchovies. Medium size vessels up to 12.1 m L_{OA} conduct multi-day fishing trips of 2-3 days duration targeting shrimps, squids and fish. They make 4-5 hauls of 1.5-3.0 h duration per day. Medium sized vessels of 12.1-16.7 m L_{OA} conduct multi-day fishing trips up to 6 days and carry out 4 - 5 hauls of 1.5-3.0 h duration during day time. Large vessels of >16.7 m L_{OA} conduct multi-day fishing trips of 5-12 days, and carry out 4-5 hauls of 1.5-3.0 h duration during day time and up to 4 additional hauls, if there is night fishing. All vessels generally conduct day fishing and night fishing is undertaken according to the availability of shrimps and cephalopods.

3.3.1.6 Diesel consumption

Diesel cost forms the major share in the operational cost of trawlers. The diesel consumption per hour varies from 8 to 18 litres, depending on installed engine power, size and displacement of vessels, tow duration, and other factors. A 16.6 m vessel engaged in 5 days fishing trips typically consumes 200 litres of diesel per day when undertaking day-time fishing and 350 litres per day if night fishing is also conducted. Installing turbo-charged engines and retrofitting turbo-charging in old engines have been popular for realizing increased fuel economy.

3.3.1.7 Otter board

Flat rectangular wooden otter boards with steel reinforcements have been the popular sheer device in majority of trawlers in Quilon area up to late 1990s. During that time about 76% of trawlers used flat rectangular otter boards, 20% used V - form steel otter boards and rest of them used oval slotted steel boards (Shibu and Hameed, 1999). However, during the current study, it was revealed that almost 80% of the trawlers of 9.7 m L_{OA} and above in Quilon area use V-form steel otter boards (Fig. 3.1). Oval slotted boards are currently not in use. The weight of otter board ranges from 50-85 kg each. Table 3.2 gives the details of otter boards commonly used in Quilon area. Small trawlers below 9.7 m L_{OA} use flat rectangular otter boards (15-20%).

Table 3.2: Details of otter boards used in Quilon area

Engine (hp)	Length (mm)	Breadth (mm)	Weight (kg)
V-form steel otter boards			
ALM 370	1320	760	60 -70
ALM 400	1320	760	70 -75
ALM 402	1320	760	75
ALM 412	1370	810	75 -78
ALM 680	1370	810 - 840	80 -85
Flat rectangular wood and steel otter boards			
ALM 370	1250	625	50
ALM 370	1370	690	60
ALM 400	1450	725	65
ALM 402	1500	750	72
ALM 412	1520	760	75
ALM 680	1600	800	80

Fig. 3.1 V-form otter boards

3.3.1.8 Trawl winch

Almost all the trawlers in the area used locally manufactured winches of the mechanical type. Small and medium sized trawlers used 8 mm or 9 mm dia steel wire rope (SWR) as warp which costs about Rs. 26-30 per metre and larger vessels used 10-11 mm SWR which costs about Rs. 30-32 per metre. Total warp length used was up to 700 m per winch drum in small vessels and up to 1500-2000 m in large vessels.

3.3.1.9 Fish hold

Smaller boats operating for 9 h were not provided with built-in fish holds. In some cases, 1 or 2 boxes of 500 kg capacity were used. In larger boats, fish hold capacity ranged from 2 to 10 tonnes. The fish hold is insulated using thermocol and more recently using puff insulation which costs around Rs. 0.1 million. Crushed ice is stored separately in this fish hold.

3.3.1.10 Ice and water

Vessels undertaking single day operation did not carry ice. Vessels undertaking multi-day fishing carried ice in large quantities. A 16.7 m vessel carried 20-30 blocks of ice, each weighing 25 kg, for each day of fishing. Large vessels undertaking 5-day trips typically carry 150 blocks of ice per trip. Ice is crushed using crushing machine at the harbour or in ice plant and stored in the fish hold of the vessel. Small vessels carry 500-1000 liters of water and large vessels 1000-4000 liters, depending upon the duration of fishing trip.

3.3.1.11 Electronic equipments

Almost all large vessels and 75-80 % of medium-sized trawlers in the Quilon area were equipped with modern electronic navigation and fish detection equipment such as Global Positioning System (GPS), echosounder and radiotelephone. Echosounder is used for navigation, monitoring the depth of operation, determine the nature of fishing ground and to detect fish. GPS is used for position fixing, precise navigation and access to potential fishing zones. Radiotelephone helps in communicating with the land stations or with the other boats operating in the sea.

3.3.2 Trawl nets

3.3.2.1 Shrimp trawls

Karikkadi vala

This is a two-seam shrimp trawl with a head rope length of 29.0 m used for harvesting kiddi shrimp (*Parapenaeopsis stylifera*) (Fig. 3.2). It is fabricated with 0.75 mm dia twisted polyethylene (PE) twine except the codend, which is made of 1.25 mm dia netting. Its wings and square were made of 35 mm and the belly sections with 30 and 35 mm mesh netting. Codend was 350 meshes deep and made of 20 mm mesh netting. The head rope and footrope were made of 14.0 mm dia polypropylene (PP). A codend cover of 30 meshes in depth made of 3.0 mm dia twine 100 mm mesh PE netting was provided to protect the codend from wear and tear. An average of 30 kg lead weight and tickler chain were attached to the footrope and about 7-9 numbers of 150 mm or 200 mm floats were attached to the head rope.

Naran vala

Naran vala is a two-seam shrimp trawl with a head rope length of 32.4 m, used for harvesting *Fenneropenaeus indicus* (Fig. 3.3). Overall longitudinal length of the trawl was 36.1 m. The wings were fabricated of 50 mm mesh netting. Netting of 40 mm and 30 mm mesh were in the square and belly sections. Codend was 350 meshes with a mesh size of 20 mm. Netting of 0.75 mm dia twisted PE twine were used in all panel sections except codend, which is made of 1.25 mm dia twine. A codend cover of 30 meshes in depth made of 3.0 mm dia twine 120 mm mesh PE netting was also provided. PP rope of 14.0 mm dia was used for head rope and footrope. Spindle-shaped lead weights of 20-40 g each, were attached to the footrope using 3 mm PP twine. About 30 kg lead weights and tickler chain and 7 numbers of 150 mm or 200 mm floats were used during operations.

Poovalan vala

Poovalan vala is a two-seam shrimp trawl with head rope length of 28.8 m, used for harvesting *Metapenaeus dobsoni* (Fig. 3.4). Overall longitudinal length of the trawl was 30.5 m. The wings, square and front belly sections were fabricated using 35 mm mesh and hind belly sections using 30 mm mesh netting. Netting material used except for codend was of 0.5 mm dia twisted PE. Codend is 350 meshes deep and made of 20 mm mesh netting of 1.25 mm dia twine. A codend cover of 25 meshes in depth made of 3.0 mm dia wine 120 mm PE netting was also provided. The head rope and footrope were made of 14 mm dia PP rope. About 30 kg of lead weight and tickler chain were attached to the footrope and 11-13 numbers of 150 mm or 200 mm floats were used during operations.

Pullan vala

Pullan vala is a two-seam shrimp trawl net with head rope length of 32.4 m, used for harvesting deep-sea shrimps (Fig. 3.5). Overall longitudinal length of the trawl was 37.5 m. The wings, square and front belly sections were fabricated out of 40 mm mesh netting and hind belly sections using 30 mm netting. Codend was made of 26 mm mesh netting and 270 meshes in depth. The net was made of 0.75 mm dia twine twisted PE netting except for codend, which was of 1.25 mm dia twine. A codend cover of 25 meshes in depth made of 3.0 mm dia twine 120 mm PE netting was also provided. The head rope and footrope were made of 14.0 mm dia PP rope. About 35 kg lead weight and tickler chain were attached to the footrope. Floats were not used in this net, during operations. This is to reduce the vertical opening of the trawl, in order to reduce the associated bycatch of finfishes.

Kai vala

This is small two-seam shrimp trawl with a head rope length of 21.4 m operated from small-sized trawlers of less than 9.7 m L_{OA} during peak shrimp trawling season, in coastal waters (Fig. 3.6). The net is operated manually without winch. It was 27.4 m in overall longitudinal length and made of netting of 0.75 mm twisted PE twine netting except for codend, which was of 1.25 mm dia twine. The wings and square were fabricated of 30 mm mesh netting, front belly sections using 26 mm mesh netting and hind belly using 24 mm mesh netting. Codend was 350 meshes deep and made of 20 mm mesh netting. A codend cover of 30 meshes in depth made of 100 mm mesh 3.0 mm dia twine netting was provided in the of the codend, to protect the codend from wear and tear. The head rope and footrope were made of 14.0 mm dia PP. About of 30 kg lead weight and tickler chain were attached to the footrope and 5-7 numbers of 150 mm or 200 mm dia floats were used for operations.

3.3.2.2 Fish Trawls

Chooda vala

Chooda vala is a two-seam fish trawl with a head rope length of 32.6 m specially used for harvesting anchovies. It has overall longitudinal length of 46.2 m *(*Fig. 3.7). The wings were fabricated of 200 mm mesh netting and square using 160 mm mesh netting. Mesh size in the five belly sections ranged from 160 mm to 40 mm. The extension piece between belly and codend was made of 30 mm mesh netting. Codend was made of 20 mm mesh size and 350 meshes deep. The netting used was of 1.25 mm dia twine from wings to the front belly panel sections, and of 0.75 mm dia twine in the hind belly sections and extension piece. Codend was made of 20 mm PE netting and was provided with inner liner of 10 mm knotless polyamide (PA) netting in order to retain the anchovies. The head rope and footrope were made 16.0 mm dia PP rope. About 20 kg of lead weights was attached to the footrope and 11 - 21 numbers of 200 mm floats were attached to head rope, during operations.

Mixture vala

Mixture vala is a two-seam fish trawl with a head rope length of 30.6 m newly introduced for harvesting demersal and off-bottom fish resources (Fig. 3.8). The trawl had an overall longitudinal length of 39.6 m. Large mesh netting of 1000 mm mesh was used in the wings and square. Mesh size in the six belly sections ranged from 800 mm to 40 mm. Codend was 350 meshes deep and made of 20 mm mesh netting. Twine size of the netting was 2.0 mm dia in the wings, square and front belly sections, 1.5 mm to 1.25

mm dia in the hind belly sections and codend. A codend cover of 25 meshes in depth made of 3.0 mm dia twine 120 mm mesh size PE netting was provided to protect the codend from wear and tear. The head rope and footrope were made of 16.0 mm dia PP rope. About 5-7 numbers of 350 mm or 300 mm floats and 35 kg of lead weights were used, during operations.

Meen vala

Meen vala is a popular fish trawl of two-seam construction with a head rope length of 28.2 m used for harvesting demersal fishes (Fig. 3.9). It has overall longitudinal length of 38.2 m. In this trawl, 500 mm mesh netting was used in the wings and square. Belly was constructed of six panel sections of 500 mm, 400 mm, 200 mm, 120 mm, 60 mm and 40 mm mesh nettings. Codend was 350 meshes deep and made of 20 mm mesh netting. Netting with 2.00 mm dia twine was used in wings and square, 1.5 mm dia twine in belly panel sections and 1.25 mm dia twine in codend. A codend cover of 25 meshes in depth made of 3.00 mm dia 120 mm mesh size PE netting was also provided. The head rope and footrope was made of 16.0 mm dia PP. About 5-7 numbers of 350 mm or 300 mm floats and 35 kg of lead weights were used for operations.

3.3.2.3 Cephalopod trawl

Kanava vala

Kanava vala is a two-seam trawl with a head rope length of 37.6 m, used for harvesting cephalopods (Fig. 3.10). It is 51.3 m in longitudinal length and is fabricated of 1.5 mm dia twisted PE twine netting. PE netting of

200 mm mesh size is used in the wings, square and front belly sections. Mesh sizes ranging from 160, 120, 80, 60 to 40 mm were used in the rest of belly sections. Codend is 350 meshes deep and made of 20 mm mesh netting. A codend cover of 25 meshes in depth made of 3.0 mm dia twine 120 mm mesh size PE netting was also provided. 14.0 mm dia PP rope is used for head rope and footrope. About 35 kg lead weights were used in the footrope and up to 11 numbers of 200 mm floats were used, during operations.

3.3.2.4 Whelk trawl

Whelk trawl, known as *chanku vala* in vernacular, was developed by modification of shrimp trawl design and rigging through local innovation of the net makers, exclusively for whelk fishing. *Chanku vala* is a two-seam trawl with a head rope length of 24.0 m which is specially used to harvest the whelk resources (Fig 3.11). It has overall longitudinal length of 27.4 m and is fabricated of 1.25 mm dia twisted PE twine netting. Wing and square panels are made of 80 mm mesh netting. Mesh size in the belly sections ranged from 60 mm to 40 mm. Codend is 350 meshes deep with a mesh size of 20 mm. The whelk trawl is fabricated using thicker twines compared to traditional shrimp trawl designs. This is to withstand the abrasion and strain due to operation of the heavily rigged gear close to bottom, especially when there is a heavy load of shell catch. Typical bottom trawls operated in Quilon use only 20 to 35 kg weight in the footrope. The foot rope is provided with about 55 kg of lead weights to tend the bottom closely during operations, to harvest the gastropods lying buried in the mud. 7-9 numbers of 150 mm or 200 mm floats were attached to the head rope.

3.3.3 Netting materials and accessories

Netting material used for fabrication of trawl nets are invariably high density polyethylene netting. Mesh sizes used vary from 1000 mm to 20 mm in fish trawls, 50 mm to 26 mm or 20 mm in shrimp trawls, 200 mm to 20 mm in cephalopod trawl, and 80 mm to 20 mm in *chanku vala*. In *chooda vala* small-meshed polyamide knotless netting is used as a liner inside the codend to retain anchovies. Indigenously manufactured spherical hard plastic floats were used for floatation. Float sizes varied from 150-350 mm (Table 3.3). Sinkers were usually made of lead and were available in 25, 30, 50, 100, 200 g sizes. Cast iron is also used in some cases. Iron link chain was not preferred by most of the net makers as it corrodes rapidly and could stain and damage the net, during stowage. However, it is used to adjust weight during operations depending on requirements. Link chains are also used in deep sea shrimp trawls. More recently, rubber discs of 650 g each have also been in use in bottom trawls, to increase weight and protect the foot rope and net from damage. Polypropylene ropes are the general choice for head rope, footrope, bridles and other ropes used for trawling and rope sizes vary from 14-16 mm dia.

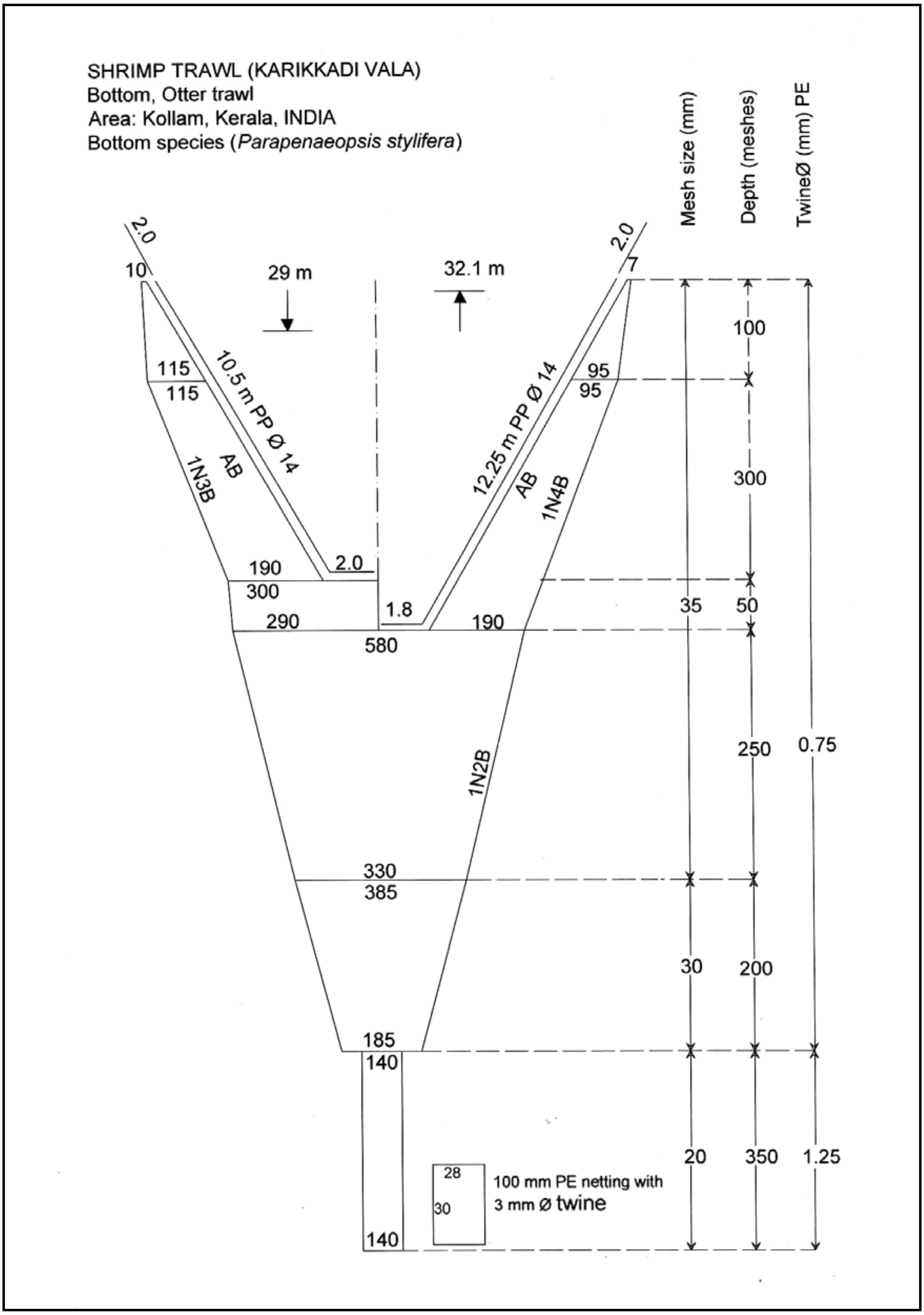


Fig. 3.2 Design of *Karikkadi vala*

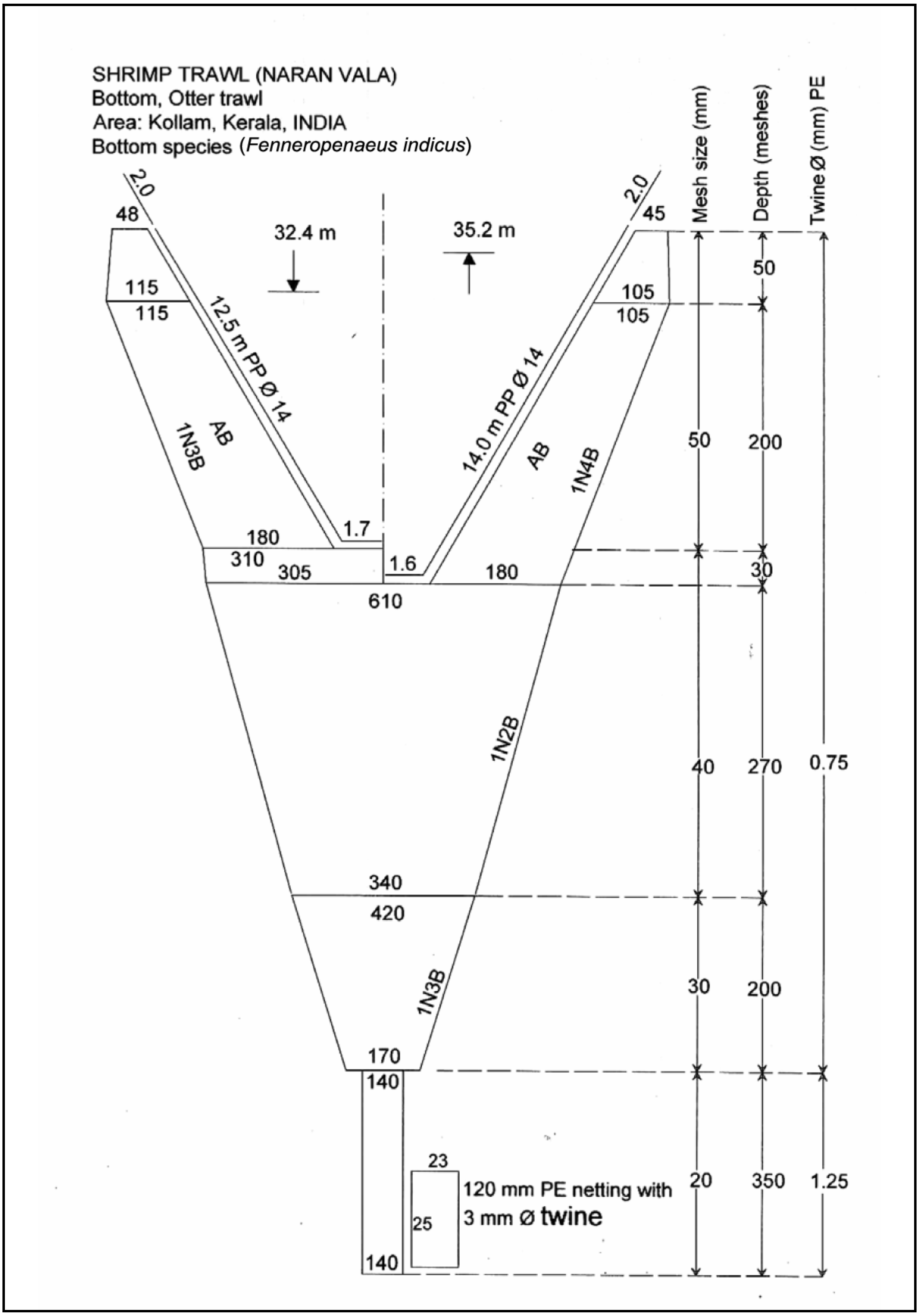


Fig. 3.3 Design of *Naran vala*

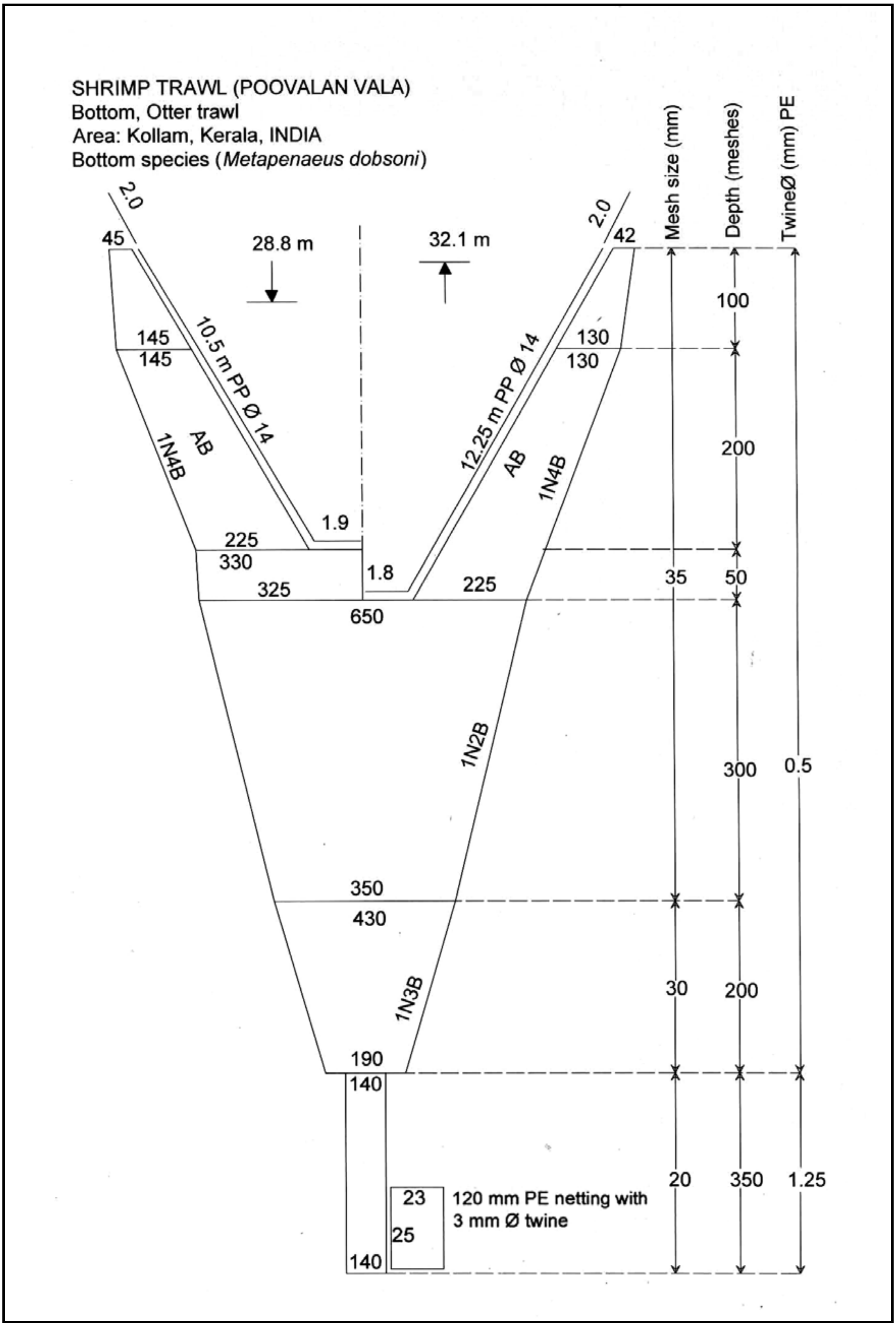


Fig. 3.4 Design of *Poovalan vala*

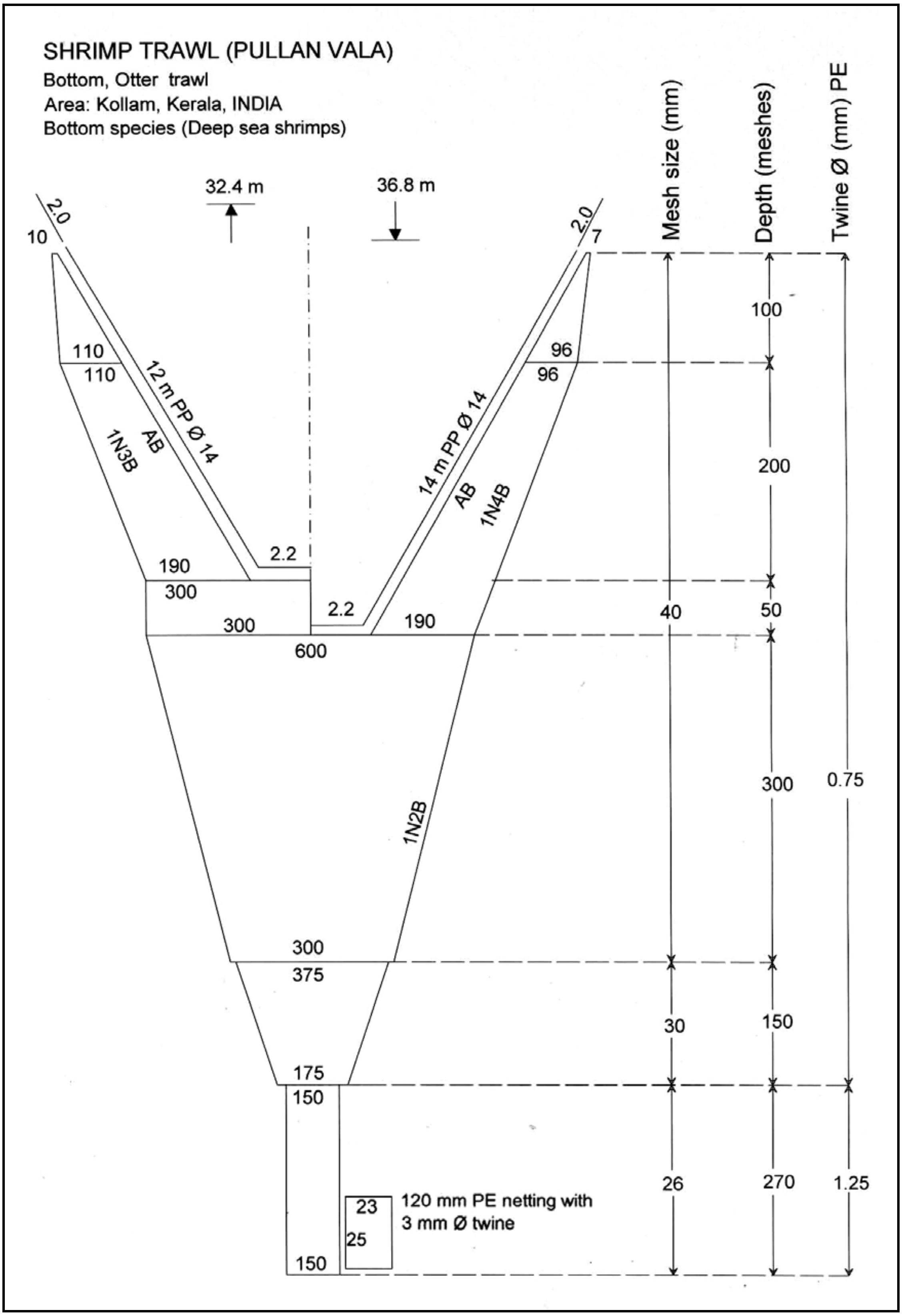


Fig. 3.5 Design of *Pullan vala*

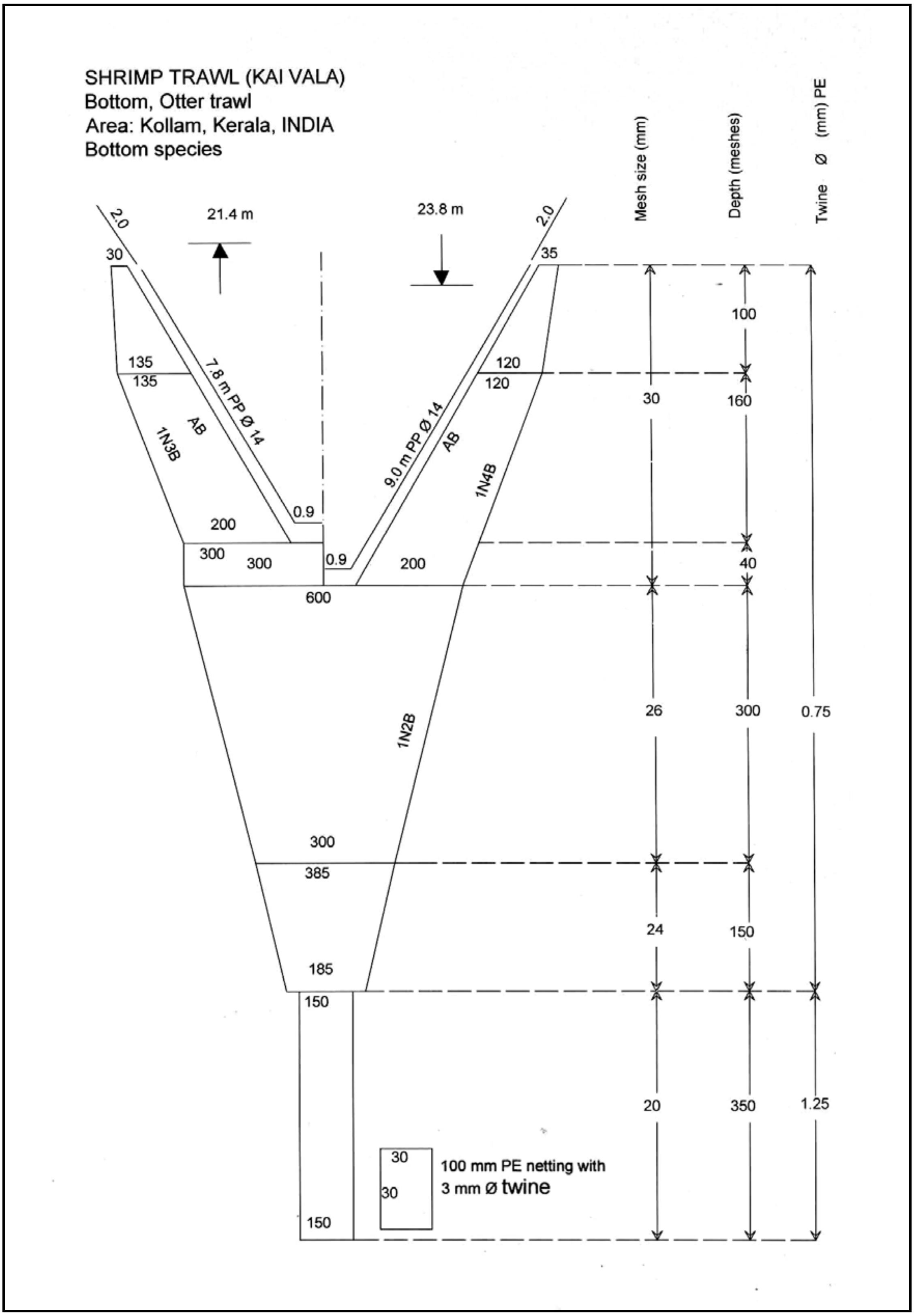


Fig. 3.6 Design of Kai vala

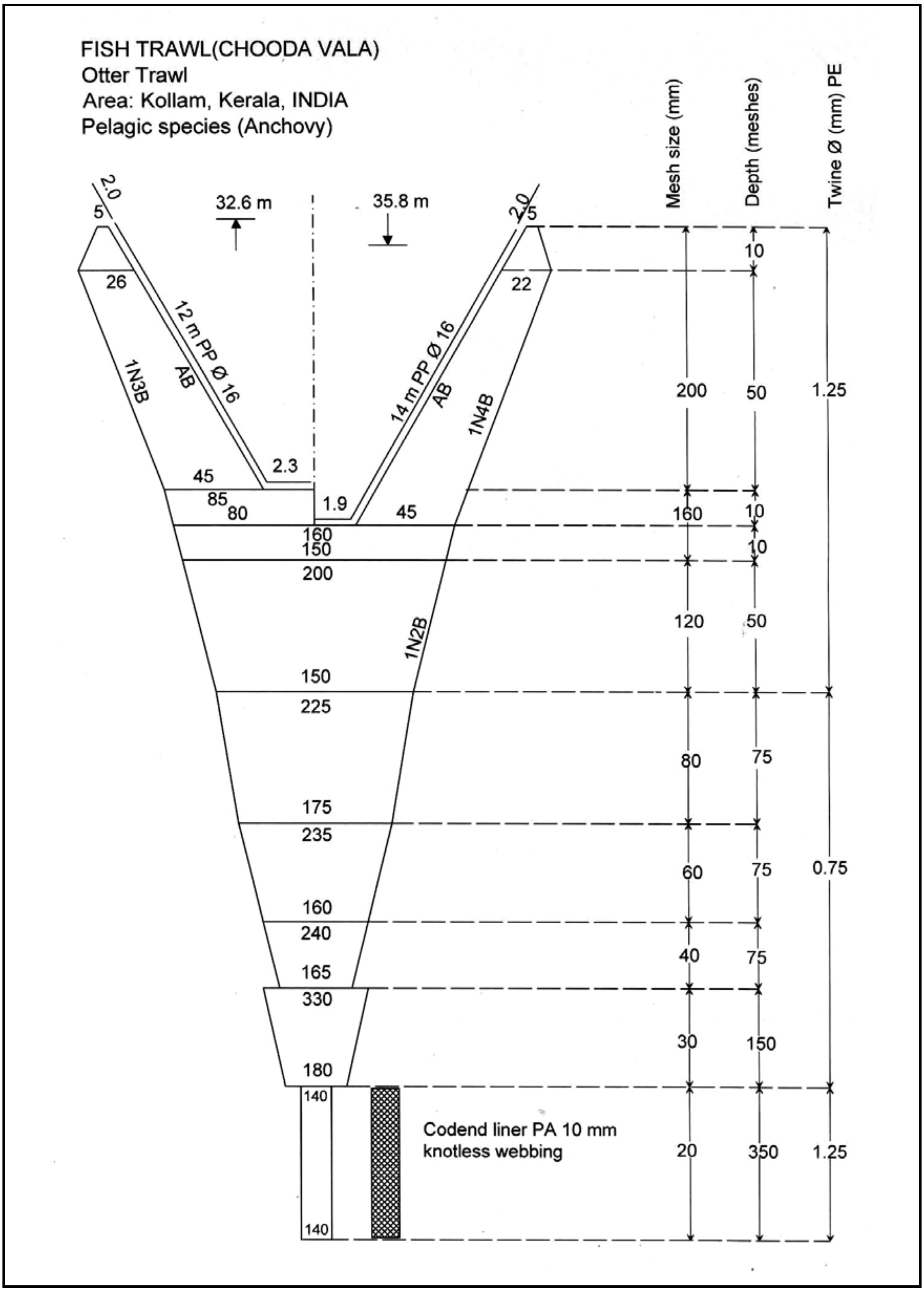


Fig. 3.7 Design of *Chooda vala*

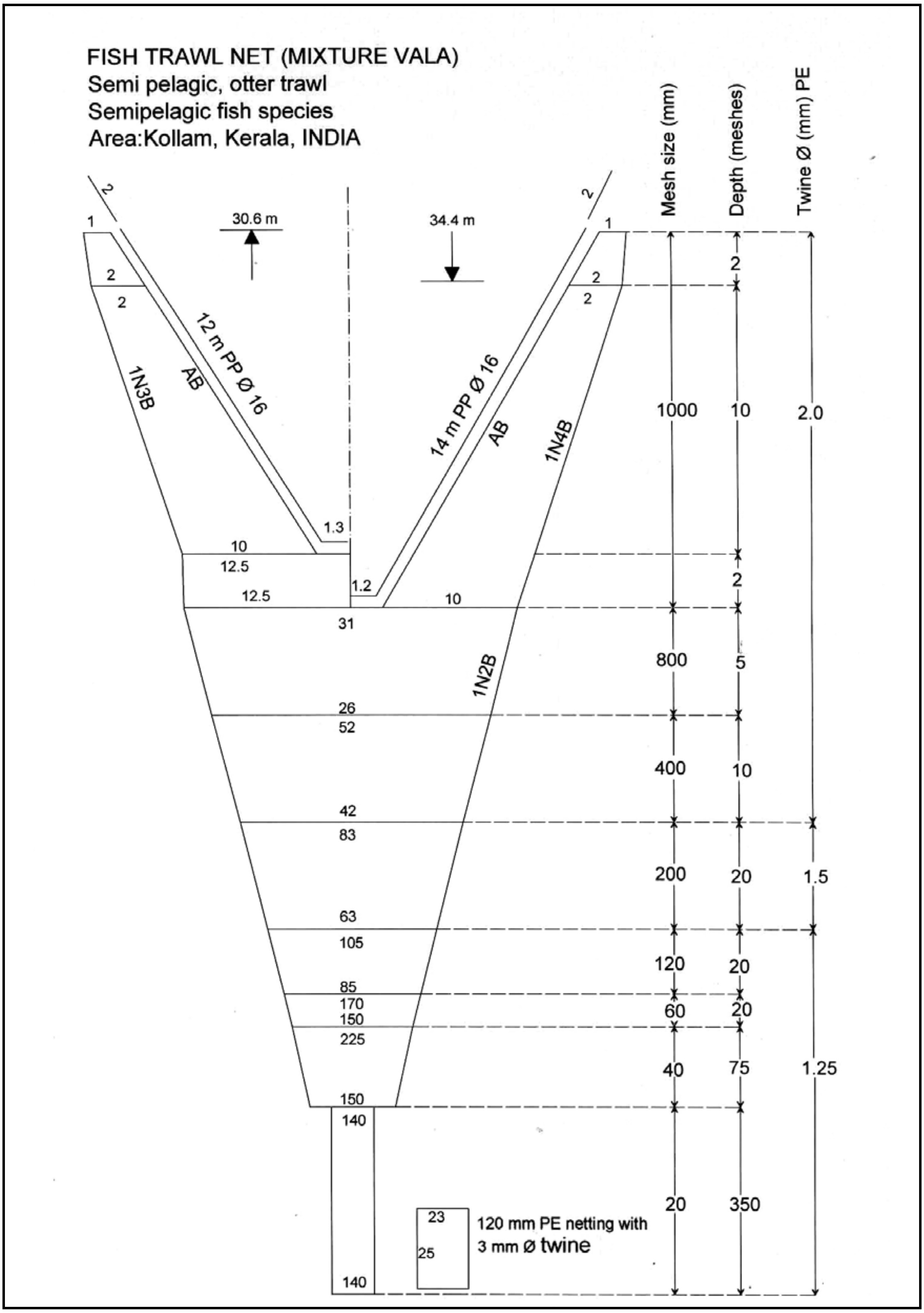


Fig. 3.8 Design of *Mixture vala*

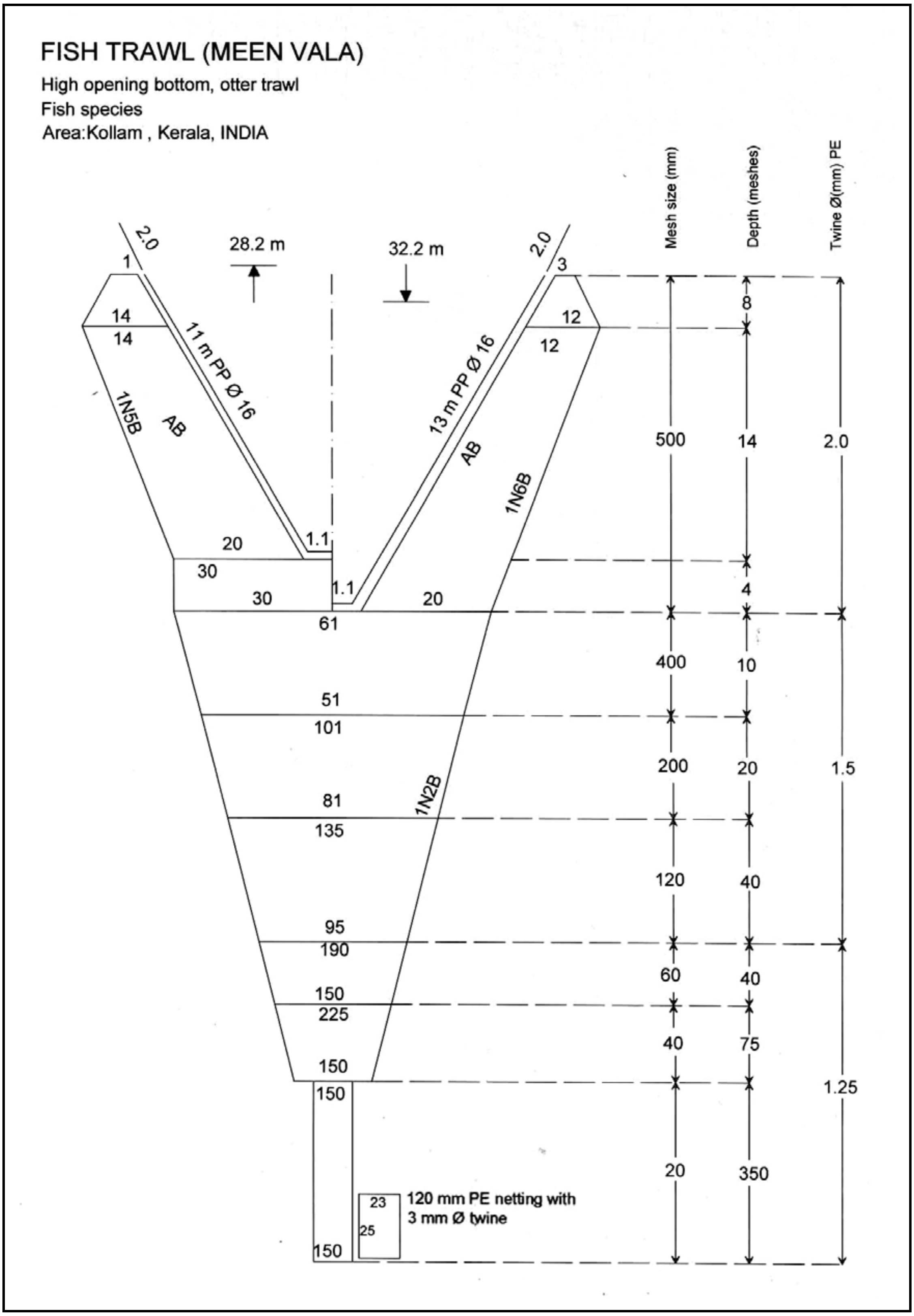


Fig. 3.9 Design of *Meen vala*

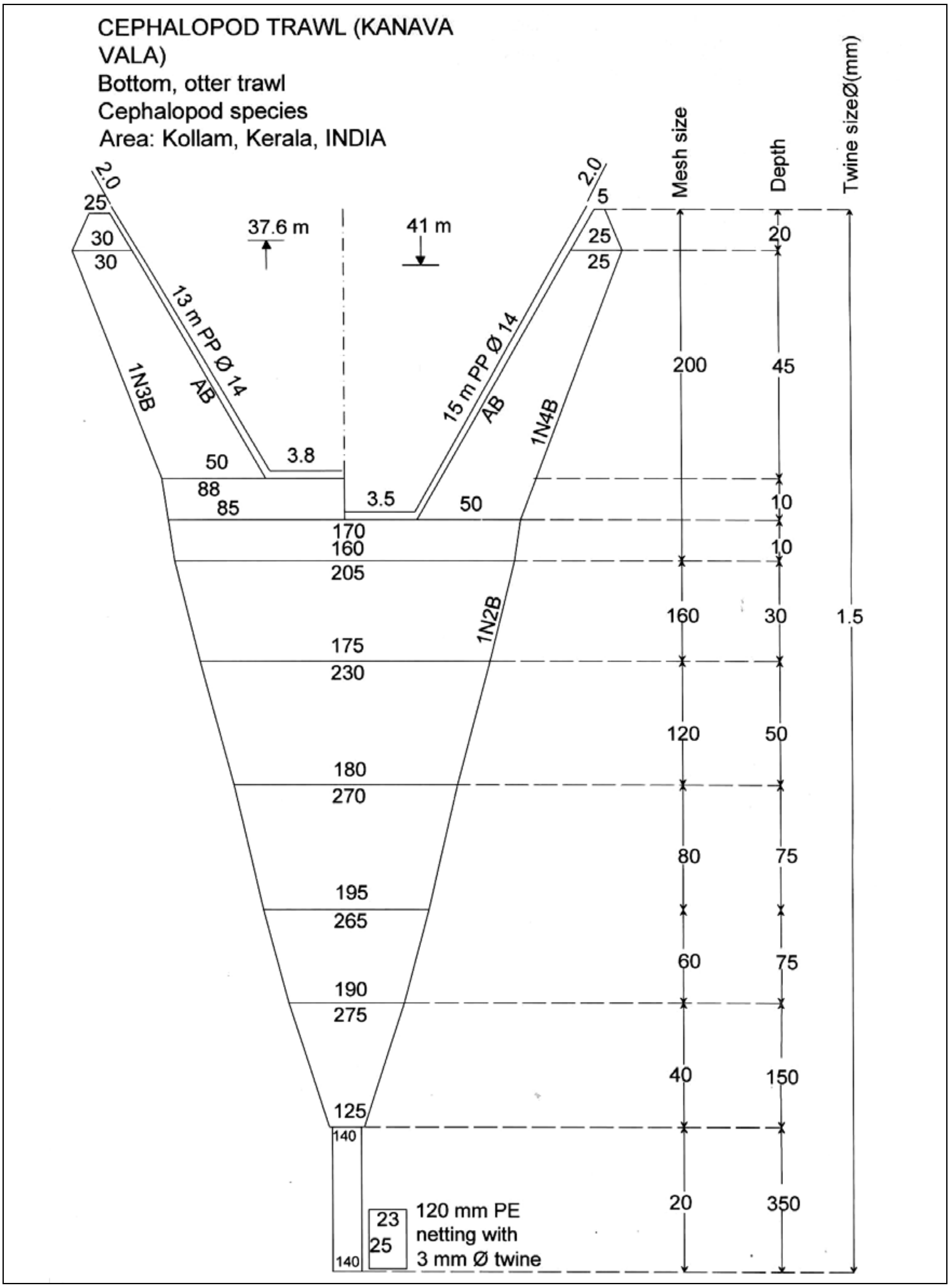


Fig. 3.10 Design of *Kanava vala*

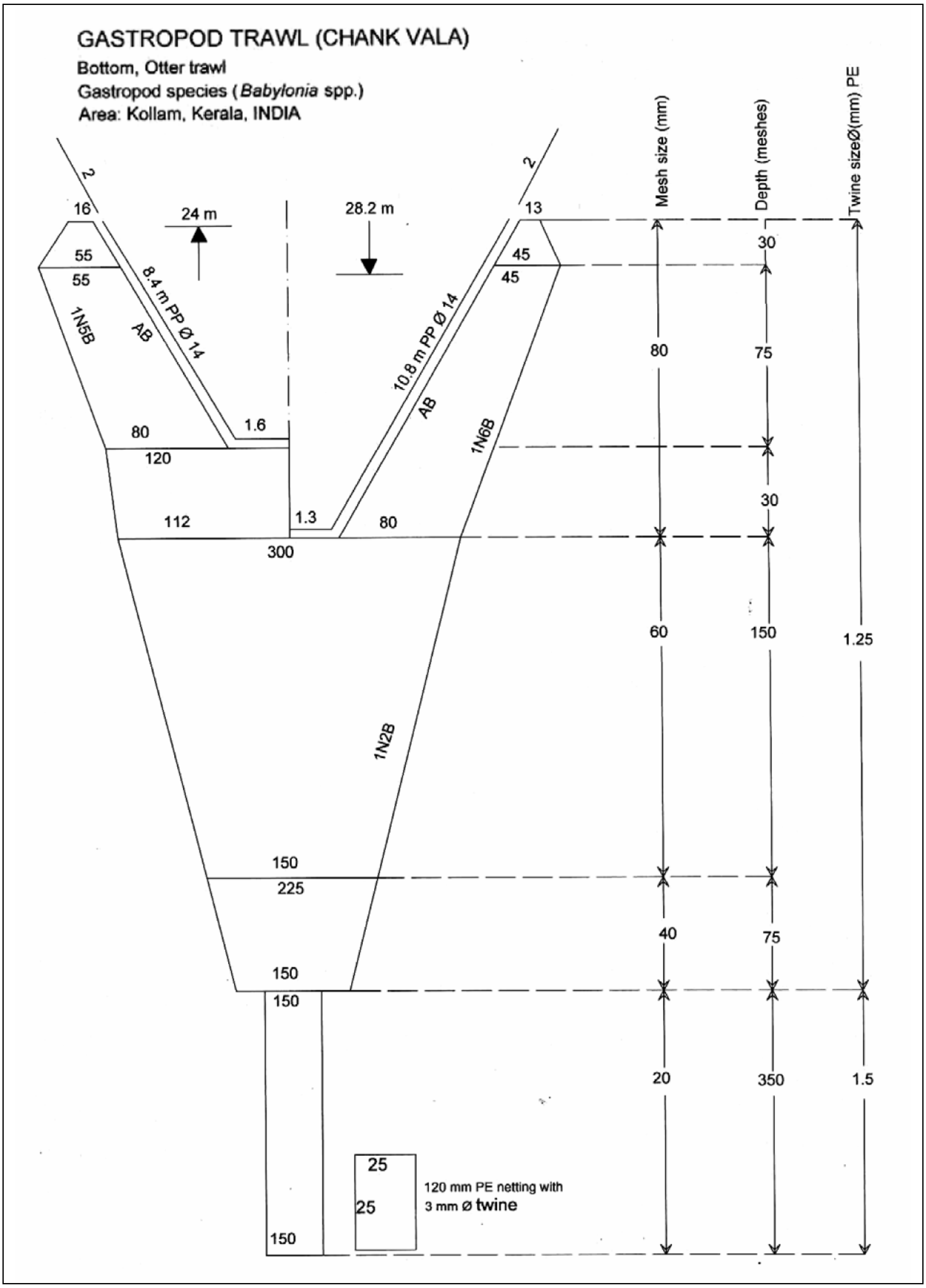


Fig. 3.11 Design of *Chanku vala*

Table 3.3: Details of floats used in trawl nets

Type of net	Size of float, mm Ø	No. of floats
Mixture vala	300-350	5 – 7
Meen vala	250-300	5 – 7
Chooda vala	200	11 – 21
Karikkadi vala	150-200	7 – 9
Poovalan vala	150-200	11 – 13
Naran vala	150-200	7
Kai vala	150-200	5 – 7
Kanava vala	200	11
Chanku vala	150-200	7 – 9
Pullan vala	-	No floats

3.3.4 Trawl bycatch

Bycatch is that part of a fisher's catch that is non-targeted and can be defined as discarded catch plus incidental catch (Alverson *et al.,* 1994 and Rao, 1998). Bycatch is a serious ecological issue in trawl fisheries (Alverson *et al.,* 1994; Hameed and Boopendranath*.,* 2000). Bycatch in shrimp trawling in Kerala was estimated at 65-70% (Pillai, 1998). Discarded items in trawling include juveniles and low value components of finfishes, crabs, gastropods, shrimps, cephalopods, jellyfish, stomatopods and snakes and crabs formed the major item of trawl bycatch discards in Quilon. (Kurup *et al.,* 2004).

Survey results on bycatch have indicated that discard rate by trawlers based at Quilon is between 20 and 70%. Fishermen always practice high grading during multi-day fishing and as better valued species comes low value catch previously retained are discarded, in view of limited storage facilities. Field observations during the period study have shown that 50% of the bycatch retained by trawlers was constituted by juveniles and sub-adults of finfishes, shrimps and cephalopods. Finfish juveniles observed during the study included sciaenids, *Lagocephalus* sp., C*ynoglossus* spp., *Muraenosox* sp., *Conger* sp., *Platycephalus* sp., carangids, cardinal fishes, damsels, leather jackets, sardines, threadfin breams and lizard fishes. Mollsucan species observed in the bycatch included *Anadara granosa, Babylonia* spp., *Turritella* spp., *Xancus pyrum*. Commonly found crab species included *Charybdis cruciata, Charybdis feriatus, Charybdis natator*, *Portunus sanguinolentus*, *Portunus pelagicus, Calappa lophos* and*, Porphyra* sp. Other prominent components of bycatch are stomatopods (*Oratosquilla nepa*) and echinoderms (sea urchins, star fishes and brittle stars).

Views of trawlers, landings of shrimp and bycatch, sorting of catch and related activiies at Sakthiklangara and Neendakara centres in Quilon, south Kerala are represented in Fig. 3.12 to 3.23.

Bycatch in trawl fisheries contributes a prominent share in the fisherman's income. In recent times, the demand for bycatch has increased due to the increased utilization of bycatch by the fish drying/curing industries and fishmeal industries outside the state. The low value fishes like Japanese thread fin breams (*Nemipterus japonicus)* and lizard fishes (*Saurida* sp.) that were included in the bycatch discards earlier, have got better demand from *surimi* industry and are now-a-days retained and marketed. Some of the molluscan species such as whelk and chanks are also landed according to market demand, especially when shrimp landings are poor.

The use of Bycatch reduction Devices was not prevalent in trawl fisheries of southern Kerala, during the period of observations.

Fig. 3.12 A view of the Sakthikulangara fishing harbour, Quilon, South Kerala

Fig. 3.13 A scene from Sakthikulangara fishing harbour, Quilon, South Kerala

Fig. 3.14 Kiddy shrimp (*Parapenaeopsis stylifera*) landed by trawler based at Sakthikulangara, Quilon, South Kerala

Fig. 3.15 Squid caught by cephalopod trawl, at Sakthikulangara, Quilon, South Kerala

Fig. 3.16 Sorting of trawl caught landings onboard a small trawler, off Quilon, South Kerala

Fig. 3.17 Squid (*Uroteuthis duvauceli*) landed by trawlers based at Sakthikulangara, Quilon, South Kerala

Fig. 3.18 A scene from Neendakara fishing harbour, Quilon, South Kerala

Fig. 3.19 A small trawler based at Neendakara, Quilon, South Kerala

Fig. 3.20 Japanese threadfin bream (*Nemipterus japonicus*) landed by trawlers based at Neendakara, Quilon, South Kerala

Fig. 3.21 Sole (*Cynoglossus* sp.) being sorted from bycatch landed by trawlers based at Neendakara, Quilon, South Kerala

Fig. 3.22 Sorting of trawl caught landings at Neendakara fishing harbour, Quilon, South Kerala

Fig. 3.23 Trawl fabrication at Quilon, South Kerala

3.4 Conclusion

The trawl fisheries in Quilon area has expanded over the years. With increase in fishing intensity and diminishing landings from the coastal zone, there has been a shift towards larger and higher powered trawlers with increased fishing range and multi-day fishing. There has been a shift towards steel as the preferred boat building material due to scarcity of good quality wood and its high cost. Most trawlers based at Quilon were engaged in multi-day fishing targeting fish, squids and cuttlefish in addition to shrimps. In view of this multi-species nature of operations, different designs of trawl nets were kept onboard. The large vessels carry between 12 and 15 nets and small vessels carry up to 8 nets, during fishing trips. Ten different designs of trawl nets were observed to be in use in the study area. Among these, five were shrimp trawls, three were fish trawls, one was cephalopod trawl and one was gastropod trawl.

Discard rate by trawlers based at Quilon ranged between 20 and 70% and consisted of 50% of juveniles and sub adults. Bycatch included finfishes such as sciaenids, *Lagocephalus* sp., C*ynoglossus* spp., *Muraenosox* sp., *Conger* sp., *Platycephalus* sp., carangids, cardinal fishes, damsels, leather jackets, sardines, threadfin breams and lizard fishes, Mollsucan species such as *Anadara granosa, Babylonia* spp., *Turritella* spp., *Xancus pyrum* and crustaceans such as *Charybdis cruciata, Charybdis feriatus, Charybdis natator*, *Portunus sanguinolentus*, *Portunus pelagicus, Calappa lophos Porphyra* sp., stomatopods and echinoderms. The use of Bycatch Reduction Devices was not found to be prevalent in trawl fisheries of southern Kerala.

Chapter 4

Radial Escapement Devices

4.1 Introduction

Radial Escapement Device consists of a small mesh funnel surrounded by a radial section of large square mesh netting (Watson and Taylor, 1988). Shrimps are retained in the codend while fishes swim back and escape through the large square mesh section. This BRD is based on the differences in the swimming ability of finfish species and shrimps. They are inserted between hind belly and codend of the trawl. A small meshed funnel accelerates the water flow inside the trawl and carries the catch towards the codend. Actively swimming fishes swim back and escape through the large mesh netting section surrounding the funnel, where the water flow rate is weak, while the shrimps are retained in the codend. Mesh size of the netting in the square mesh section, is so regulated as to exclude the fishes constituting the bycatch (Brewer *et al*., 1998; Pillai (1998).

Development of Radial Escapement Section took place in 1980s in Norway to separate haddock and cod from shrimp trawls (West *et al*., 1984). During these studies, 61% of the haddock (<39 cm) and 30% of cod (<42 cm) were seen excluded from the shrimp trawls equipped with Radial Escapement Section (Watson *et al*., 1986). Valdemarsen (1986) and Valdemarsen and Isaksen (1988) opined that the Radial Escapement Section is able to separate fish and shrimp and also to exclude undersized shrimp from the catch. Eayrs and Prado (1997) demonstrated the performance of Radial Escapement Device in Iranian shrimp fishery. An escapement section of 230 mm square meshes was used for the device. They concluded that Radial Escapement Device maintained shrimp catch with poor bycatch exclusion (Eayrs and Prado, 1998b). In Australia's Northern Prawn Fishery (NPF), evaluation of Radial Escapement Device consisting of a small mesh funnel surrounded by 225 mm large square mesh netting cylinder, 3 bars wide and one wire hoop encased in plastic to support the codend at the aft end of the funnel has given 20 to 40% reduction in bycatch (Brewer *et al*., 1998).

In Indi, Pillai (1998) described Radial Escapement Device for shrimp trawling and Pillai *et al*. (2004) made preliminary observation of the performance of Radial Escapement Device in the seas off Cochin. Field trials with a design having 80 mm square mesh netting cylinder with two stainless steel hoops at either end, surrounding a small mesh guiding funnel, has given a reduction of 18% in bycatch, mostly constituted by juveniles.

4.2 Materials and Methods

Two design variations of Radial Escapement Devices (RED) *viz.,* RED having escapement section of 100 mm square mesh (RED-100) and RED having escapement section of 150 mm square mesh (RED-150) were evaluated during the study. The RED was positioned between the hind belly and codend of a 28.8 m shrimp trawl. Small mesh cover codend was used for retaining the excluded species. Detailed description of materials and methods adopted for the study is given in Chapter section 2.1.1. The first set of experiments using RED-150 was conducted using covered codend method. A cover made of polyamide netting of 15 mm mesh size and 7.0 m in hung length was attached to the front hoop for retaining the excluded catch. In the subsequent set of experiments with RED, a modified version of codend cover arrangement with an additional hoop frame of 1200 mm dia for attachment of the cover was used in order to minimize the masking effect of the cover on exclusion performance.

4.3 Results and Discussion

Results of field trials conducted using RED-150 and RED-100, during January-March 2006 are presented in Tables 4.1-4.7.

4.3.1 RED with 150 mm square mesh escapement section

During the first set of field trials, a total of 10 hauls were taken using RED-150 installed in a 28.8 m shrimp trawl (Fig. 4.1). Total catch obtained was 257.67 kg with an average CPUE of 24.54 $kg.h^{-1}$ of which 77.61% was retained in the codend and 22.39% was excluded. The overall catch during this period consisted of 49 species of finfishes, 6 species of shrimps, 4 species of crabs, 1 species of cephalopod, 7 species of molluscan shells and 1 species of stomatopod. The results of performance evaluation of RED-150 are given in Tables 4.1, 4.2 and 4.3.

Among the species which were excluded through the 150 mm RED, 7 species of finfishes *viz*., *Uroconger lepturus, Nibea maculata, Scatophagus argus, Selar crumenophthalmus, Trypauchen vagina, Leiognathus brevirostris* and *Penaeus semisulcatus* showed 100% exclusion. Eight species *viz., Johnius carouna, Lactarius lactarius, Lagocephalus spadiceus, Rastrelliger kanagurta, Ambassis ambassis, Liza parsia, Esculosa thoracata* and *Epinepheleus diacanthus* showed exclusion above 50%. Among 68 species encountered during operations 19 species *viz*., *Bufonaria echinata, Babylonia zeylanica, Murex carvonnieri, Tonna dolium, Congresox talabonoides, Octopus* sp., *Metapenaeus affinis, Thryssa setirostris, Marcia opima, Pampus argenteus, Johnius dussumieri, Pisedonophis cancrivorus, Leiognathus equulus, Fenneropenaeus indicus, Penaeus monodon, Mugil cephalus, Charybdis natator, Libinia emarginata, Opisthopterus tardoore* did not show any exclusion. Shrimp loss was 8.32% and bycatch exclusion was 26.04%.

Among the species groups encountered crabs showed an overall exclusion of 37.30%, followed by finfishes (34.02%), shrimps (8.32%) and miscellaneous species (4.1%).

Table 4.1: Results of experiments with RED-150

No. of hauls	10
Total catch (kg)	257.67
CPUE (kg.h^{-1})	24.54
Retained catch (kg)	199.97
Retained catch (%)	77.61
Excluded catch (kg)	57.69
Excluded catch (%)	22.39
Retained shrimp catch (kg)	48.55
Retained shrimp catch (%)	91.68
Excluded shrimp catch (kg)	4.40
Excluded shrimp catch (%)	8.32
Retained bycatch (catch other than shrimps) (kg)	151.42
Retained bycatch (catch other than shrimps) (%)	73.96
Excluded bycatch (catch other than shrimps) (kg)	58.77
Excluded bycatch (catch other than shrimps) (%)	26.04
No. of species caught	68
Fish species	49
Shrimp species	6
Other species	13
100% exclusion (No. of species)	7
>50% exclusion (No. of species)	8
Up to 50% exclusion (No. of species)	34
0% exclusion (No. of species)	19

Table 4.2: Group-wise exclusion rate due to the installation of RED-150

Species groups	Encountered catch, kg	Retained, %	Excluded, %
All species	257.67	77.61	22.39
Finfishes	147.67	65.98	34.02
Shrimps	52.95	91.68	8.32
Crabs	2.18	62.70	37.30
Cephalopods	0.4	100.00	0.00
Miscellaneous	54.46	95.9	4.1

Table 4.3: Species-wise exclusion rate in RED-150 (covered codend method)

Species	Encountered catch, kg	Retained, %	Excluded, %
Uroconger lepturus	0.10	0.00	100.00
Nibea maculata	0.08	0.00	100.00
Scatophagus argus	0.05	0.00	100.00
Selar crumenophthalmus	0.02	0.00	100.00
Trypauchen vagina	0.02	0.00	100.00
Leiognathus brevirostris	0.01	0.00	100.00
Penaeus semisulcatus	0.01	0.00	100.00
Johnius carouna	0.42	2.38	97.62
Lactarius lactarius	0.17	29.41	70.59
Lagocephalus spadiceus	0.09	38.89	61.11
Rastrelliger kanagurta	0.18	42.86	57.14
Ambassis ambassis	31.23	45.63	54.37
Liza parsia	2.71	47.05	52.95
Esculosa thoracata	0.70	48.57	51.43
Epinepheleus diacanthus	2.13	49.77	50.23
Arius jella	0.32	50.79	49.21
Charybdis feriatus	1.15	52.40	47.60
Alepes kleinii	2.48	65.66	34.34
Valamugil speigleri	0.26	68.63	31.37
Stolephorus commersonnii	1.05	69.86	30.14

Sardinella longiceps	83.93	69.88	30.12
Anadontostoma chacunda	0.53	71.43	28.57
Megalaspis cordyla	2.92	71.87	28.13
Portunus sanguinolentus	1.02	73.53	26.47
Cynoglossus macrostomus	1.22	75.41	24.59
Stolephorus indicus	0.47	76.60	23.40
Gerres erythrourus	0.20	80.00	20.00
Stolephorus waitei	0.05	80.00	20.00
Otolithes ruber	1.68	81.79	18.21
Secutor insidiator	0.47	84.04	15.96
Pellona ditchella	0.34	86.57	13.43
Thryssa puruva	0.23	86.96	13.04
Johnius carutta	0.25	88.00	12.00
Sardinella fimbriatus	0.65	89.15	10.85
Thryssa mystax	1.30	89.58	10.42
Oratosquilla nepa.	24.33	91.35	8.65
Leiognathus splendens	2.14	91.36	8.64
Metapeneaeus dobsoni	48.43	91.38	8.62
Secutor ruconius	0.82	92.68	7.32
Lepturacanthus savala	1.57	92.99	7.01
Gerres limbatus	0.30	93.33	6.67
Johnius borneensis	3.52	93.75	6.25
Parapenaeopsis stylifera	4.13	94.55	5.45
Sillago sihama	0.10	95.00	5.00
Encrasicholina devisii	0.42	95.24	4.76
Thryssa malabarica	0.44	97.70	2.30
Babylonia spirata	3.18	99.06	0.94
Thryssa kammalensis	0.83	99.40	0.60
Turitella attenuata	24.10	99.59	0.41
Miscellaneous species	5.00	100.00	0.00
All species	**257.67**	**77.61**	**22.39**

Fig 4.1 Operation of RED-150, off Cochin

4.3.2 Comparative performance of RED-100 and RED-150

The second set of experiments for evaluating the comparative performance of RED-150 and RED-100 was conducted using modified covered codend arrangement and the results are represented in Tables 4.4 to 4.7. Views of experimental operations are given in Fig. 4.2-4.3.

Table 4.4: Results of experiments with Radial Escapement Devices (Modified cover codend arrangement)

	RED- 100	RED-150
No. of hauls	11	11
Total catch (kg)	86.65	87.69
CPUE (kg/h)	7.25	7.34
Retained catch (kg)	68.73	74.01
Retained catch (%)	79.32	84.40
Excluded catch (kg)	17.91	13.36
Excluded catch (%)	20.68	15.60
Retained shrimp catch (kg)	9.07	12.31
Retained shrimp catch (%)	75.71	79.67
Excluded shrimp catch (kg)	2.91	3.14
Excluded shrimp catch (%)	24.29	20.33

Retained bycatch (catch other than shrimps) (kg)	59.66	61.70
Retained bycatch (catch other than shrimps) (%)	79.91	85.40
Excluded bycatch (catch other than shrimps) (kg)	15.00	10.55
Excluded bycatch (catch other than shrimps) (%)	20.09	14.60
No. of species caught	66	66
Fish species	51	54
Shrimp species	5	5
Other species	10	7
100% exclusion (No. of species)	9	9
>50% exclusion (No. of species)	14	10
Up to 50% exclusion (No. of species)	28	29
0% exclusion (No. of species)	16	19

Table 4.5: Group-wise exclusion rate due to installation of RED (modified cover codend arrangement)

RED type	Species groups	Encountered catch, kg	Retained catch, %	Excluded catch, %
RED-100	**All species**	**86.65**	**79.32**	**20.67**
	Finfishes	41.32	66.67	33.33
	Shrimps	11.98	75.71	24.29
	Crabs	0.61	47.93	52.07
	Cephalopods	0.07	100.00	0.00
	Miscellaneous	32.67	97.20	2.80
RED-150	**All species**	**87.69**	**84.40**	**15.60**
	Finfishes	43.30	76.65	23.35
	Shrimps	15.45	79.67	20.33
	Crabs	0.37	91.78	8.22
	Cephalopods	0.27	98.11	1.89
	Miscellaneous	28.31	98.59	1.41

Fig. 4.2 Scenes from field trials of RED, off Cochin

Fig. 4.3 A view of the excluded catch from RED

4.3.2.1 Performance of RED-100

Total catch obtained during this period using 100 mm RED, was 86.65 kg of which 79.32% retained in the codend and 20.68% was excluded through 100 mm square meshes. Bycatch (catch other than shrimp) excluded through this BRD was 20.09% and the shrimp loss was 24.29% (Table 4.4).

Overall catch during this period included 51 species of finfishes, 5 species of shrimps, 5 species of crabs, 2 species of cephalopods, 2 species of molluscan shell and 1 species of stomatopod (Table 4.4). Among the 66 species encountered during the operations, 9 species *viz., Otolithes ruber, Uroconger lepturus, Selar crumenophthalmus, Cynoglossus bilineatus, Terapon theraps, Leiognathus brevirostris, Lagocephalus spadiceus, Scylla serrata* and *Portunus sanguinolentus* showed 100% exclusion, 14 species *viz., Leiognathus dussumieri, Alepes kleinii, Megalaspis cordyla, Pomadasys maculates, Nibea maculate, Gerres oyena, Mugil cephalus, Alepes djedaba, Leiognathus bindus, Anadontostoma chacunda, Sillago sihama, Kathala axillaris, Cynoglossus arel* and *Rastrelliger kanagurta* showed exclusion above 50% and 28 species showed exclusion at levels up to 50% (Table 4.6). Sixteen species *viz., Atropus atropus, Caranx sexfasciatus, Charybdis feriatus, Johnius amblycephalus, Johnius carutta, Lactarius lactarius, Libinia emarginata, Liza subviridis, Murex carvonnieri, Otolithes cuveiri, Pelates quadrilineatus, Sepiella inermis, Thryssa puruva, Triacanthus biaculeatus, Turitella attenuata, Uroteuthis duvauceli* did not show any exclusion.

Among the species groups encountered crabs showed an overall exclusion of 52.07%, followed by finfishes (33.33%), shrimps (24.29%) and miscellaneous species (2.8%) (Table 4.5)

Table 4.6: Species-wise exclusion rates in RED-100

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
Otolithes ruber	0.32	0.00	100.00
Uroconger lepturus	0.20	0.00	100.00
Scylla serrata	0.15	0.00	100.00
Portunus sanguinolentus	0.14	0.00	100.00
Selar crumenophthalmus	0.13	0.00	100.00
Cynoglossus biliniatus	0.08	0.00	100.00
Terapon theraps	0.03	0.00	100.00
Leiognathus brevirostris	0.02	0.00	100.00
Lagocephalus spadiceus	0.01	0.00	100.00
Leiognathus dussumieri	2.01	0.25	99.75
Alepes kleinii	0.21	7.32	92.68
Megalaspis cordyla	0.83	12.12	87.88
Pomadasys maculatus	0.42	17.86	82.14
Nibea maculata	0.57	19.30	80.70
Gerres oyena	0.09	22.22	77.78
Mugil cephalus	0.15	23.33	76.67
Alepes djedaba	0.16	25.81	74.19
Leiognathus bindus	0.02	33.33	66.67
Anadontostoma chacunda	0.14	35.71	64.29
Sillago sihama	0.03	40.00	60.00
Kathala axillaris	1.85	40.38	59.62
Cynoglossus arel	0.18	42.86	57.14
Rastrelliger kanagurta	1.12	48.88	51.12
Sardinella longiceps	8.67	57.01	42.99
Ambassis ambassis	0.05	60.00	40.00
Secutor insidiator	0.51	60.78	39.22
Valamugil cunnesious	0.04	62.50	37.50

Thryssa malabarica	0.30	62.71	37.29
Pellona ditchella	0.87	63.58	36.42
Epinepheleus diacanthus	0.45	66.29	33.71
Metapenaeus affinis	0.99	68.53	31.47
Metapeneaeus dobsoni	7.55	68.54	31.46
Johnius dussumieri.	2.27	75.99	24.01
Stolephorus waitei	0.76	76.32	23.68
Pampus argenteus	3.05	77.05	22.95
Fenneropenaeus indicus	0.07	78.57	21.43
Dasciana albida	0.19	78.95	21.05
Johnius borneensis	1.31	79.01	20.99
Johnius carouna	0.65	79.84	20.16
Gerres limbatus	0.05	80.00	20.00
Leiognathus splendens	0.19	81.58	18.42
Thryssa dussumieri	0.40	82.28	17.72
Thryssa mystax	0.74	86.39	13.61
Charybdis natator	0.23	86.96	13.04
Metapenaeus monoceros	0.56	89.29	10.71
Stolephorus commersonnii	1.38	93.82	6.18
Cynoglossus macrostomus	0.17	93.94	6.06
Parapenaeopsis stylifera	2.82	94.67	5.33
Lepturacanthus savala	10.02	96.16	3.84
Oratosquilla nepa.	20.62	96.68	3.32
Waste (vegetation)	11.98	98.08	1.92
Miscellaneous species	1.03	100.00	0.00
All species	**86.65**	**79.33**	**20.67**

4.3.2.2 Performance of RED-150

A total catch of 87.69 kg was obtained during operations of which 84.40% was retained in the codend and 15.60% was excluded through the large square meshes. Bycatch (catch other than shrimp) exclusion through this BRD was 14.60% and shrimp loss was 20.33% (Table 4.4).

Overall catch during the period of observations included 54 species of finfishes 5 species of shrimps, 3 species of crabs, 2 species of cephalopods, 1 species of molluscan shell and 1 species of stomatopod (Table 4.4). Among the 66 species encountered, 9 species of finfishes *viz., Valamugil cunnesius, Dasciana albida, Scatophagus argus, Terapon jarbua, Anadontostoma chacunda, Valamugil spiegleri, Alectis indicus, Liza subviridis* and *Terapon theraps* showed 100% exclusion, 10 species *viz., Alepes djedaba, Megalaspis cordyla, Selar crumenophthalmus, Alepes kleinii, Johnius dussumieri, Congresox talabonoides, Rastrelliger kanagurta, Kathala axillaris, Otolithes ruber, Mugil cephalus* showed escapement above 50% and 29 species showed exclusion up to 50% (Table 4.7). Nineteen species *viz., Apogon fasciatus, Babylonia spirata, Cynoglossus dubius, Decapterus russeli, Gerres limbatus, Gerres oyena, Johnius amblycephalus, Johnius carutta, Lagocephalus spadiceus, Leiognathus dussumieri, Liza parsia, Parastromateus niger, Portunus pelagicus, Portunus sanguinolentus, Secutor ruconius, Sillago sihama, Thryssa dussumieri, Uroteuthis duvauceli and Zebrias quagga* did not show any exclusion.

Among the species groups encountered, finfishes showed an overall exclusion of 23.35%, followed by shrimps (20.33%), crabs (8.22%), cephalopods (1.89%) and miscellaneous species (1.41%) (Table 4.5).

Table 4.7: Species-wise exclusion rates in RED-150

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
Valamugil cunnesius	0.15	0.00	100.00
Dasciana albida	0.13	0.00	100.00
Scatophagus argus	0.03	0.00	100.00
Terapon jarbua	0.03	0.00	100.00
Anadontostoma chacunda	0.03	0.00	100.00
Valamugil speigleri	0.02	0.00	100.00
Alectis indicus	0.01	0.00	100.00
Liza subviridis	0.01	0.00	100.00
Terapon theraps	0.01	0.00	100.00
Alepes djedaba	0.17	5.88	94.12
Megalaspis cordyla	2.13	11.76	88.24
Selar crumenophthalmus	0.25	20.00	80.00
Alepes kleinii	0.14	22.22	77.78
Johnius dussumieri.	0.87	29.31	70.69
Congresox talabonoides	0.08	33.33	66.67
Rastrelliger kanagurta	1.25	34.94	65.06
Kathala axillaris	3.68	40.22	59.78
Otolithes ruber	0.65	46.15	53.85
Mugil cephalus	0.42	48.81	51.19
Ambassis ambassis	0.44	54.02	45.98
Nibea maculata	0.21	56.10	43.90
Leiognathus splendens	0.23	64.44	35.56
Leiognathus equulus	0.02	66.67	33.33
Leiognathus brevirostris	0.09	70.59	29.41
Epinepheleus diacanthus	0.20	75.00	25.00
Pomadasys maculatus	0.77	75.82	24.18
Metapeneaeus dobsoni	12.63	76.56	23.44
Secutor insidiator	0.31	77.42	22.58
Pellona ditchella	1.13	78.32	21.68
Thryssa malabarica	0.40	80.00	20.00
Cynoglossus macrostomus	0.08	81.25	18.75
Charybdis natator	0.19	83.78	16.22
Thryssa mystax	0.69	85.51	14.49
Johnius borneensis	0.63	86.40	13.60

Sardinella longiceps	7.44	87.29	12.71
Stolephorus waitei	1.37	87.59	12.41
Lactarius lactarius	0.20	90.00	10.00
Stolephorus commersonnii	2.94	90.80	9.20
Parapenaeopsis stylifera	1.75	92.86	7.14
Metapenaeus affinis	0.73	94.48	5.52
Fenneropenaeus indicus	0.20	94.87	5.13
Metapenaeus monoceros	0.15	95.39	4.61
Pampus argenteus	2.93	95.73	4.27
Johnius carouna	0.39	96.15	3.85
Lepturacanthus savala	9.78	96.37	3.63
Sepiella inermis	0.16	96.77	3.23
Oratosquilla nepa.	15.00	98.00	2.00
Waste (vegetation)	13.30	99.25	0.75
Miscellaneous species	3.38	100.00	0.00
All species	**87.69**	**84.39**	**15.61**

4.3.2.3 Statistical analysis

Statistical analysis using Student's *t*-test has shown that the difference in performance between RED-100 and RED-150 in terms of exclusion rates was not statistically significant ($p>0.05$).

4.3.3 Selectivity analysis

Results of selectivity analysis in respect of 8 species *viz*., *Ambassis ambassis, Johnius dussumieri, Kathala axillaris, Pellona ditchella, Lepturacanthus savala, Secutor insidiator, Parapenaeopsis stylifera* and *Metapenaeus dobsoni* are presented in Table 4.8 and Fig. 4.4 to 4.10.

L_{50} values lower than length at first maturity (L_m) values indicate better exclusion opportunities for immature fishes below L_m, as the mid-length classes were plotted against excluded fractions in the selectivity estimates. The L_{50} values of *Johnius dussumieri* were found to be lower than their L_m in both the BRDs. L_{50} values in respect of *Pellona ditchella, Parapenaeopsis stylifera* and *Metapenaeus dobsoni* were higher than L_m values reported. Comparatively better juvenile escapement was observed in RED-100 in respect of *Metapenaeus dobsoni* and *Parapenaeopsis stylifera* as indicated by lower L_{50} values.

Table 4.8: Selectivity parameters for Radial Escapement Devices

Species	RED type	L_{25}	L_{50}	L_{75}	Selection range, mm	Length at first maturity, mm (TL)
Ambassis ambassis	RED-100	78.66	86.66	94.66	16.00	NA
	RED-150	64.54	80.97	97.40	32.86	
Johnius dussumieri	RED-100	31.95	66.26	100.57	68.62	115
	RED-150	99.08	103.47	107.85	8.77	(Fishbase, 2008)
Kathalla axillaries	RED-100	100.18	131.06	161.94	61.75	NA
	RED-150	99.19	118.57	137.94	38.7	
Lepturacanthus savala	RED-100	373.98	404.13	434.29	60.31	NA
Metapenaeus dobsonii	RED-100	52.28	94.91	137.54	85.26	88.6
	RED-150	79.90	107.62	135.33	55.43	(Rao, 1967)
Pellona ditchella	RED-150	134.65	160.20	185.75	51.10	135 (Fishbase, 2008)
Parapenaeopsis stylifera	RED-100	37.09	116.12	195.14	158.04	63.2
	RED-150	113.23	141.53	169.82	56.59	(Rao., 1967)

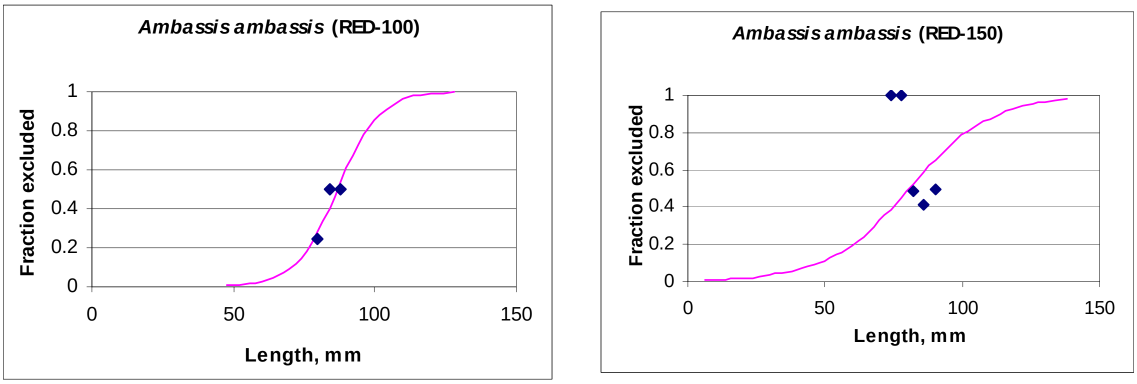


Fig. 4.4 Selectivity curves for *Ambassis ambassis*

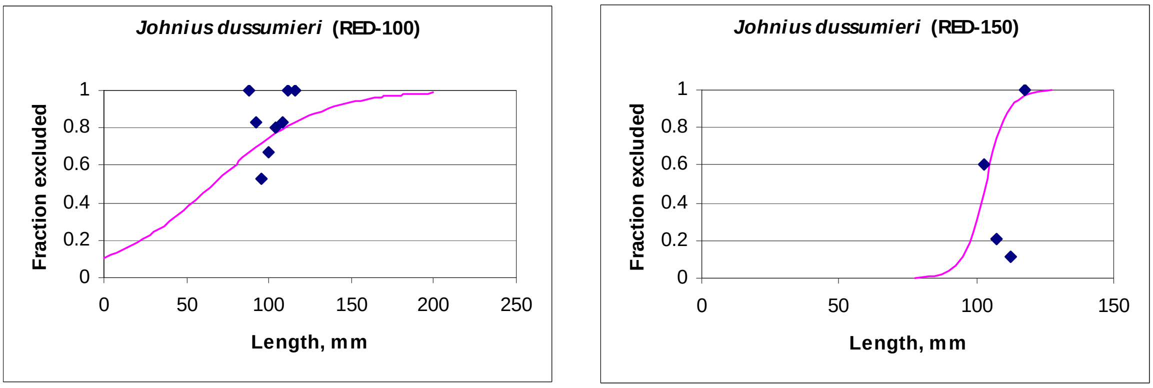


Fig. 4.5 Selectivity curves for *Johnius dussumieri*

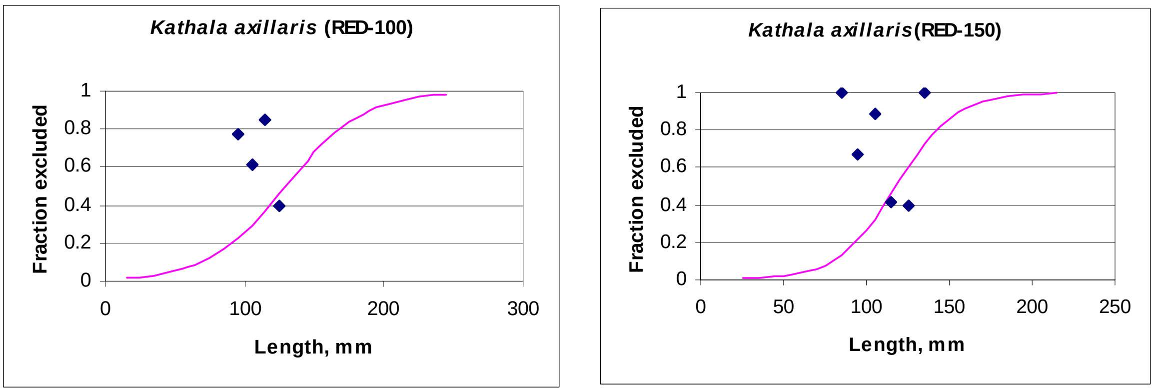


Fig. 4.6 Selectivity curves for *Kathala axillaris*

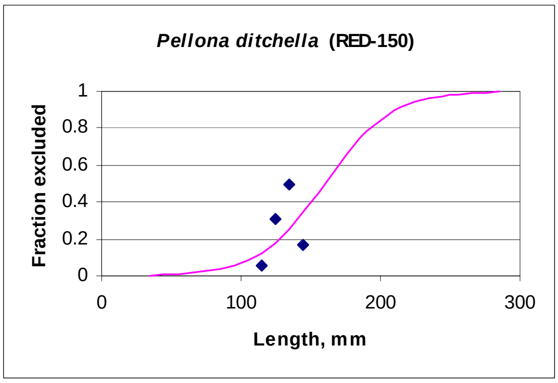


Fig. 4.7 Selectivity curve for *Pellona ditchella*

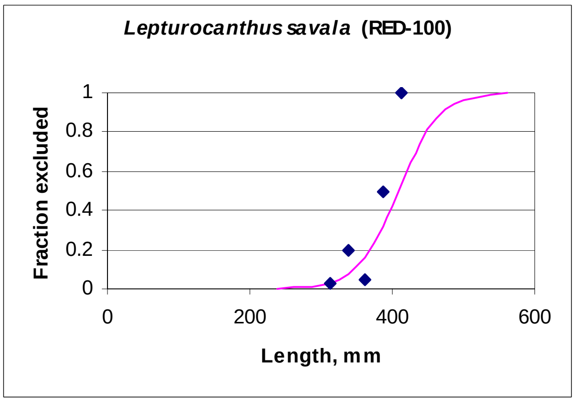


Fig. 4.8 Selectivity curve for *Lepturacanthus savala*

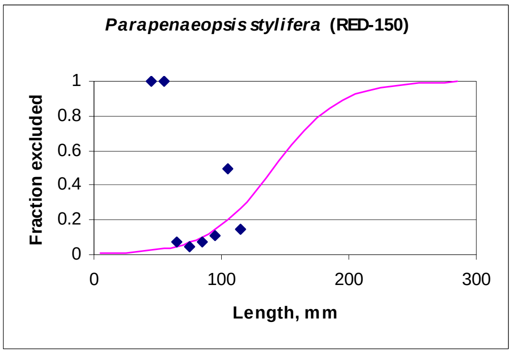


Fig. 4.9 Selectivity curve for *Parapenaeopsis stylifera*

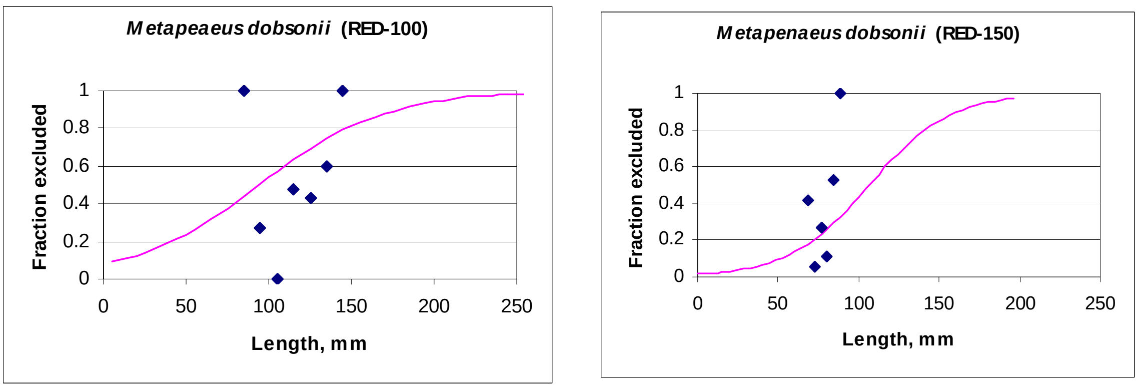


Fig. 4.10 Selectivity curves for *Metapenaeus dobsoni*

Comparative length wise exclusion characteristics of selected trawl caught species were studied in the RED installed operations. Length wise exclusion characteristics of *Ambassis ambassis, Kathala axillaris, Lepturacanthus savala, Metapenaeus dobsonii* and *Parapenaeopsis stylifera* are given in Fig 4.11 to 4.15. In the case of *Ambassis ambassis* length classes up to 75-78 mm was completely retained and from 79-82 mm there was an increasing trend in exclusion rates. Length classes up to 77-80 was completely excluded in RED-150 and around 50% exclusion was observed in length classes from 81-84 and 89-92 mm. In RED-100, length class 81-90 mm in respect of *Kathala axillaris* was completely retained and length classes of 91 to 30 mm showed an exclusion rate of 40-85%. In RED-150 length classes of 81-90 mm in respect of *Kathala axillaris* was completely excluded and length classes from 101 to 130 mm showed an increasing trend in retention. In the case of *Lepturacanthus savala* length class 276-300 mm showed 100% retention in RED-100, length classes from 301 to 400 mm showed an increasing trend in exclusion and length class 401-425 mm showed 100% exclusion.

In the case of RED-150, length classes from 201 to 440 mm showed retention rates exceeding 95%. In RED-100, length classes of *Metapenaeus dobsoni* from 61 to 80 mm showed retention rates exceeding 70%, length classes from 81 to 110 mm showed an increasing trend in exclusion and length class 111-120 mm showed 100% exclusion. In the case of RED-150, length classes of 66 to 90 mm showed retention rates between 48-93% and length class of 91-95 mm showed 100% exclusion. Length classes 51 to 110 mm in respect of *Parapenaeopsis stylifera* showed retention rates in excess of 85% in RED-100. In the case of RED-150, length classes of 41 to 60 mm showed 100% exclusion while length classes of 61 to 120 mm showed retention rates between 50 and 95%.

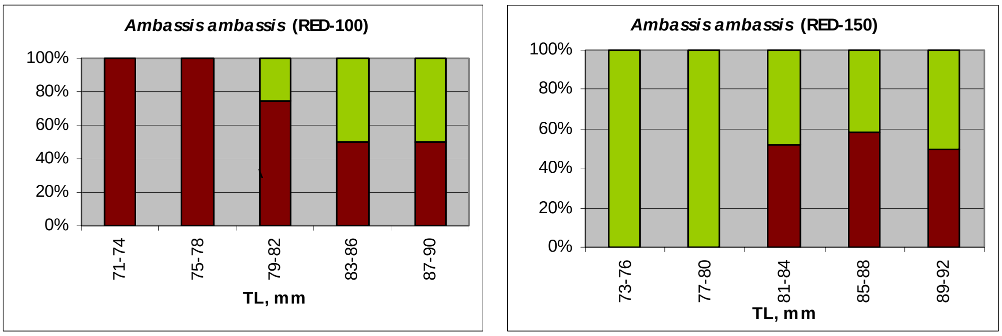


Fig. 4.11 Retention and exclusion rates of *Ambassis ambassis*

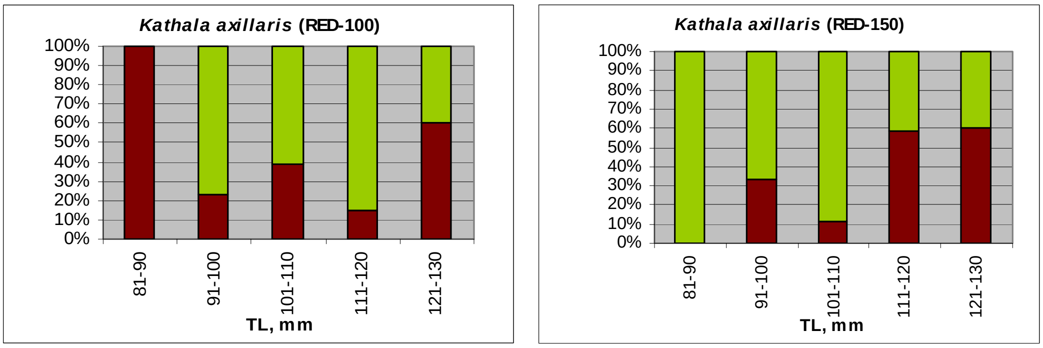


Fig. 4.12 Retention and exclusion rates of *Kathala axillaris*

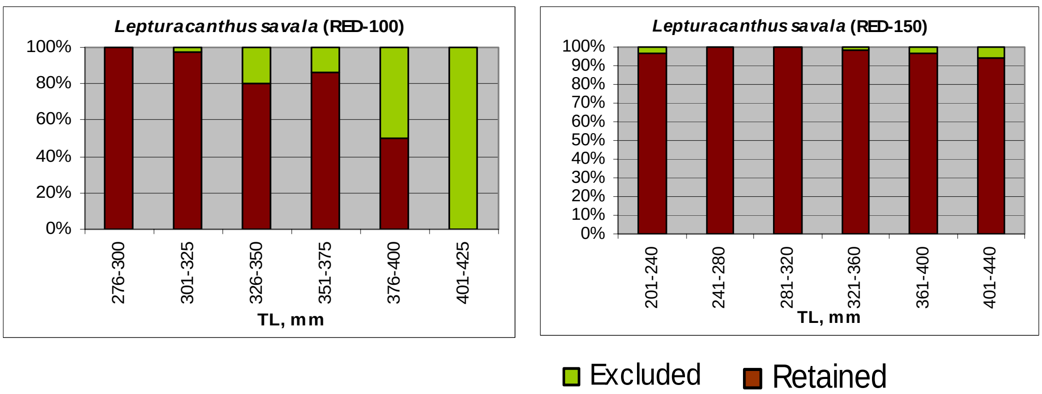


Fig. 4.13 Retention and exclusion rates of *Lepturacanthus savala*

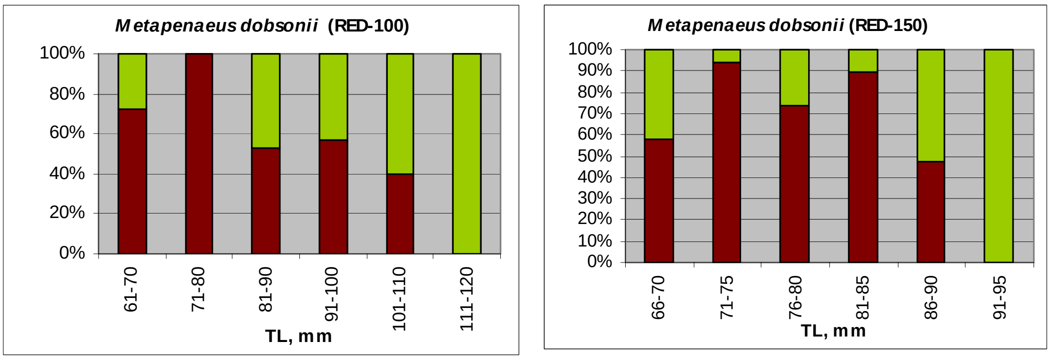


Fig. 4.14 Retention and exclusion rates of *Metapenaeus dobsoni*

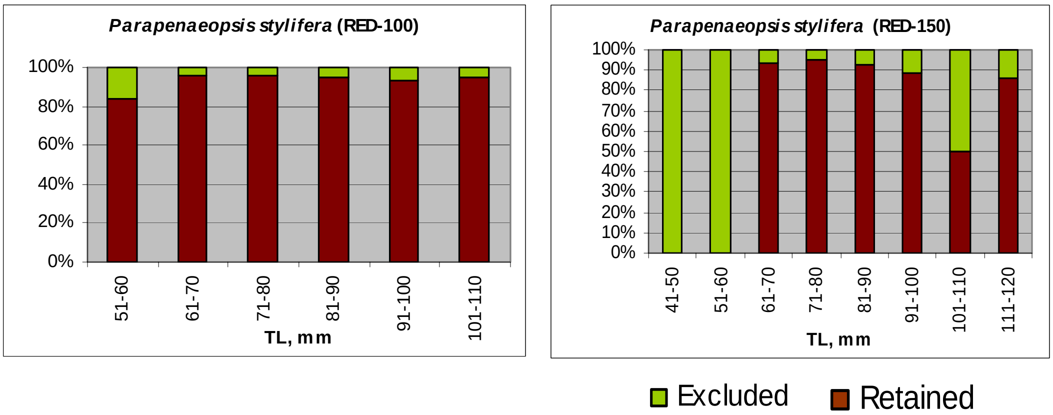


Fig. 4.15 Retention and exclusion rates of *Parapenaeopsis stylifera*

4.3.4 Catch diversity analysis

PRIMER software package (Version 5.2.9; Plymouth marine Laboratory, Plymouth, UK) was used for SIMPER analysis, plotting k-dominance curves, and estimating diversity indices such as total number of species (S), Margalef richness (d), Pielou's evenness (J'), Brillouin index (H), Shannon index (H'), Simpson's dominance index (λ'). Simpson's evenness measure (E1/D) was calculated by dividing reciprocal of Simpson's dominance index with total number of species (S) in the sample. In the k-dominance plot, the cumulative ranked abundances of species obtained in each BRD were plotted against species rank. The results showing diversity indices and k-dominance plot of Radial Escapement Devices are given in Table: 4.9 and Fig: 4.16.

Table 4.9: Mean Diversity indices of species excluded through Radial Escapement Devices

RED type	S	D	J'	H	H'	N1	λ'	E1/D
RED-100	51	9.47	0.54	1.93	2.13	8.41	0.22	0.09
RED-150	43	8.28	0.52	1.62	1.94	6.99	0.30	0.08

The catch excluded from RED-100 was found to have more diversity than the RED-150 in terms of S, d, J', H, H', N1 and E1/D. Higher dominance (Simpson's dominance index, λ') of species was observed in RED-100. In the k-dominance plot, the curve for RED-100 starts from the lower side which indicates higher diversity in catch compared to the catch excluded from RED-150.

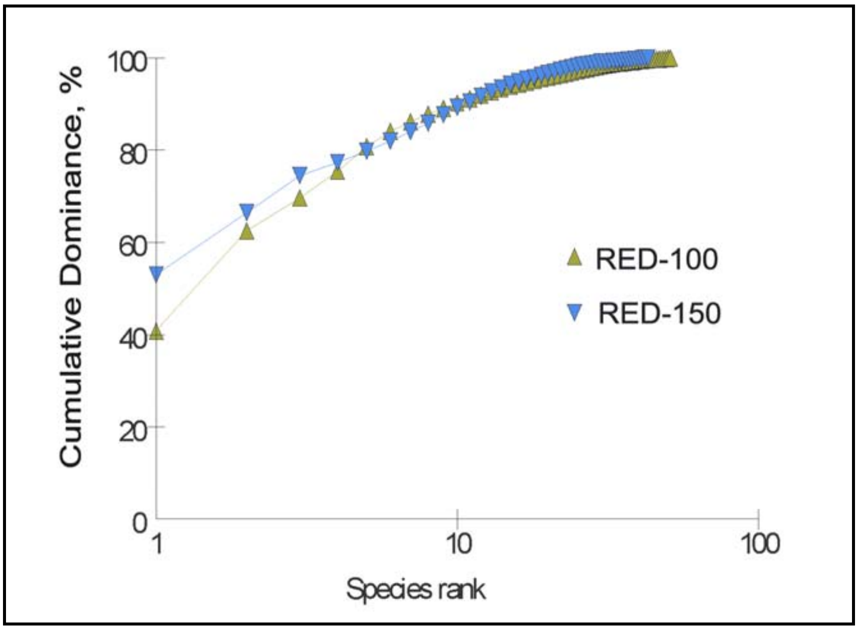


Fig. 4.16 k-dominance plot of Radial Escapement Devices

4.4 Conclusion

Experiments with two designs of Radial Escapement Device (RED-100 mm and RED-150 mm) in the seas off Cochin have given bycatch exclusion rates ranging from 12 to 21% and shrimp loss ranging from 8 to 24%. Among the two REDs evaluated RED-150 performed better in terms of bycatch exclusion and shrimp retention. Exclusion in excess of 50% was observed in the case of 23 species in respect of RED-100 and 19 species in respect of RED-150. Species excluded from RED-100 was observed to be more diverse compared to RED-150. Difference in performance between the two REDs in terms of exclusion rates was not found to be statistically significant ($p>0.05$). In view of low bycatch exclusion and high shrimp loss observed during the field trials, Radial Escapement Device may not be an appropriate BRD for Indian fisheries conditions.

Chapter 5

Bigeye Bycatch Reduction Devices

5.1 Introduction

Bigeye BRD consists of a simple horizontal slit in the upper part of the codend or hind belly, where the opening is maintained by means of floats and sinkers or by binding with twine. Differences in the behaviour of fish and shrimp are utilized in the design of this category of BRDs. Fishes that enteres the codend are given opportunity to swim back and escape by providing slits in the netting on the topside of the codend or hind belly, while shrimps are retained in the codend. The Bigeye BRD is very simple in design and can be easily incorporated in an existing commercial trawl. Size of the slit can be easily adjusted according to the size of the animals, which need to be excluded (Robins *et al*., 1999).

Bigeye BRD has been reported to reduce bycatch by 30 to 40% during day time and 10 to 15% during night or turbid conditions, in shrimp fleet, Queensland east coast waters (Robins *et al*., 1999). Large slits in the top of the codend or side panels are used to exclude turtles and large bycatch species like sting rays and sharks in Australia's Northern prawn trawl fisheries and this device is referred to as John Thomas Bigeye TED (Day, 2000). According to Queensland Fisheries Service (QFS) survey, Bigeye BRD has been the most preferred design to reduce bycatch in the East coast trawl fishery during 2001-2002 period (GBR-MPA, 2003).

5.2 Materials and Methods

Comparative performance evaluation of Bigeye BRDs fixed at two different positions on shrimp trawl codends was conducted off Cochin, during May-July 2006 and April 2007. Fourteen paired hauls were used for analysis. Bigeye BRDs positioned at (i) 0.5 m from the leading edge of the codend (Bigeye-0.5) (ii) 1.5 m from the distal end of codend (Bigeye-1.5) were constructed on 20 mm diamond mesh codends. Design details and methodology are described in Chapter section 2.1.2.

5.3 Results and Discussion

Results of field trials conducted using BRDs positioned at 0.5 m from the leading edge of the codend (Bigeye-0.5) and 1.5 m from the distal end of codend (Bigeye-1.5), during May-July 2006 and April 2007 are presented in Tables 5.1-5.4 and Fig 5.1.

5.3.1 Performance of Bigeye-0.5 BRD

The total catch obtained by this BRD is 71.79 kg with an average CPUE of 5.6 $kg.h^{-1}$ of which 93.87% of catch retained in the codend and only 6.13% was excluded. Bycatch (catch other than shrimp) exclusion from this BRD was 7.83% of total catch and the shrimp loss was only 0.81%. The overall catch during this period using this BRD consisted of 48 species of finfishes, 6 species of shrimps, 3 species of crabs, 1 species of cephalopod, 1 species of stomatopod, 1 species of Echinoderm and 1 species of jelly fish. No species showed 100% and more than 50% exclusion from this BRD (Table. 5.1).

Among the 61 species encountered, Twenty species *viz*., *Stolephorus indicus, Leiognathus bindus, Esculosa thoracata, Stolephorus commersonnii, Sardinella longiceps, Stolephorus waitei, Thryssa mystax, Encrasicholina devisii, Anadontostoma chacunda, Megalaspis cordyla, Dussumieria acuta, Pampus argenteus, Pomadasys maculata, Johnius carouna, Johnius borneensis, Secutor insidiator, Charybdis natator, Portunus sanguinolentus, Metapenaeus dobsoni* and *Parapenaeopsis stylifera* showed exclusion upto 50% from this Big eye BRD (Table. 5.3). Fourty-one species *viz*., *Alepes djedaba, Ambassis ambassis, Anadontostoma chacunda, Caranx ignobilis, Cynoglossus dubius, Cynoglossus macrostomus, Decapterus russeli, Eleutheronema tetradactylum, Encrasicholina heteroloba, Johnius dussumieri, Lactarius lactarius, Lagocephalus spadiceus, Leiognathus brevirostris, Leiognathus dussumieri, Leiognathus splendens, Lepturacanthus savala, Opisthopterus tardoore, Otolithes cuveiri, Otolithes ruber, Pampus chinenesis, Parastromateus niger, Platycephalus indicus, Rastrelliger kanagurta, Scomberoides tala, Scomberomorus guttatus, Selar crumenophthalmus, Sillago sihama, Sphyraena jello, Sphyraena obtusata, Terapon jarbua, Trypauchen vagina, Uroteuthis duvauceli, Valamugil cunnesius, Portunus pelagicus, Fenneropenaeus indicus, Metapenaeus affinis, Metapenaeus monoceros, Penaeus monodon, Oratosquilla nepa, Holothuria* spp. and jellyfish *(Rhopilema* spp.) did not show any exclusion through this BRD. Among the target shrimps *Metapenaeus dobsoni* showed 98.35% retention and other shrimps, *viz*., *Parapenaeopsis stylifera, Fenneropenaeus indicus, Meapenaeus monoceros* and *Metapenaeus affinis* showed 100% retention in the main codend.

Among the species groups encountered, finfishes showed an overall exclusion of 10.77%, followed by crabs (1.46%), shrimps (0.81%) (Table 5.2).

Table 5.1 Results of experiments with Bigeye BRD

	Bigeye-0.5	Bigeye-1.5
No. of hauls	14	14
Total catch (kg)	71.79	81.49
CPUE ($kg.h^{-1}$)	5.60	6.15
Retained catch (kg)	67.39	74.02
Retained catch (%)	93.87	90.83
Excluded catch (kg)	4.40	7.48
Excluded catch (%)	6.13	9.17
Retained shrimp catch (kg)	17.21	19.56
Retained shrimp catch (%)	99.19	97.73
Excluded shrimp catch (kg)	0.14	0.46
Excluded shrimp catch (%)	0.81	2.27
Retained bycatch (catch other than shrimps) (kg)	50.18	54.46
Retained bycatch (catch other than shrimps) (%)	92.17	88.58
Excluded bycatch (catch other than shrimps) (kg)	4.26	7.02
Excluded bycatch (catch other than shrimps) (%)	7.83	11.42
No. of species caught	61	70
Fish species	48	55
Shrimp species	6	5
Other species	7	10
100% exclusion (No. of species)	0	6
>50% exclusion (No. of species)	0	5
Up to 50% exclusion (No. of species)	20	25
0% exclusion (No. of species)	41	35

Table 5.2: Group-wise exclusion rate due to the installation of Bigeye BRD

Bigeye type	Species groups	Encountered catch, kg	Retained catch, %	Excluded catch, %
Bigeye-0.5	**All species**	**71.79**	**93.87**	**6.13**
	Finfishes	39.44	88.85	10.77
	Shrimps	17.35	99.19	0.81
	Crabs	1.03	98.54	1.46
	Cephalopods	5.08	100.00	0.00
	Miscellaneous	8.89	100.00	0.00
Bigeye-1.5	**All species**	**81.49**	**90.83**	**9.17**
	Finfishs	42.60	83.62	16.38
	Shrimps	20.01	97.73	2.27
	Crabs	0.34	100.00	0.00
	Cephalopods	2.00	99.25	0.75
	Miscellaneous	16.54	100.00	0.00

Table 5.3 Species-wise exclusion rate in Bigeye-0.5 BRD

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
Stolephorus indicus	0.21	51.64	48.36
Leiognathus bindus	0.22	63.64	36.36
Esculosa thoracata	0.08	75.00	25.00
Stolephorus commersonnii	2.82	76.24	23.76
Sardinella longiceps	14.04	82.48	17.52
Stolephorus waitei	2.28	85.09	14.91
Thryssa mystax	0.23	86.96	13.04
Encrasicholina devisii	0.12	87.50	12.50
Anadontostoma chacunda	0.35	88.57	11.43
Megalaspis cordyla	3.90	92.05	7.95
Charybdis natator	0.07	92.31	7.69
Dussumieria acuta	0.62	95.16	4.84
Pampus argenteus	3.58	93.02	2.79
Pomadasys maculate	0.19	97.37	2.63
Johnius carouna	0.51	98.04	1.96

Metapenaeus dobsoni	4.25	98.35	1.65
Johnius borneensis	1.03	98.54	1.46
Portunus sanguinolentus	0.95	98.95	1.05
Secutor insidiator	2.56	99.22	0.78
Parapenaeopsis stylifera	12.13	99.42	0.58
Alepes djedaba	1.23	100.00	0.00
Miscellaneous species	20.61	100.00	0.00
All species	**71.79**	**93.87**	**6.13**

5.3.2 Performance of Bigeye-1.5 BRD

The total catch obtained during Bigeye-1.5 BRD installed operations was 81.49 kg with an average CPUE of 6.15 kg.h^{-1} of which 90.83% retained in the codend and 9.17% was excluded. Bycatch (catch other than shrimp) exclusion from this BRD was 11.42% of total catch and shrimp loss was 2.27%. Among the target catch *Parapenaeopsis stylifera, Fenneropenaeus indicus, Metapenaeus affinis* and *Metapenaeus dobsoni* showed more than 97% retention in the codend. The overall catch during the period of observations consisted of 55 species of finfishes, 5 species of shrimps, 3 species of crabs, 2 species of molluscan shells, 1 species of cephalopod, 1 species of elasmobranch, 1 species of stomatopod, 1 species of echinoderm and 1 species of jellyfish (Table. 5.1).

Among the 70 species encountered, 6 species of finfishes *viz., Ambassis ambassis, Gerrus limbatus, Mene maculata, Pelates quadrilineatus, Secutor ruconius* and *Valamugil cunnesius* were fully excluded. Six species *viz., Johnius borneensis, Rastrelliger kanagurta, Parastromateus niger, Johnis carutta,* and *Sardinella longiceps* showed exclusion rates above 50%, and another 24 species showed exclusion up to

50% during the experiment (Table 5.4). Thirty-four species *viz., Alepes kleinii, Caranx sexfasciatus, Cynoglossus dubius, Cynoglossus macrostomus, Encrasicholina punctifer, Esculosa thoracata, Ilisha filigera, Johnius carouna, Johnius dussumieri, Kathala axillaris, Lactarius lactarius, Leiognathus brevirostris, Leiognathus dussumieri, Leiognathus equulus, Leiognathus splendens, Nibea maculata, Otolithes cuveiri, Pellona ditchella, Sardinella fimbriatus, Scomberomorus guttatus, Selar crumenophthalmus, Sillago sihama, Terapon jarbua, Terapon theraps, Thryssa puruva, Charybdis lucifera, Portunus pelagicus, Portunus sanguinolentus, Himantura gerrardi, Oratosquilla nepa, Marcia opima, Turitella attenuata, Holothuria* spp. and jellyfish (*Rhopilema* spp.) did not show any exclusion from this BRD.

Among the species groups encountered, finfishes showed an overall exclusion of 16.38%, followed by shrimps (2.27%) and cephalopods (0.75%) (Table 5.2).

Table 5.4 Species- wise exclusion rate in Bigeye-1.5 BRD

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
Ambassis ambassis	0.01	0.00	100.00
Gerres limbatus	0.01	0.00	100.00
Mene maculata	0.02	0.00	100.00
Peletus quadrilineatus	0.02	0.00	100.00
Secutor ruconius	0.23	0.00	100.00
Valamugil cunnesius	0.02	0.00	100.00
Johnius borneensis	0.06	27.27	72.73
Rastrelliger kanagurta	2.94	30.49	69.51
Parastromateus niger	0.04	42.86	57.14
Johnius carutta	0.23	43.48	56.52
Sardinella longiceps	3.68	47.83	52.17
Nemepterus mesoprion	0.03	50.00	50.00

Alepes djedaba	0.37	59.46	40.54
Otolithes ruber	0.45	64.44	35.56
Megalaspis cordyla	1.84	68.48	31.52
Encrasicholina devisii	0.05	70.00	30.00
Trypauchen vagina	1.31	76.63	23.37
Lagocephalus spadiceus	0.87	77.01	22.99
Anadontostoma chacunda	0.79	77.22	22.78
Metapenaeus monoceros	0.14	81.75	18.25
Thryssa mystax	0.34	82.35	17.65
Stolephorus commersonnii	4.44	88.51	11.49
Sphyraena obtusata	0.14	88.89	11.11
Leiognathus bindus	0.20	90.00	10.00
Stolephorus indicus	1.06	92.45	7.55
Scomberoides tala	0.22	95.45	4.55
Stolephorus waitei	3.14	96.82	3.18
Metapenaeus dobsoni	11.53	97.14	2.86
Pampus argenteus	3.13	97.76	2.24
Metapenaeus affinis	1.05	98.10	1.90
Lepturacanthus savala	0.31	98.36	1.64
Parapenaeopsis stylifera	6.87	98.54	1.46
Dussumieria acuta	3.69	98.92	1.08
Fenneropenaeus indicus	0.56	99.11	0.89
Uroteuthis duvauceli	2.00	99.25	0.75
Secutor insidiator	1.35	99.63	0.37
Alepes kleinii	0.04	100.00	0.00
Miscellaneous species	27.9	100.00	0.00
All species	**81.49**	**90.83**	**9.17**

5.3.3 Statistical analysis

Statistical analysis using Student's *t*-test has shown that the difference in performance between Bigeye-0.5 and Bigeye-1.5 in terms of exclusion rate was not statistically significant ($p>0.05$).

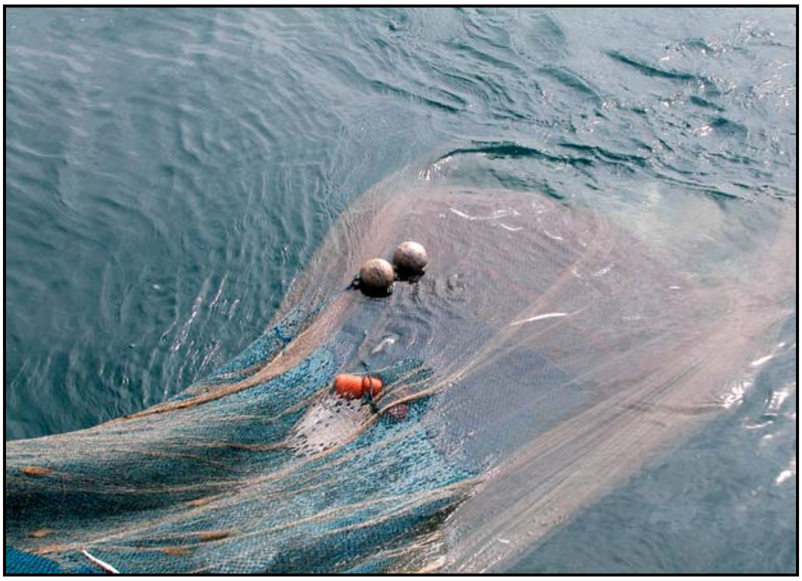


Fig 5.1 A scene from field trials of Bigeye-1.5 BRD, off Cochin

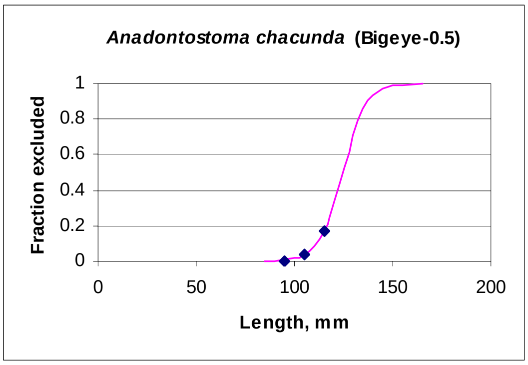
5.3.4 Selectivity analysis

In Bigeye BRD, fishes are given opportunity to escape by providing adequate opening at specific locations. The swimming speed is related to the body length of the species. Results of selectivity analysis of Bigeye-0.5 and Bigeye-1.5 BRDs in respect of seven species *viz. Alepes djedaba, Anadontostoma chacunda, Megalaspis cordyla, Rastrelliger kanagurta, Sardinella longiceps*, *Stolephorus indicus* and *Thryssa mystax* are presented in Table 5.5 and Fig 5.2 to 5.8.

L_{50} values lower than length at first maturity (L_m) values indicate better exclusion opportunities for immature fishes below L_m, as the mid-length classes were plotted against excluded fractions in the selectivity estimates. L_{50} values in respect of *Megalaspis cordyla, Sardinella longiceps, Stolephorus indicus* and *Thryssa mystax* were found to be lower than L_m for Bigeye-0.5. L_{50} values in respect of *Alepes djedaba, Megalaspis cordyla, Rastrelliger kanagurta, Sardinela longicpes* and *Stolephorus indicus* were found to be lower than L_m values for Bigeye-1.5 BRD. Lower L_{50} values obtained for *Anadontostoma chacunda, Sardinella longiceps, Stolephorus indicus* and *Thryssa mystax* in respect of Bigeye-0.5 BRD is indicative of better escapement opportunity for juveniles of these species, compared to Bigeye-1.5 BRD (Table 5.5).

Table. 5.5: Selectivity parameters for Bigeye BRDs

Species	Bigeye BRD	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection Range, mm	Length at first maturity (TL), mm
Alepes djedaba	Bigeye-1.5	130.0	136.13	142.26	12.26	180-189 (Fishbase, 2008)
Anadontostoma chacunda	Bigeye-0.5	118.03	124.54	131.06	13.06	NA
	Bigeye-1.5	113.00	184.71	256.42	143.42	
Megalaspis cordyla	Bigeye-0.5	113.40	125.21	137.02	23.61	250 (Fishbase, 2008)
	Bigeye-1.5	86.62	104.31	121.99	35.37	
Rastrelliger kanagurta	Bigeye-1.5	111.31	122.22	133.12	21.81	190-220 (Fishbase, 2008)
Sardinella longiceps	Bigeye-0.5	48.69	109.78	170.87	122.18	150-162 (Fishbase, 2008)
	Bigeye-1.5	127.72	159.74	191.77	64.04	
Stolephorus indicus	Bigeye-0.5	76.37	92.22	108.07	31.70	120 (Fishbase, 2008)
	Bigeye-1.5	104.42	110.59	116.76	12.35	
Thryssa mystax	Bigeye-0.5	65.18	78.38	91.58	26.40	130 (Fishbase, 2008)
	Bigeye-1.5	122.41	155.76	189.11	66.70	



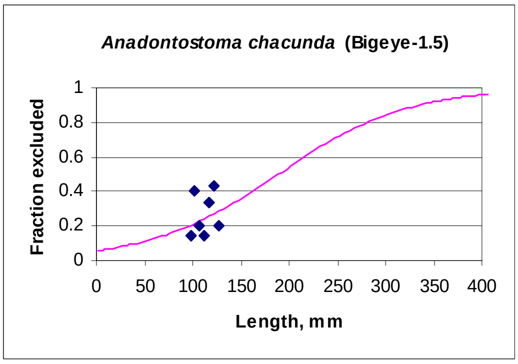


Fig. 5.2 Selectivity curves for *Anadontostoma chacunda*

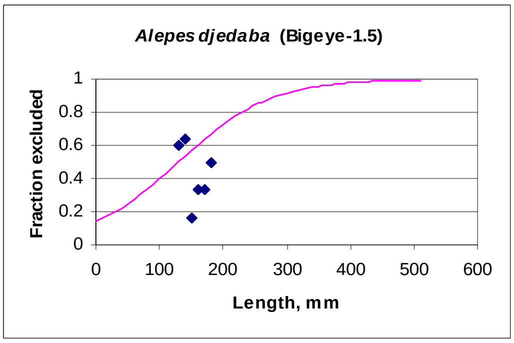


Fig. 5.3 Selectivity curve for *Alepes djedaba*

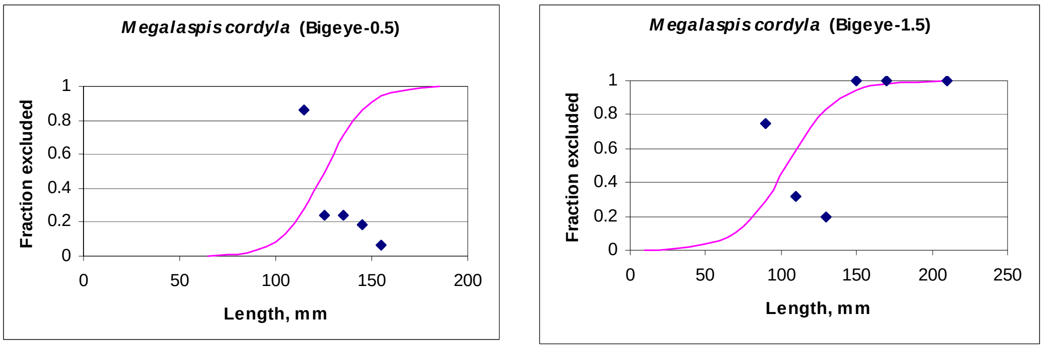


Fig. 5.4 Selectivity curves for *Megalaspis cordyla*

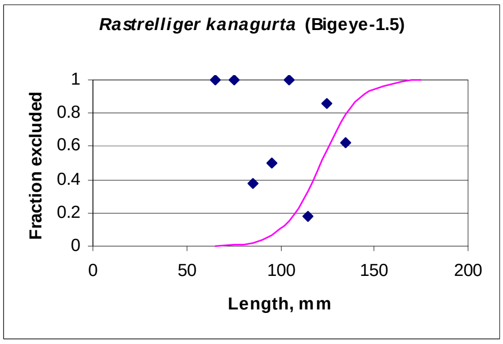


Fig. 5.5 Selectivity curve for *Rastrelliger kanagurta*

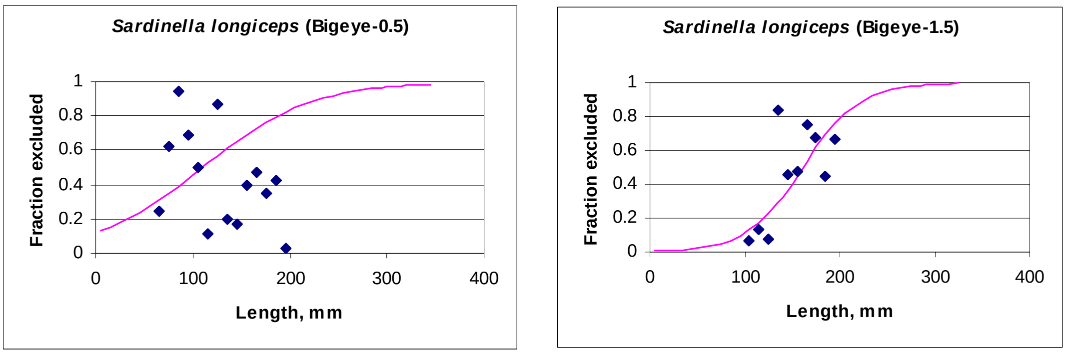


Fig. 5.6 Selectivity curves for *Sardinella longiceps*

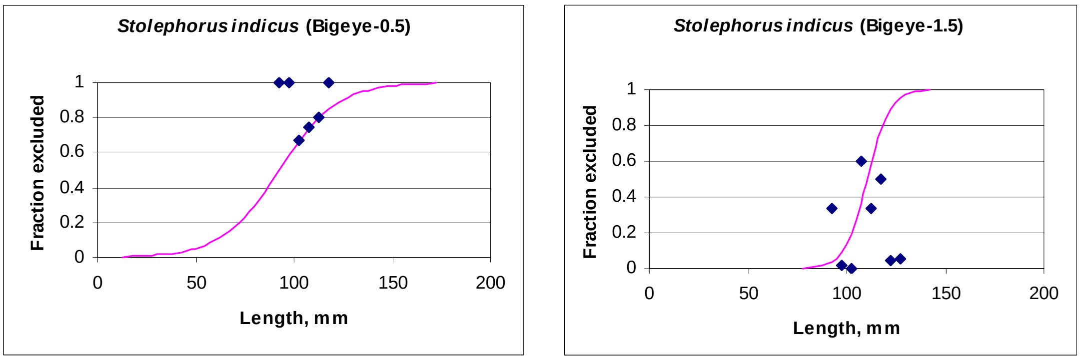


Fig. 5.7 Selectivity curves for *Stolephorus indicus*

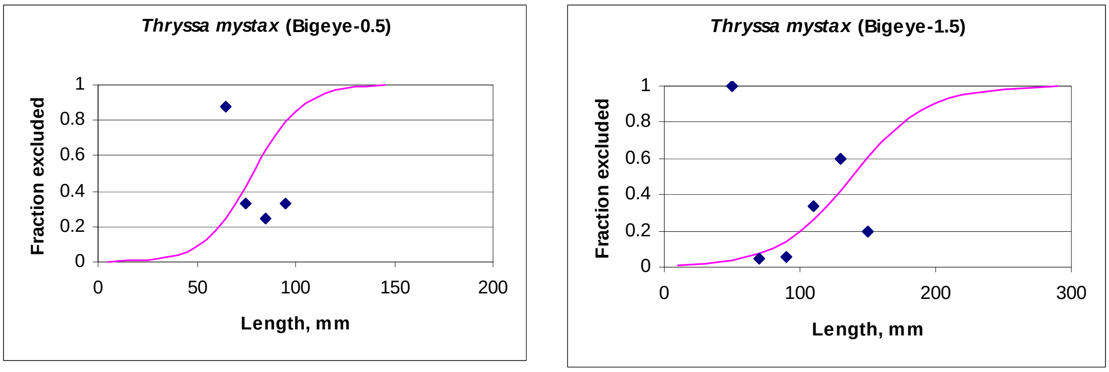


Fig. 5.8 Selectivity curves for *Thryssa mystax*

Length wise exclusion characteristics of selected trawl caught species namely *Anadontostoma chacunda, Megalaspis cordyla, Metapenaeus dobsoni, Sardinella longiceps, Stolephorus indicus* and *Thryssa mystax* in Bigeye installed trawl operations are given in Fig. 5.9 to 5.14. In Bigeye-0.5, length classes from 81 to 100 mm and from 121 to 140 mm of *Anadontostoma chacunda* was 100% retained and length classes from 101 to 120 mm showed exclusion up to 16%. In the case of Bigeye-1.5, 91-95 mm length class of *Anadontostoma chacunda* showed 100% retention and length classes from 96 to 130 mm showed exclusion in the range of 15-40%. In Bigeye-1.5 BRD, length classes of *Megalaspis cordyla* from 81 to 160 mm showed retention in the range of 25-80% while length classes from 161 to 220 mm was completely excluded. In both Bigeye BRDs, length classes of

Metapenaeus dobsoni from 51 to 100 mm showed retention in the range of 85 to 100%. In Bigeye-0.5, length classes from 61 to 80 mm of *Sardinella longiceps* showed exclusion in the range of 25 to 60% and length classes from 81 to 210 mm there was an increasing trend in retention ranging from 5 to 100%. In Bigeye-0.5, length classes of *Stolephorus indicus* from 91 to 100 mm was 100% excluded and length classes from 101 to 115 mm showed retention ranging from 20 to 35%. In Bigeye-1.5, length classes of *Thryssa mystax* from 61 to 160 mm showed exclusion rates in the range of 5 to 60%.

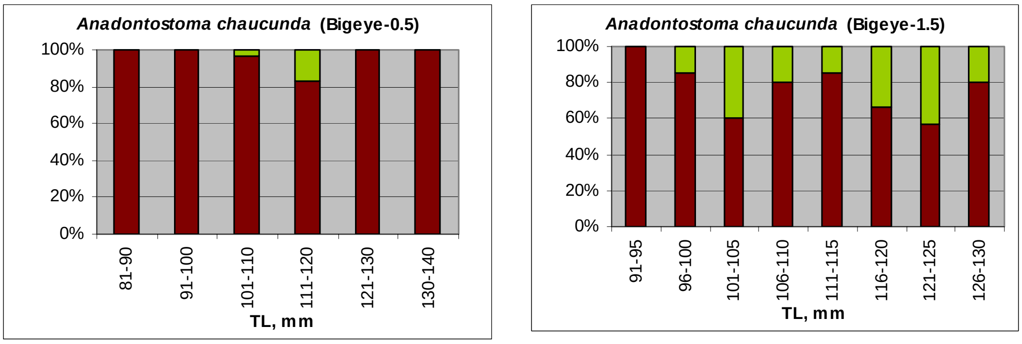


Fig.5.9 Length-wise retention and exclusion of *Anadontostoma chacunda*

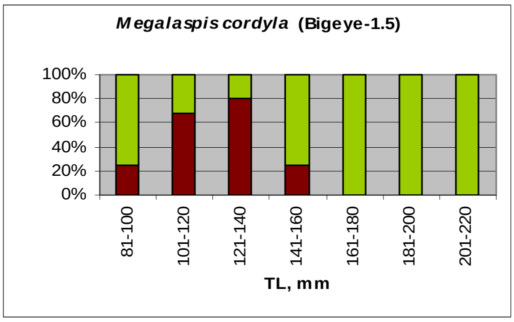


Fig.5.10 Length-wise retention and exclusion of *Megalaspis cordyla*

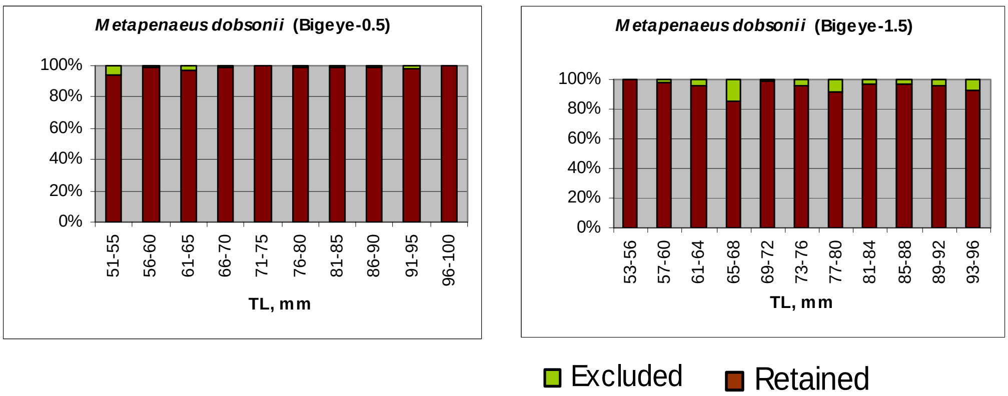


Fig.5.11 Length-wise retention and exclusion of *Metapenaeus dobsoni*

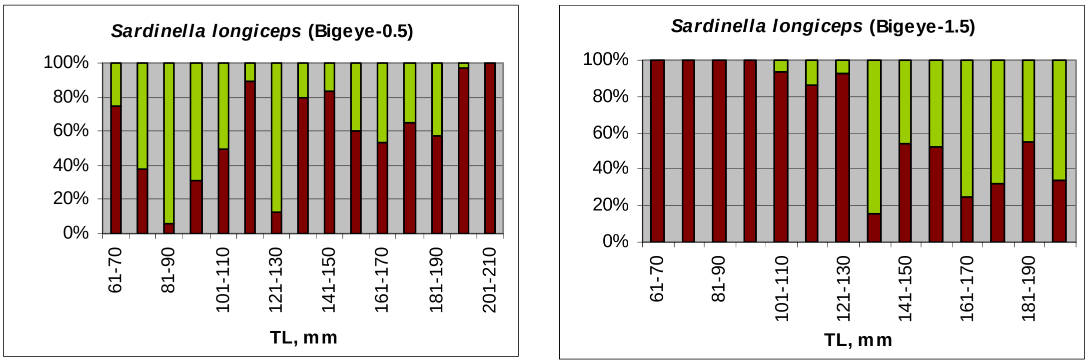


Fig.5.12 Length-wise retention and exclusion of *Sardinella longiceps*

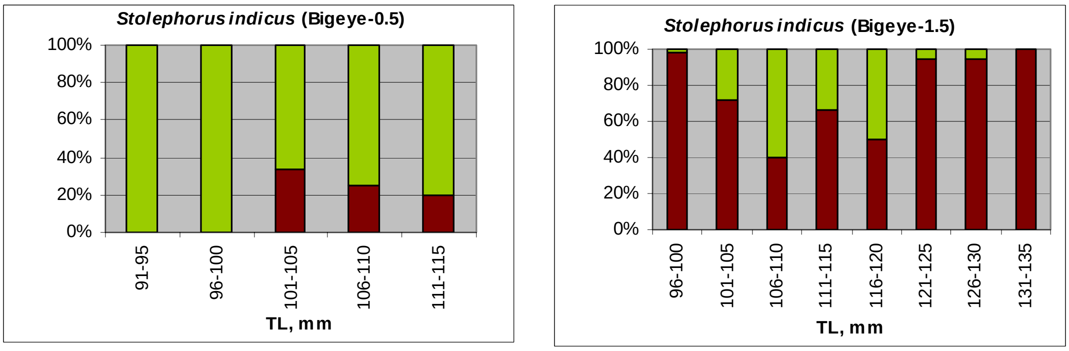


Fig.5.13 Length-wise retention and exclusion of *Stolephorus indicus*

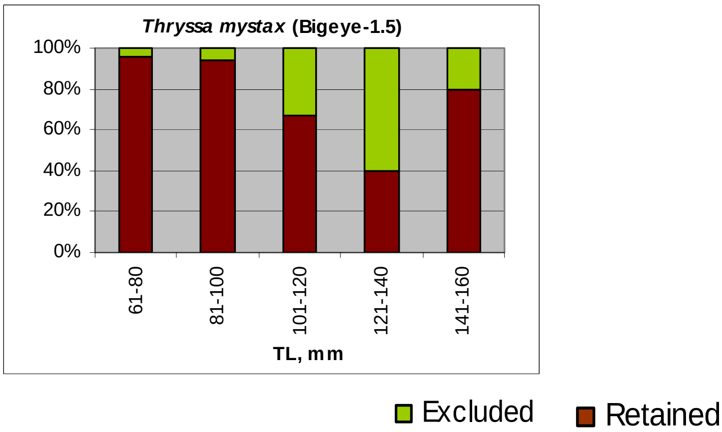


Fig.5.14 Length-wise retention and exclusion of *Thryssa mystax*

5.3.5 Catch diversity analysis

The results of diversity analysis has shown that the catch excluded from the Bigeye-1.5 was more diverse in terms of S, d, J', H, H' and N1. Higher dominance was also observed in the Bigeye-1.5 in terms of Simpson's dominance index (λ') as more than 80% of the total number of species was represented by only 3 species *viz*, *Stolephorus waiteii, Stolephorus commersonii* and *Sardinella longiceps.* Diversity parameters and the k-dominance curve for the Bigeye BRDs are given in Table 5.6 and Fig. 5.15, respectively.

The cumulative ranked abundances of the species obtained from the k-dominance curve when plotted against the species rank, the curve for Bigeye-1.5 was observed to begin lower than Bigeye-0.5, indicating higher diversity in the catch excluded from the Bigeye-1.5.

Table 5.6 Mean diversity indices of species excluded from Bigeye BRDs

Bigeye BRD	S	d	J'	H	H'	N1	λ'	$E_{1/D}$
Bigeye-0.5	17	4.26	0.62	1.44	1.74	5.72	**0.22**	0.27
Bigeye-1.5	**38**	**7.46**	**0.62**	**2.04**	**2.25**	**9.46**	0.14	**0.19**

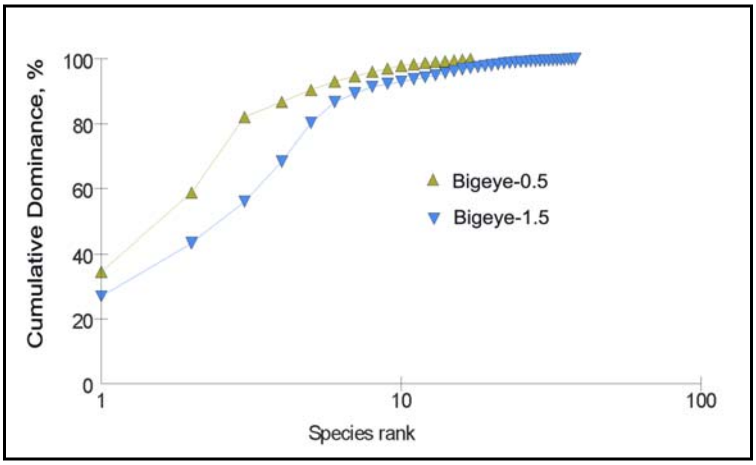


Fig. 5.15 k-dominance plot of Bigeye BRDs

5.4. Conclusion

Experiments with two designs of Bigeye BRDs (Bigeye-0.5 and Bigeye-1.5) in the seas off Cochin have given bycatch exclusion rates ranging from 8 to 11% and shrimp loss ranging from 1 to 2%. Among the two Bigeye BRDs evaluated Bigeye-1.5 performed comparatively better in terms of bycatch exclusion. Exclusion in excess of 50% was observed in the case of 11 species in respect of Bigeye-1.5 while no species was excluded above 50% through Bigeye-0.5. Species excluded from Bigeye-1.5 was observed to be more diverse compared to Bigeye-0.5. Selectivity results has indicated comparatively better exclusion of juveniles from Bigeye-0.5 than the Bigeye-1.5 BRD. Difference in performance between the two Bigeye BRDs in terms of exclusion rates was not found to be statistically significant ($p>0.05$).

The performance of the Bigeye BRDs in terms of shrimp retention was favourable as it was more than 97%. Major advantages of the Bigeye BRD is that it is very simple in design and can be easily fabricated and installed. Bigeye BRD is very simple in design, very easy to fabricate according to the need, low cost. Considering these advantages, Bigeye BRD positioned at 1.5 m from the distal end of the codend has the potential for adoption by the shrimp trawling industry in India to reduce finfish bycatch from shrimp trawls.

Chapter 6

Comparative Evaluation of Bigeye and Fisheye BRDs

6.1 Introduction

Bigeye BRD consists of a simple horizontal slit in the upper part of codend or hind belly, where the opening is maintained by floats and sinkers. The Bigeye BRD is very simple in design and can be easily incorporated in an existing commercial trawl. Size of the slit can be easily adjusted according to the size of the animals, which need to be excluded (Robins *et al.,* 1999; Anon, 2004b). Fisheye is an important bycatch reduction device facilitating the escapement of fish especially those which are undersized, from the codend (Pillai, 1998; Pillai *et al.,* 2004; Brewer *et al.,* 1998). It consists of an oval shaped rigid structure with 8-15 cm height and 30-40 cm width with supporting frames and made of stainless steel rods of 8 mm diameter. Both the BRDs functions similar operational principles. Differences in the behaviour of fish and shrimp are utilized in the design of these categories of BRDs. Fast swimming fishes that has entered the codend has an opportunity to swim back and escape through the exit opening provided on topside of the codend or hind belly, while shrimps are retained in the codend.

In the previous experiments, Bigeye BRDs positioned at two different locations in the codend were evaluated to study their efficiency in terms of bycatch exclusion and shrimp retention characteristics. In this study, an attempt has been made to evaluate the comparative performance of Bigeye

BRD and semicircular Fisheye BRD with 300x200 mm semicircular exit and horizontal orientation, positioned at 1.5 m from the distal end of the codend.

6.2 Materials and Methods

Bigeye BRD (Bigeye) and Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation (Fisheye), positioned at 1.5 m from the distal end of the codend were used for comparative performance evaluation. Design and construction details of Bigeye BRD are described in Chapter section 2.1.2 Semicircular Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation was used for the comparative analysis with Bigeye BRD. The Fisheye BRD was constructed with 6 mm dia stainless steel rods (Fig. 6.1). The BRDs were fitted on the topside of the trawl codend at a distance of 1.5 m (75 meshes) from the rear end of the codend. Ten paired hauls were undertaken, during November 2006, off Cochin, using a 28.8 m shrimp trawl installed with BRD. A small meshed cover codend was provided around the exit opening of BRDs, in order to retain the excluded catch for analysis.

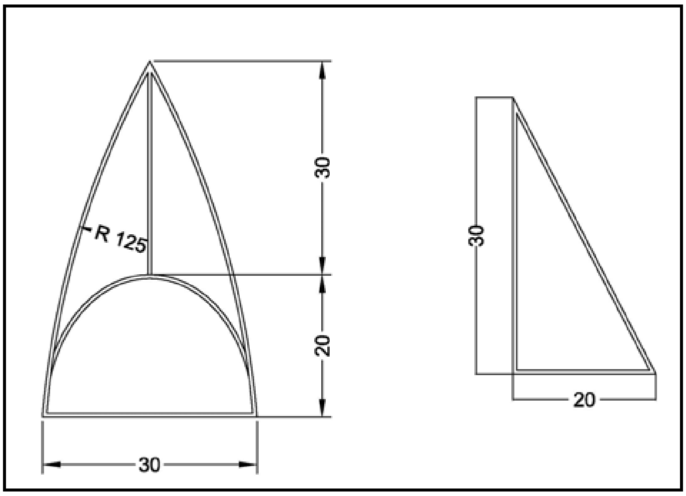


Fig. 6.1 Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation

6.3 Results and Discussion

The results of comparative field trials conducted using Bigeye and Fisheye BRDs, off Cochin, during November 2006, are presented in Tables 6.1 to 6.4. Scenes from field trials are represented in Fig 6.2 to 6.3.

Table 6.1: Results of comparative evaluation of Bigeye and Fisheye

	Bigeye	Fisheye
No. of hauls	10	10
Total catch (kg)	234.76	223.23
CPUE ($kg.h^{-1}$)	22.90	21.78
Retained catch (kg)	163.02	93.70
Retained catch (%)	69.44	41.97
Excluded catch (kg)	71.72	129.53
Excluded catch (%)	30.56	58.03
Retained shrimp catch (kg)	13.95	16.94
Retained shrimp catch (%)	98.73	96.21
Excluded shrimp catch (kg)	0.60	0.67
Excluded shrimp catch (%)	4.25	3.79
Retained bycatch (catch other than shrimps) (kg)	149.07	76.77
Retained bycatch (catch other than shrimps) (%)	67.46	37.33
Excluded bycatch (catch other than shrimps) (kg)	71.65	128.86
Excluded bycatch (catch other than shrimps) (%)	32.54	62.67
No. of species caught	69	72
Fish species	56	56
Shrimp species	6	6
Other species	7	10
100% exclusion (No. of species)	10	11
>50% exclusion (No. of species)	5	17
Up to 50% exclusion (No. of species)	36	20
0% exclusion (No. of species)	18	24

Table 6.2: Group-wise exclusion rate through Bigeye and Fisheye BRDs

BRD type	Species groups	Encountered catch, kg	Retained catch, %	Excluded catch, %
Bigeye	**All species**	**234.76**	**69.44**	**30.56**
	Finfishes	195.59	63.92	36.08
	Shrimps	14.13	95.75	4.25
	Crabs	0.33	100.00	0.00
	Cephalopods	1.40	92.86	7.14
	Miscellaneous	23.31	99.66	0.34
Fisheye	**All species**	**223.23**	**41.97**	**58.03**
	Fin fishs	189.22	31.96	68.04
	Shrimps	17.60	96.21	3.79
	Crabs	0.42	100.00	0.00
	Cephalopods	0.15	10.34	89.66
	Miscellaneous	15.85	100.00	0.00

6.3.1 Performance of Bigeye BRD

The total catch obtained during Bigeye installed operations was 234.76 kg with an average CPUE of 22.90 $kg.h^{-1}$ of which 69.44% was retained in the codend and 30.56% was excluded. The overall catch during this period consisted of 56 species of finfishes, 6 species of shrimps, 2 species of cephalopods, 2 species of crabs, 2 species of molluscan shells and 1 species of stomatopod. Bycatch (catch other than shrimp) exclusion through this BRD was 32.54% and shrimp loss was 4.25% (Table 6.1).

Among the species excluded through the Bigeye BRD, ten species of finfishes *viz*., *Arius jella, Caranx sexfasciatus, Esculosa thoracata, Selar crumenophthalmus, Valamugil speigleri, Gerres limbatus, Thryssa malabarica, Apogon fasciatus, Ilisha filigera,* and *Gerres filamentosus* showed 100% exclusion; five species of finfishes *viz., Megalaspis cordyla, Valamugil cunnesius, Johnius carutta, Alepes kleinii* and *Rastrelliger kanagurta* showed more than 50% exclusion and 36 species showed exclusion up to 50% (Table 6.3). Out of a total of 69 species, 18 species *viz., Secutor insidiator, Sillago sihama, Sphyraena jello, Thryssa malabarica, Thryssa setirostris, Thryssa dussumieri, Cynoglossus arel, Cynoglossus dubius, Eleutheronema tetradactylum, Fenneropenaeus indicus, Metapenaeus monoceros, Penaeus monodon, Uroteuthis duvauceli, Libinia emarginata, Charybdis natator, Tonna dolium, Turitella attenuate* and *Oratosquilla nepa* did not show any exclusion through the Bigeye.

Among the species groups encountered, finfishes showed an overall exclusion of 36.08%, followed by cephalopods (7.14%), shrimps (4.25%) and miscellaneous species (0.34%).

Table 6.3: Species- wise exclusion rate in Bigeye

Species	Encountered catch, (kg)	Retained catch, %	Excluded catch, %
Selar crumenophthalmus	0.19	0.00	100.00
Arius jella	0.15	0.00	100.00
Caranx sexfasciatus	0.10	0.00	100.00
Gerres filamentosus	0.05	0.00	100.00
Ilisha filigera	0.03	0.00	100.00
Valamugil speigleri	0.02	0.00	100.00
Gerres limbatus	0.02	0.00	100.00
Thryssa malabarica	0.02	0.00	100.00
Esculosa thoracata	0.01	0.00	100.00
Apogon fasciatus	0.01	0.00	100.00
Megalaspis cordyla	2.98	5.04	94.96
Valamugil cunnesius	1.18	7.63	92.37
Johnius carutta	0.56	19.64	80.36

Alepes kleinii	0.87	32.18	67.82
Rastrelliger kanagurta	3.09	40.29	59.71
Johnius amblycephalus	1.20	50.00	50.00
Congresox talabonoides	0.10	50.00	50.00
Sardinella longiceps	97.87	50.77	49.23
Alepes djedaba	0.49	56.12	43.88
Mugil cephalus	0.71	56.34	43.66
Johnius carouna	2.58	57.75	42.25
Anadontostoma chacunda	0.42	57.83	42.17
Epinepheleus diacanthus	0.19	57.89	42.11
Johnius dussumieri.	2.50	58.12	41.88
Ambassis ambassis	19.83	65.20	34.80
Nibea maculata	0.03	68.75	31.25
Kathala axillaris	8.70	74.71	25.29
Opisthopterus tardoore	0.13	76.92	23.08
Thryssa mystax	0.75	81.33	18.67
Metapenaeus affinis	0.50	84.00	16.00
Stolephorus commersonnii	0.49	85.71	14.29
Parastromateus niger	0.30	86.67	13.33
Leiognathus brevirostris	0.08	86.67	13.33
Pellona ditchella	3.43	87.32	12.68
Secutor ruconius	0.16	87.50	12.50
Gerres oyena	0.08	87.50	12.50
Leiognathus splendens	3.03	89.59	10.41
Stolephorus indicus	0.82	90.85	9.15
Stolephorus waiteii	1.80	91.92	8.08
Parapenaeopsis stylifera	2.42	92.13	7.87
Sepiella inermis	1.30	92.31	7.69
Metapenaeus dobsoni	11.51	93.22	6.78
Lactarius lactarius	1.51	93.38	6.62
Pomadasys maculatus	0.27	94.34	5.66
Pampus argenteus	11.68	96.36	3.64
Leiognathus dussumieri	0.17	96.97	3.03

Johnius borneensis	8.95	97.21	2.79
Leiognathus equulus	1.16	97.84	2.16
Cynoglossus macrostomus	0.66	98.47	1.53
Lepturacanthus savala	13.93	98.56	1.44
Otolithes cuveiri	1.42	98.94	1.06
Miscellaneous species	24.41	100.00	0.00
All species	**234.76**	**69.44**	**30.56**

6.3.2 Performance of Fisheye BRD

The total catch obtained during Fisheye installed operations was 223.23 kg with an average CPUE of 21.78 kg.h^{-1} of which 41.97% was retained in the codend and 58.03% was excluded. Overall catch during the operations consisted of 56 species of finfishes, 6 species of shrimps, 5 species of crabs, 2 species of cephalopods, 2 species of molluscan shells and 1 species of stomatopod. Bycatch (catch other than shrimp) exclusion from the Fisheye was 62.67% and shrimp loss was 3.79% (Table 6.1).

Among the species excluded through Fisheye BRD, ten finfish species *viz., Decapterus russeli, Dasciana albida, Anadontostoma chacunda, Pampus chinenesis, Megalaspis cordyla, Thryssa purava, Johnius amblycephalus,, Parastromateus niger, Sillago sihama, Caranx sexfasciatus* and 1 species of cephalopod (*Sepiella inermis*) showed 100% exclusion. Seventeen species *viz., Rastrelliger kanagurta, Selar crumenophthalmus, Alepes kleinii, Gerres erythrourus, Sardinella longiceps, Alepes djedaba, Johnius dussumieri, Ambassis ambassis, Valamugil cunnesius, Otolithes ruber, Nibea maculata, Johnius carouna, Pomadasys maculates, Secutor insidiator, Leiognathus brevirostris, Kathala axillaris* and

Uroteuthis duvauceli showed more than 50% exclusion through the Fisheye. Twenty species showed exclusion up to 50%. Out of a total of 72 species, 24 species *viz., Otolithes cuveiri, Thryssa malabarica, Cynoglossus arel, Sillago sihama, Epinepheleus diacanthus, Cynoglossus dubius, Terapon theraps, Valamugil speigleri, Acetus indicus, Scylla serrata, Gerres filamentosus, Congresox talabonoides, Filimanus heptadactylus, Apogon fasciatus, Metapenaeus affinis, Metapenaeus monoceros, Penaeus semisulcatus, Charybdis feriatus, Charybdis lucifera, Portunus sanguinolentus, Libinia emarginata, Ficus gracilis, Turitella attenuata* and *Oratosquilla nepa* did not show any exclusion through Fisheye.

Among the species groups encountered cephalopods showed an overall exclusion of 89.66%, followed by finfishes (68.04%) and shrimps (3.79%).

Table 6.6: Species wise catch retention and escape from semi circular Fishe eye BRD

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
Megalaspis cordyla	1.65	0.00	100.00
Caranx sexfasciatus	0.44	0.00	100.00
Decapterus russeli	0.29	0.00	100.00
Dasciana albida	0.25	0.00	100.00
Anadontostoma chacunda	0.18	0.00	100.00
Johnius amblycephalus	0.13	0.00	100.00
Sepiella inermis	0.10	0.00	100.00
Sillago sihama	0.08	0.00	100.00
Pampus chinenesis	0.03	0.00	100.00
Thryssa puruva	0.02	0.00	100.00
Parastromateus niger	0.01	0.00	100.00
Rastrelliger kanagurta	13.72	5.61	94.39

Selar crumenophthalmus	0.82	9.20	90.80
Alepes kleinii	3.03	9.90	90.10
Gerres erythrourus	0.09	16.67	83.33
Sardinella longiceps	73.42	17.56	82.44
Alepes djedaba	1.64	22.02	77.98
Johnius dussumieri.	1.25	24.00	76.00
Ambassis ambassis	43.63	24.36	75.64
Valamugil cunnesius	1.00	24.50	75.50
Otolithes ruber	0.65	30.77	69.23
Nibea maculata	0.12	33.33	66.67
Uroteuthis duvauceli	0.05	33.33	66.67
Johnius carouna	3.98	41.71	58.29
Pomadasys maculatus	0.07	42.86	57.14
Secutor insidiator	0.10	47.37	52.63
Leiognathus brevirostris	0.12	47.83	52.17
Kathala axillaris	9.27	49.57	50.43
Leiognathus dussumieri	0.08	53.33	46.67
Mugil cephalus	0.71	53.52	46.48
Pellona ditchella	3.17	56.15	43.85
Leiognathus equulus	0.46	69.23	30.77
Gerres oyena	0.13	69.23	30.77
Johnius borneensis	0.68	77.78	22.22
Pampus argenteus	5.80	79.74	20.26
Lepturacanthus savala	6.92	87.78	12.22
Stolephorus commersonnii	2.49	89.74	10.26
Leiognathus splendens	3.45	89.84	10.16
Thryssa mystax	0.56	91.96	8.04
Fenneropenaeus indicus	0.68	92.59	7.41
Secutor ruconius	0.38	93.33	6.67
Stolephorus indicus	0.70	94.24	5.76
Johnius carutta	1.01	95.02	4.98
Lactarius lactarius	1.13	95.13	4.87
Metapeneaeus dobsoni	13.36	95.45	4.55

Stolephorus waitei	1.70	95.59	4.41
Cynoglossus macrostomus	0.41	97.56	2.44
Parapenaeopsis stylifera	2.01	99.50	0.50
Miscellaneous species	21.41	100.00	0.00
All species	**223.23**	**41.97**	**58.03**

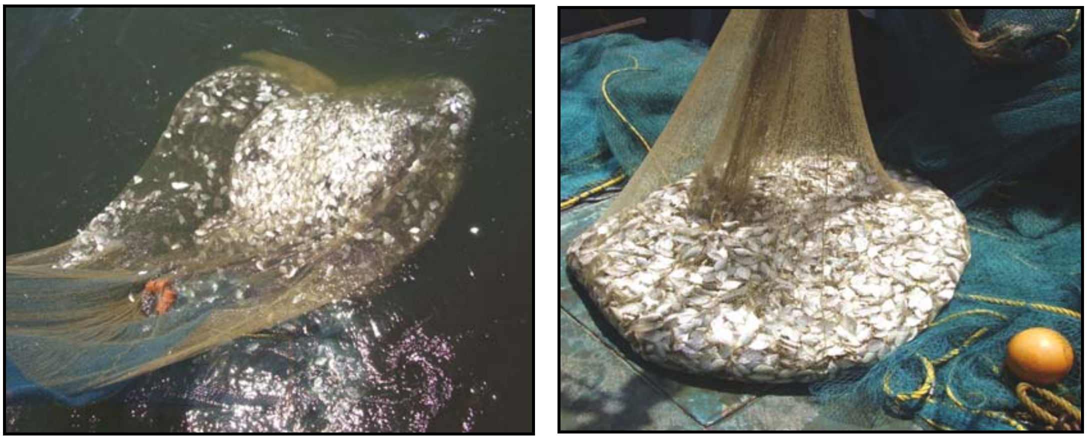


Fig 6.2 Scenes of excluded catch during field trials of Bigeye BRD

Fig 6.3 Scenes of excluded catch during field trials of Fisheye BRD

6.3.3 Statistical analysis

Statistical analysis using Student's *t*-test has shown that the difference in exclusion rates was significantly higher in Fisheye BRD, in respect of *Alepes kleinii* (P=0.021), *Johnius carouna* (P=0.049), *Lepturacanthus savala* (P=0.027), *Otolithes ruber* (P=0.040) and *Selar crumenophthalmus* (P=0.026).

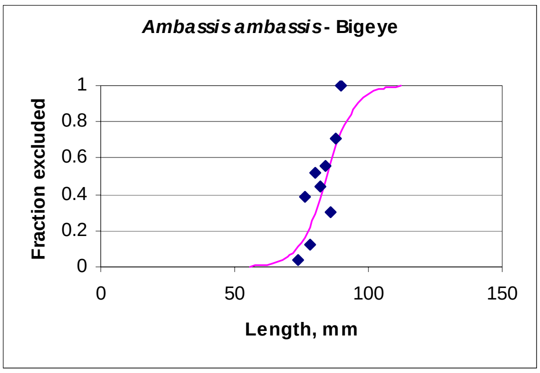
6.3.4 Selectivity analysis

The results of selectivity analysis of Bigeye and Fisheye BRD in respect of ten species *viz., Ambassis ambassis, Alepes djedaba, Alepes kleinii, Johnius borneensis, Johnius carouna, Johnuis dussumieri, Pellona ditchella, Sardinella longiceps* and *Stolephorus waiteii* are presented in Table 6.5 and in Fig. 6.4 to 6.9.

L_{50} values lower than length at first maturity (L_m) values indicate better exclusion opportunities for immature fishes below L_m, as the mid-length classes were plotted against excluded fractions in the selectivity estimates. In Bigeye BRD, L_{50} vlaues in respect of *Alepes djedaba, Alepes klieni, Johnius dussumieri* and *Sardinella longiceps* were lower than L_m values reported. In Fisheye BRD, L_{50} values in respect of *Alepes djedaba, Johnius borneensis, Johnius dussumieri* and *Pellona ditchella* were lower than L_m values reported. Comparatively better juvenile exclusion was indicated by the lower L_{50} values in respect of *Johnius carouna, Johnius borneensis, Johnius dussumieri, Pellona ditchella* and *Stolephorus waiteii* in Fisheye BRD and in respect of *Ambassis ambassis, Alepes djedaba, Alepes klieni,* and *Sardinella longiceps* in Bigeye.

Table 6.7: Selectivity parameters for Bigeye and Fisheye BRDs

Species	BRD type	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection Range, mm	Length at first maturity TL, mm
Ambassis ambassis	Bigeye	78.87	84.47	90.07	11.21	NA
	Fisheye	77.41	89.39	101.38	23.97	
Alepes djedaba	Bigeye	106.02	127.53	149.04	43.02	180-189 (Fishbase, 2008)
	Fisheye	139.01	159.51	180.01	40.99	
Alepes kleinii	Bigeye	91.71	97.35	103.00	11.29	129 (Fishbase, 2008)
	Fisheye	126.31	137.42	148.53	22.22	
Johnius carouna	Bigeye	126.04	151.98	177.91	51.87	NA
	Fisheye	99.60	131.75	163.91	64.31	
Johnius borneensis	Bigeye	199.88	246.48	293.02	93.14	159 (Fishbase, 2008)
	Fisheye	130.38	149.68	168.99	38.62	
Johnius dussumieri	Bigeye	109.23	111.79	114.34	5.10	115 (Fishbase, 2008)
	Fisheye	97.41	106.00	114.58	17.17	
Pellona ditchella	Bigeye	123.32	143.14	162.97	39.65	135 (Fishbase, 2008)
	Fisheye	103.98	110.69	117.40	13.42	
Sardinella longiceps	Bigeye	92.22	110.88	129.53	37.31	150-162 (Fishbase, 2008)
	Fisheye	128.43	186.89	245.34	116.91	
Stolephorus waitei	Bigeye	90.44	105.37	120.30	29.86	81-84 (Fishbase, 2008)
	Fisheye	80.88	85.59	90.30	9.42	



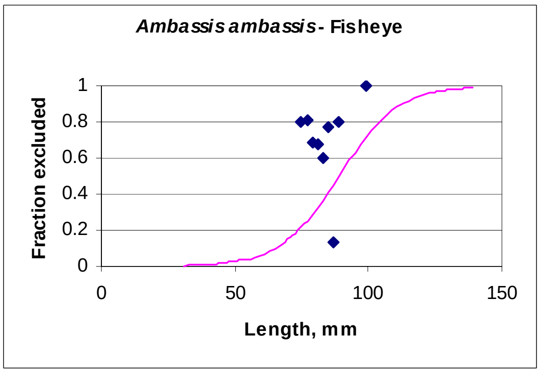


Fig. 6.4 Selectivity curves for *Ambassis ambassis*

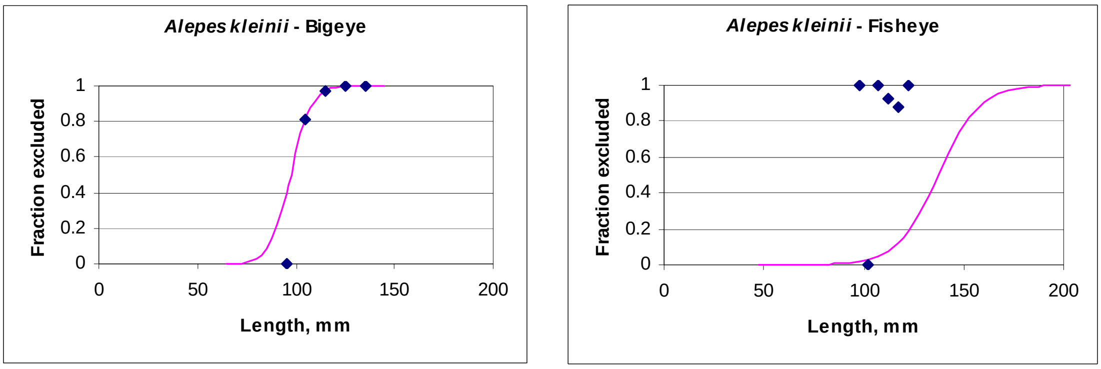


Fig. 6.5 Selectivity curves for *Alepes kleinii*

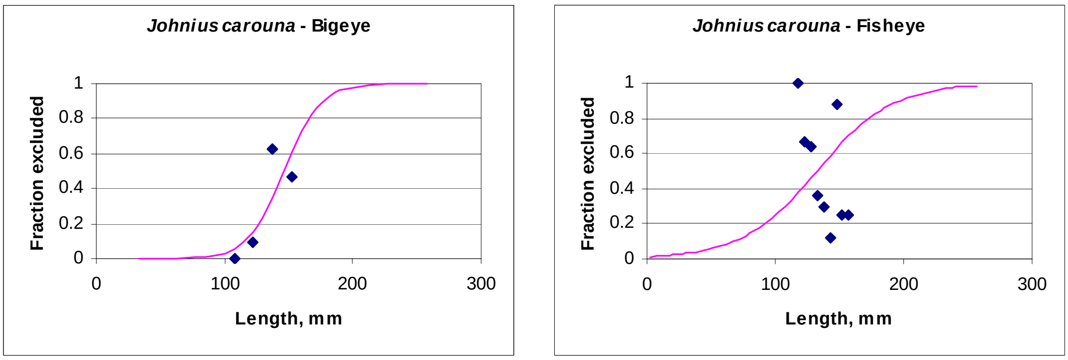


Fig. 6.6 Selectivity curves for *Johnius carouna*

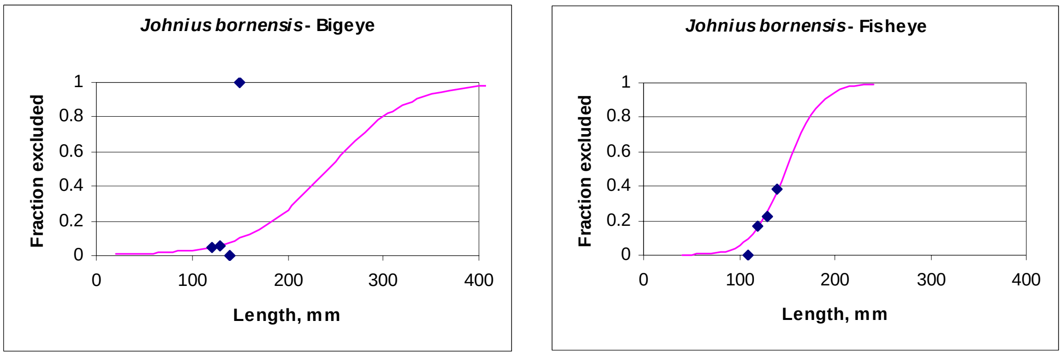


Fig. 6.7 Selectivity curves for *Johnius borneensis*

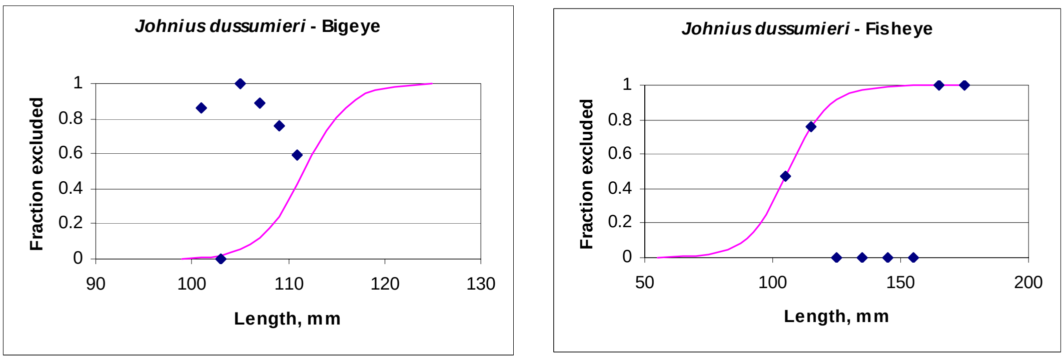


Fig. 6.8 Selectivity curves for *Johnius dussumieri*

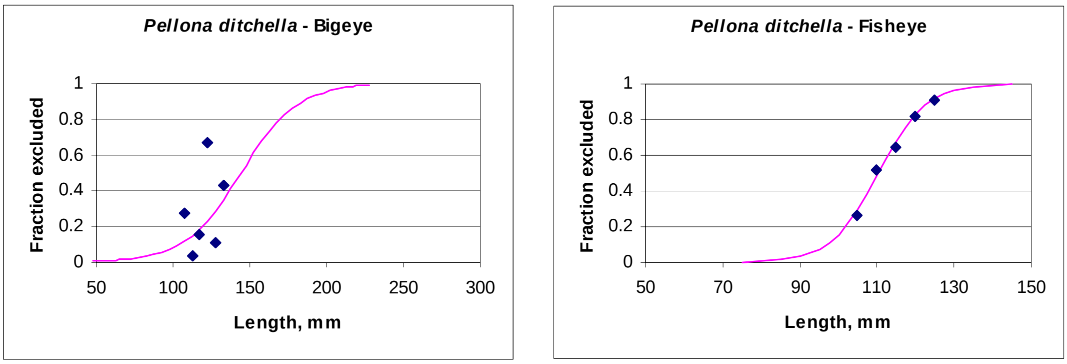


Fig. 6.9 Selectivity curves for *Pellona ditchella*

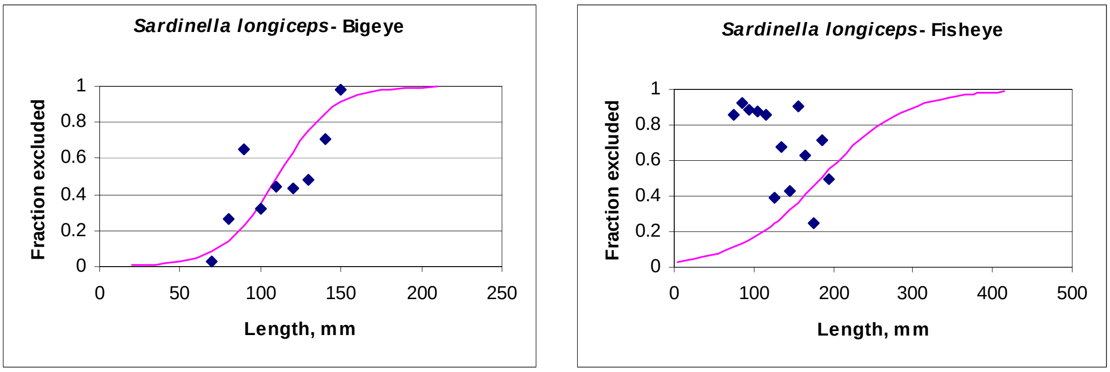


Fig. 6.10 Selectivity curves for *Sardinella longiceps*

Length-wise exclusion characteristics of different length classes of *Ambassis ambassis, Alepes kleinii, Johnius carouna, Pellona ditchella, Sardinella longiceps* and *Stolephorus waitei* are given in Fig.6.11 to 6.17.

In Bigeye, length classes of *Ambassis ambassis* from 74 to 91 mm showed an increasing trend in exclusion from 5 to 100%. Length classes from 73 to 92 mm of *Ambassis ambassis* in Fisheye also showed an increasing trend in exclusion from 35 to 85%. In Bigeye, 101-105 mm length class of *Alepes djedaba* showed 100% exclusion and length classes from 106 to 120 mm showed exclusion in the range of 60-78%. In Fisheye, 101-105 mm length class of *Alepes djedaba* was fully excluded, length classes from 106 to 125 mm showed exclusion rates above 85% and 126-130 mm length class showed 100% retention. In Bigeye, *Alepes kleinii* showed an increasing trend in exclusion (50 to 100%) in length classes from 81 to 140 mm. In Fisheye, length classes of *Alepes kleinii* from 76 to 105 mm was fully excluded and length classes from 106 to 125 mm was excluded at rates above 90%. In Bigeye, length classes from 71 to 115 mm of *Johnius carouna* was completely retained and length classes from 116 to 160 mm was excluded at rates ranging from 10 to 65%. In Fisheye, 116-120 mm length class of *Johnius carouna* was completely excluded and length classes from 121 to 165 mm showed exclusion rates ranging from 15 to 65%.

An increasing trend in the exclusion of length classes from 66 to 155 mm of *Sardinella longiceps* in the range of 4 to 100% was observed in Bigeye. In Fisheye, length classes from 71 to 200 mm of *Sardinella longiceps* showed exclusion rates in the range of 25 to 95%. In Bigeye, *Pellona ditchella* in length classes from 106 to 140 mm showed exclusion rates of 2 to 76% and 141-155 mm length class showed 100% retention. In Fisheye, length classes of *Pellona ditchella* from 106 to 130 mm showed an increasing trend in exclusion ranging from 27 to 90% and length classes from 131 to 150 mm showed 100% exclusion. In Bigeye, *Stolephorus waiteii* 71-72 mm length class showed 100% retention, length classes from 73 to 80 mm showed retention rates above 80% and length classes from 81 to 86 mm showed 100% exclusion. In Fisheye, 71-72 mm length class of *Stolephorus waiteii* was retained fully and length classes from 73 to 82 mm was excluded at a rate of 10 to 32%.

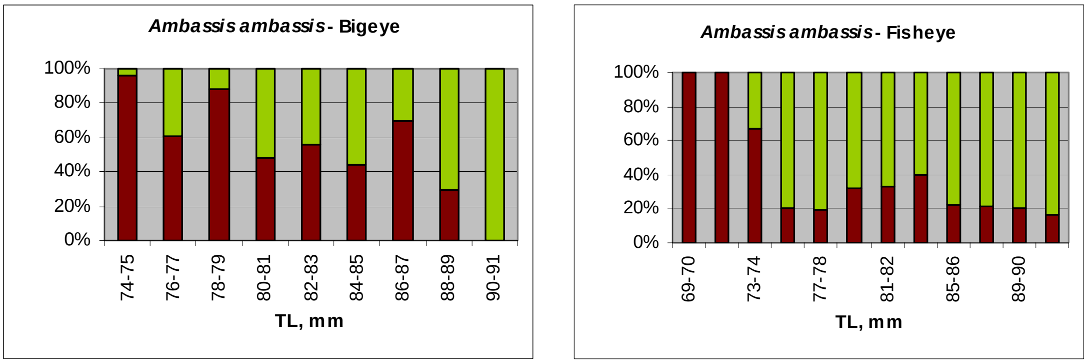


Fig. 6.11 Length-wise retention and exclusion of *Ambassis ambassis*

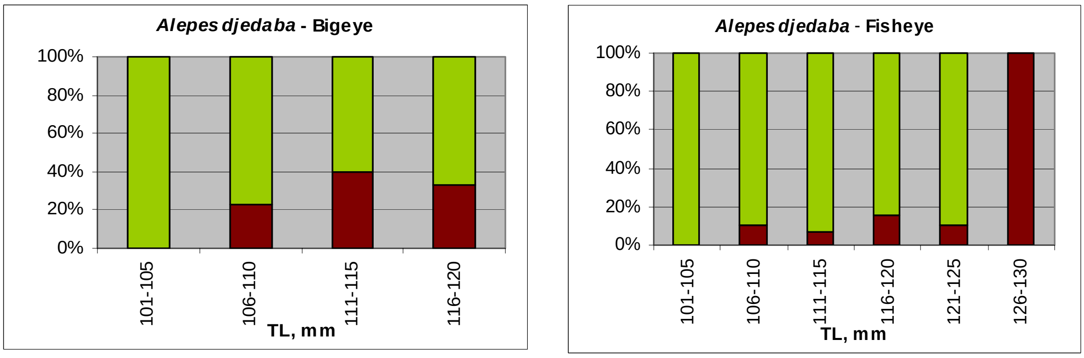


Fig. 6.12 Length-wise retention and exclusion of *Alepes djedaba*

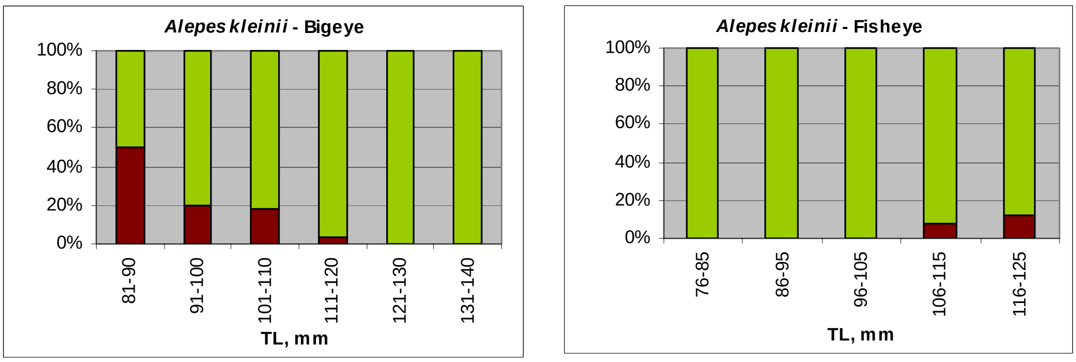


Fig. 6.13 Length-wise retention and exclusion of *Alepes kleinii*

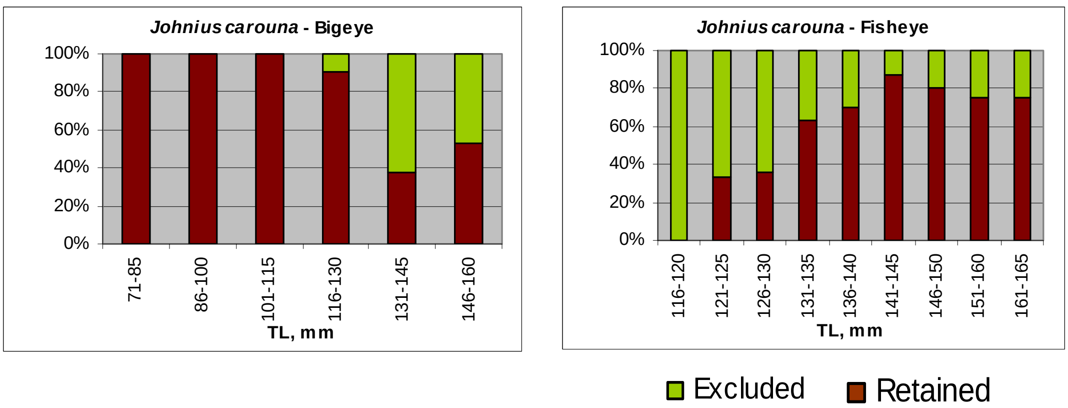


Fig. 6.14 Length-wise retention and exclusion of *Johnius carouna*

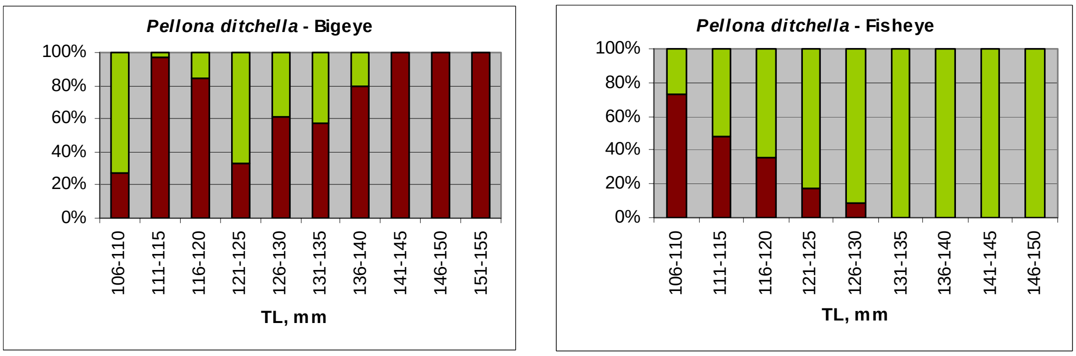


Fig. 6.15 Length-wise retention and exclusion of *Pellona ditchella*

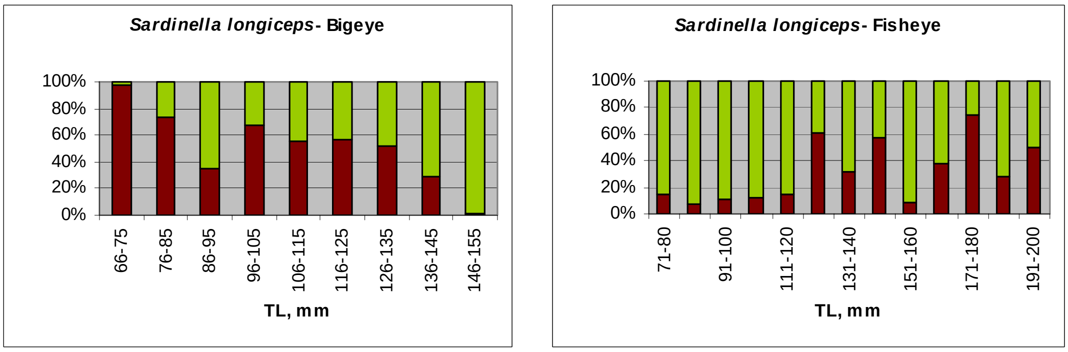


Fig. 6.16 Length-wise retention and exclusion of *Sardinella longiceps*

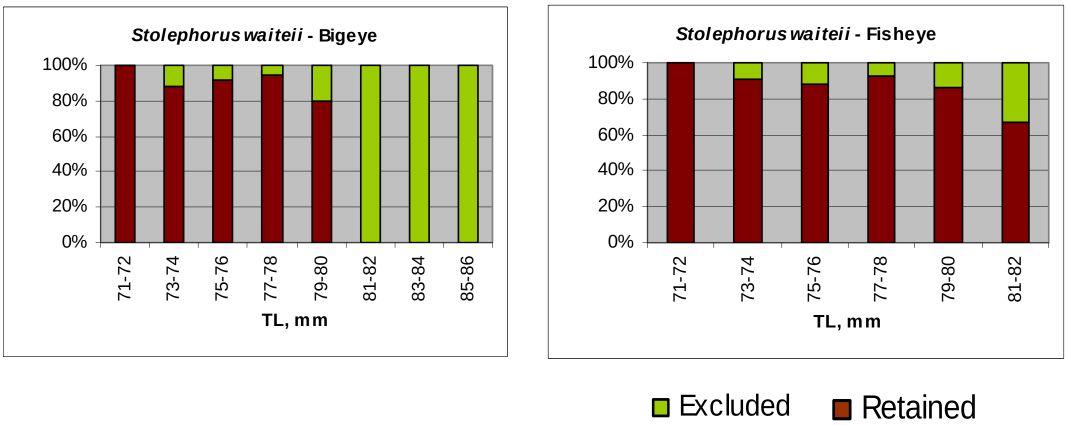


Fig. 6.17 Length-wise retention and exclusion of *Stolephorus waitei*

6.4 Catch Diversity Analysis

Diversity indices and k-dominance plot pertaining to excluded catch in respect of Bigeye and Fisheye BRDs are given in Table 6.8 and Fig. 6.16, respectively. The results of diversity analysis has shown that the catch excluded from the Bigeye was found to be more diverse in terms of S, d, J', H, H’ and N1. Higher dominance was also observed in the Bigeye-1.5 in terms of Simpson’s dominance index (λ')

The cumulative ranked abundances of species obtained from the k-dominance curve when plotted against the species rank, the curve is lying lower than that for Fisheye, indicating higher diversity of the catch excluded from Bigeye.

Table 6.8: Mean Diversity indices of species excluded through Bigeye and Fisheye BRD

BRDs	S	d	J'	H	H'	N1	λ'	$E_{1/D}$
Bigeye	46	**8.00**	**0.46**	**1.61**	**1.74**	**5.72**	0.32	**0.07**
Fisheye	**49**	7.08	0.37	1.38	1.44	4.21	**0.37**	0.06

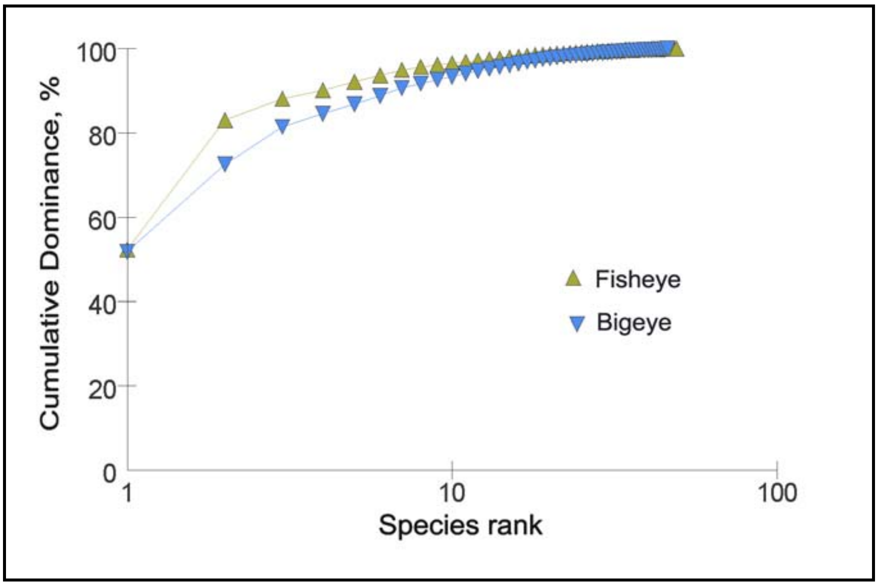


Fig. 6.17 k-dominance curve showing the diversity of catch excluded through Fisheye and Bigeye

6.5 Conclusion

During comparative field trials, the mean excluded bycatch was about 33% in the Bigeye BRD and 63% in the Fisheye BRD. Shrimp loss during the operations was about 4% in both Bigeye and Fisheye BRDs. Exclusion in excess of 50% was observed in the case 15 species in Bigeye and 28 species in the case of Fisheye. Excluded catch from Bigeye was found to be more diverse than Fisheye while selectivity results indicated comparatively better juvenile exclusion in Fisheye. Among the two BRDs evaluated, Fisheye BRD performed comparatively better in terms of bycatch exclusion while the performance of both the BRDs was almost similar in terms of shrimp retention. However, Bigeye BRD has the comparative advantage of being extremely simple in construction and installation. Bigeye BRD positioned at 1.5 m from the distal end of the codend is a cost effective solution for mitigating bycatch in the shrimp trawling industry in India.

Chapter 7

Sieve Net Bycatch Reduction Devices

7.1 Introduction

The Sieve net has a netting funnel inside the net to separate the target and non-target catch leading to an outlet codend which retain large sized bycatch components. According to Polet *et al*. (2004), sieve net is a large mesh funnel inside the net which guides the fish to a second codend with large diamond mesh netting, while shrimps pass through large meshes and accumulate in the main codend. Sieve nets (also known as veil nets) without outlet codend is used and made mandatory under EU legislation in European brown shrimp fisheries (CEFAS, 2003). Sieve net is used in commercial shrimp fleets of the Netherlands, UK, France, Germany, Denmark and Belgium (Polet *et al*., 2004). Sieve net is usually preferred by fishers to grids as it has less handling problems compared to grids and blockage is minimum due to larger sorting area (CEFAS, 2003).

Polet *et al*. (2004) made sieve net experiments in Belgium brown shrimp fishery using the commercial version of sieve net design. The funnel has a nominal mesh size of 70 mm and the outlet codend which has a mesh size of 80 mm provide escapement opportunity for juveniles, small fishes and invertebrates. Experiments using Sieve net in Belgium fishery has shown bycatch exclusion rates of 29-50% in different seasons, with less than 15% loss of shrimps. It is less effective in saving fishes less than 10 cm

(Polet *et al*., 2004). Four designs of Sieve nets were evaluated by Revill *et al.* (1999) in commercial shrimp (*Crangon crangon*) beam trawling. During this evaluation, Sieve net was found to be the most effective trawl modification which reduced discard levels of juvenile fish and shrimp. Sieve net reduced small shrimp (*Crangon crangon*) to the tune of 29% by weight and was recommended for mandatory use in beam trawls in UK (Revill *et al*., 1999; Revill and Holst, 2004). CEFAS (2003) reported the use of a cone shaped large mesh netting with bottom opening known as veil net, which is similar in operational principle to Sieve net. This device reduced the retention of juvenile fish and invertebrates in the trawls and CEFAS (2003) recommended this technology for use in other fisheries. Broadhurst and Kennelly (1996) evaluated the performance of a blubber-chute design similar to Sieve net in Clarence River prawn-trawl fishery and found it to be effective in reducing bycatch by more than 75%. Soft panel blubber chute is used by fishermen to exclude jellyfish from trawl.

7.2 Materials and Methods

Three design variations of Sieve net BRD were fabricated and evaluated through field trials. They included Sieve net (i) with a 60 mm diamond mesh funnel inside the net and 80 mm diamond mesh outlet codend (Sieve net-60 mm), (ii) with 40 mm square mesh funnel inside the net and 60 mm square mesh outlet codend (Sieve net-40 mm) and (iii) with 50 mm diamond funnel inside the net with 60 mm diamond mesh outlet codend (Sieve net-50 mm). The Sieve net BRDs installed in shrimp trawl nets of 32.4 m, 28.8 m head rope were operated during the periods from

September to December 2006 and March 2007. Details of materials and methods adopted for the study are described in Chapter section 2.1.3.

Fig. 7.1 Scenes from Sieve net BRD installed trawl operations, off Cochin

7.3 Results and discussion

Field trials were conducted using three designs of sieve nets *viz*., Sieve net-60 mm, Sieve net-40 mm and Sieve net-50 mm installed in shrimp trawls with 20 mm codend. Results are presented in Tables 7.1 to 7.4 and Tables 7.6 to 7.9.

7.3.1 Performance of Sieve net-60 mm

The first set of experiments consisted of 18 hauls, using 32.4 m shrimp trawl. A total catch of 244.4 kg with a CPUE of 13.3 kg.h^{-1} was obtained during the operations of which 56.6% was contributed by jellyfish. Out of the total catch of 244.4 kg, 28.52% was retained in the main codend, 57.25% in the 80 mm diamond mesh outlet codend and 14.23% was excluded. Jellyfish formed a dominant component of the trawl catch during the period of experimental operations. Out of total catch, 138.3 kg of jellyfish, 98.19% was diverted and retained in the outlet codend leading from the sieve net funnel and only 1.8% reached the main codend.

Analysis excluding jellyfish component in the catch, has shown that out of the total catch of 106.1 kg with a CPUE of 5.77 $kg.h^{-1}$, 63.33% of catch was retained in the main codend, 3.89% in the outlet codend and 32.78% was excluded through the large meshes of the outlet codend. The excluded bycatch (catch other than shrimps) from this BRD was 36.45% (mostly juveniles of fishes) of total catch and excluded shrimp catch was 4.47%. The overall catch during this period consisted of 47 species of finfishes, 5 species of shrimps, 2 species of crabs, 1 species of cephalopod, 2 species of elasmobranchs, 2 species of molluscan shells, 1 species of stomatopod and 1 species of jellyfish.

Among the species which excluded through the sieve net, 2 species of finfishes *viz., Mene maculata* and *Cynoglossus arel* showed 100% exclusion and 11 species *viz., Johnius carouna, Secutor insidiator, Pellona ditchella, Anadontostoma chacunda, Johnius dussumieri, Terapon theraps, Megalaspis cordyla, Otolithes ruber, Decapterus ruselli, Encrasicholina devisi* and *Sepiella inermis* showed exclusion above 50% (Table 7.2). Out of the total 61 species, 29 species showed exclusion up to 50% and 18 *species viz., Pampus argenteus, Caranx ignobilis, Congresox talabonoides,* *Cynoglossus dubius, Dussumieria acuta, Liza parsia, Scoliodon laticaudus, Sphyraena fosteri, Sphyraena obtusata*, *Stolephorus indicus, Terapon jarbua, Thryssa malabarica, Upeneus sulphurus, Valamugil speigleri Charybdis feriatus, Scylla serrata, Turritella attenuata* and *Narcine* sp. did not show any exclusion.

In the 80 mm outlet codend, 15 species were retained including 11 species of finfishes, 1 species of elasmobranch, 1 species of cephalopod, 1 species of crab and 1 species of jellyfish (*Rhopilemma* sp.). Four species *viz*., *Pampus argenteus, Caranx ignobilis, Charybdis feriatus* and 1 ray showed 100% retention in the outlet codend.

Target catch *viz., Parapenaeopsis stylifera* and *Metapenaeus dobsoni* were retained in main codend at the rate of 99.10% and 95.84%, respectively.

Table 7.1: Results of Sieve net-60 mm installed trawl operations

	Excluding jellyfish	Including jellyfish
No. of hauls	18	
Total catch (kg)	106.10	244.40
CPUE ($kg.h^{-1}$)	5.77	13.30
Retained catch in main codend (%)	63.33	28.52
Retained catch in outlet codend (%)	3.89	57.25
Excluded catch (%)	32.78	14.23
Total shrimp catch (kg)	12.17	12.17
Retained shrimp catch (%)	95.53	95.53
Excluded shrimp catch (%)	4.47	4.47
Bycatch (catch other than shrimps) (kg)	93.93	232.23
Retained bycatch (%)	63.55	85.26
Excluded bycatch (%)	36.45	14.74
Species encountered (No.)	60	61

Fish species (No.)	47	47
Shrimp species (No.)	5	5
Other species (No.)	7	8
100% exclusion (No.)	2	2
>50% exclusion (No.)	12	12
Up to 50% exclusion (No.)	28	29
0% exclusion (No.)	18	18

Table 7.2: Species-wise catch distribution in main codend, outlet codend and cover in Sieve net-60 mm BRD

Species	**Encountered catch, kg**	**Main codend, %**	**Outlet codend, %**	**Outlet codend cover, %**
Alepes djedaba	4.24	64.94	0.24	34.83
Alepes kleinii	2.78	58.20	0.00	41.80
Ambassis ambassis	35.00	56.29	0.14	43.57
Anadara granosa	0.21	97.09	0.00	2.91
Anadontostoma chacunda	0.26	38.46	0.00	61.54
Caranx ignobilis	0.04	0.00	100.00	0.00
Charybdis feriatus	0.04	100.00	0.00	0.00
Congresox talabonoides	0.02	100.00	0.00	0.00
Cynoglossus arel	0.04	0.00	0.00	100.00
Cynoglossus dubius	0.20	100.00	0.00	0.00
Cynoglossus macrostomus	1.23	95.93	0.00	4.07
Decapterus russeli	0.06	45.45	0.00	54.55
Dussumieria acuta	0.01	100.00	0.00	0.00
Encrasicholina devisi	0.38	46.05	2.63	51.32
Esculosa thoracata	0.02	50.00	0.00	50.00
Fenneropenaeus indicus	0.57	38.60	12.28	49.12
Ilisha filigera	0.32	73.44	6.25	20.31
Jellyfish (*Rhopilema* spp.)	138.30	1.81	98.19	0.00
Johnius borneensis	0.55	61.47	0.00	38.53
Johnius carouna	4.90	24.31	0.00	75.69
Johnius carutta	1.95	64.60	0.52	34.88
Johnius dussumieri	0.25	40.00	0.00	60.00
Kathala axilaris	0.17	70.59	0.00	29.41
Lactarius lactarius	2.89	56.40	0.00	43.60
Leiognathus brevirostris	0.02	66.67	0.00	33.33

Leiognathus equulus	0.13	64.00	0.00	36.00
Leiognathus splendens	11.46	86.08	2.44	11.48
Lepturacanthus savala	9.78	59.82	2.76	37.42
Liza parsia	0.03	100.00	0.00	0.00
Megalaspis cordyla	2.87	43.98	0.00	56.02
Mene maculata	0.01	0.00	0.00	100.00
Metapenaeus affinis	0.19	92.11	0.00	7.89
Metapenaeus dobsoni	4.50	95.84	0.00	4.16
Narcine sp.	0.80	0.00	100.00	0.00
Otolithes ruber	1.29	45.14	0.00	54.86
Pampus argenteus	1.68	0.00	100.00	0.00
Parapenaeopsis stylifera	6.91	99.10	0.00	0.90
Pelates quadrilineatus	0.03	50.00	0.00	50.00
Pellona ditchella	0.36	33.33	0.00	66.67
Penaeus monodon	0.19	84.21	0.00	15.79
Rastrelliger kanagurta	0.41	51.22	0.00	48.78
Sardinella longiceps	5.02	78.66	0.60	20.74
Scoliodon laticaudus	0.15	100.00	0.00	0.00
Scylla serrata	0.04	0.00	100.00	0.00
Secutor insidiator	0.32	28.57	12.70	58.73
Selar crumenophthalmus	0.04	62.50	0.00	37.50
Sepiella inermis	1.25	8.33	0.00	91.67
Sillago sihama	0.69	86.13	0.00	13.87
Sphyraena forsteri	0.03	100.00	0.00	0.00
Sphyraena obtusata	0.02	100.00	0.00	0.00
Stolephorus commersonnii	0.01	50.00	0.00	50.00
Stolephorus indicus	0.01	100.00	0.00	0.00
Stolephorus waitei	0.01	50.00	0.00	50.00
Terapon jarbua	0.02	100.00	0.00	0.00
Terapon theraps	0.05	40.00	0.00	60.00
Thryssa malabarica	0.02	100.00	0.00	0.00
Thryssa mystax	0.24	70.21	0.00	29.79
Trypouchen vagina	0.16	77.42	0.00	22.58
Turritella attenuata	1.24	100.00	0.00	0.00
Upeneus sulphurus	0.04	100.00	0.00	0.00
Valamugil speigleri	0.05	100.00	0.00	0.00
All species	**244.40**	**28.52**	**57.25**	**14.23**

Table 7.3: Species-wise exclusion rates through Sieve net-60 mm BRD

Species	Encountered catch, kg	Exclusion rate, %
Cynoglossus arel	0.04	100.00
Mene maculata	0.01	100.00
Sepiella inermis	1.25	91.67
Johnius carouna	4.90	75.69
Pellona ditchella	0.36	66.67
Anadontostoma chacunda	0.26	61.54
Johnius dussumieri	0.25	60.00
Terapon theraps	0.05	60.00
Secutor insidiator	0.32	58.73
Megalaspis cordyla	2.87	56.02
Otolithes ruber	1.29	54.86
Decapterus russeli	0.06	54.55
Encrasicholina devisi	0.38	51.32
Esculosa thoracata	0.02	50.00
Pelates quadrilineatus	0.03	50.00
Stolephorus commersonnii	0.01	50.00
Stolephorus waitei	0.01	50.00
Fenneropenaeus indicus	0.57	49.12
Rastrelliger kanagurta	0.41	48.78
Lactarius lactarius	2.89	43.60
Ambassis ambassis	35.00	43.57
Alepes kleinii	2.78	41.80
Johnius borneensis	0.55	38.53
Selar crumenophthalmus	0.04	37.50
Lepturacanthus savala	9.78	37.42
Leiognathus equulus	0.13	36.00
Johnius carutta	1.95	34.88
Alepes djedaba	4.24	34.83
Leiognathus brevirostris	0.02	33.33
Thryssa mystax	0.24	29.79
Kathala axilaris	0.17	29.41
Trypouchen vagina	0.16	22.58

Sardinella longiceps	5.02	20.74
Ilisha filigera	0.32	20.31
Penaeus monodon	0.19	15.79
Sillago sihama	0.69	13.87
Leiognathus splendens	11.46	11.48
Metapenaeus affinis	0.19	7.89
Metapenaeus dobsoni	4.50	4.16
Cynoglossus macrostomus	1.23	4.07
Anadara granosa	0.21	2.91
Parapenaeopsis stylifera	6.91	0.90
Caranx ignobilis	0.04	0.00
Charybdis feriatus	0.04	0.00
Congresox talabonoides	0.02	0.00
Cynoglossus dubius	0.20	0.00
Dussumieria acuta	0.01	0.00
Liza parsia	0.03	0.00
Narcine sp.	0.80	0.00
Pampus argenteus	1.68	0.00
Scoliodon laticaudus	0.15	0.00
Scylla serrata	0.04	0.00
Sphyraena forsteri	0.03	0.00
Sphyraena obtusata	0.02	0.00
Stolephorus indicus	0.01	0.00
Terapon jarbua	0.02	0.00
Thryssa malabarica	0.02	0.00
Turritella attenuata	1.24	0.00
Upeneus sulphurus	0.04	0.00
Valamugil speigleri	0.05	0.00
Jellyfish (*Rhopilema* sp.)	138.30	0.00
All species	**244.40**	**14.23**

Table 7.4: Sorting effect on trawl caught species in Sieve net-60 mm BRD

Species	**Retained catch, kg**	**Main codend retained catch, %**	**Outlet codend retained catch, %**
Turritella attenuata	1.24	100.00	0.00
Cynoglossus dubius	0.20	100.00	0.00
Scoliodon laticaudus	0.15	100.00	0.00
Valamugil speigleri	0.05	100.00	0.00
Charybdis feriatus	0.04	100.00	0.00
Upeneus sulphurus	0.04	100.00	0.00
Liza parsia	0.03	100.00	0.00
Sphyraena forsteri	0.03	100.00	0.00
Congresox talabonoides	0.02	100.00	0.00
Sphyraena obtusata	0.02	100.00	0.00
Terapon jarbua	0.02	100.00	0.00
Thryssa malabarica	0.02	100.00	0.00
Dussumieria acuta	0.01	100.00	0.00
Stolephorus indicus	0.01	100.00	0.00
Parapenaeopsis stylifera	6.91	99.10	0.90
Anadara granosa	0.21	97.09	2.91
Cynoglossus macrostomus	1.23	95.93	4.07
Metapenaeus dobsoni	4.50	95.84	4.16
Metapenaeus affinis	0.19	92.11	7.89
Sillago sihama	0.69	86.13	13.87
Leiognathus splendens	11.46	86.08	13.92
Penaeus monodon	0.19	84.21	15.79
Sardinella longiceps	5.02	78.66	21.34
Trypouchen vagina	0.16	77.42	22.58
Ilisha filigera	0.32	73.44	26.56
Kathala axilaris	0.17	70.59	29.41
Thryssa mystax	0.24	70.21	29.79
Leiognathus brevirostris	0.02	66.67	33.33
Alepes djedaba	4.24	64.94	35.06

Johnius carutta	1.95	64.27	35.73
Leiognathus equulus	0.13	64.00	36.00
Selar crumenophthalmus	0.04	62.50	37.50
Johnius borneensis	0.55	61.47	38.53
Lepturacanthus savala	9.78	59.82	40.18
Alepes kleinii	2.78	58.20	41.80
Lactarius lactarius	2.89	56.40	43.60
Ambassis ambassis	35.00	56.29	43.71
Rastrelliger kanagurta	0.41	51.22	48.78
Pelates quadrilineatus	0.03	50.00	50.00
Esculosa thoracata	0.02	50.00	50.00
Stolephorus commersonnii	0.01	50.00	50.00
Stolephorus waitei	0.01	50.00	50.00
Encrasicholina devisi	0.38	46.05	53.95
Decapterus russeli	0.06	45.45	54.55
Otolithes ruber	1.29	45.14	54.86
Megalaspis cordyla	2.87	43.98	56.02
Johnius dussumieri	0.25	40.00	60.00
Terapon theraps	0.05	40.00	60.00
Fenneropenaeus indicus	0.57	38.60	61.40
Anadontostoma chacunda	0.26	38.46	61.54
Pellona ditchella	0.36	33.33	66.67
Secutor insidiator	0.32	28.57	71.43
Johnius carouna	4.90	24.31	75.69
Sepiella inermis	1.25	3.20	96.80
Jellyfish (*Rhopilema* spp.)	138.30	1.81	98.19
Pampus argenteus	1.68	0.00	100.00
Narcine sp.	0.80	0.00	100.00
Caranx ignobilis	0.04	0.00	100.00
Cynoglossus arel	0.04	0.00	100.00
Scylla serrata	0.04	0.00	100.00
Mene maculata	0.01	0.00	100.00
All species	**244.40**	**71.48**	**28.52**

7.3.1.1 Statistical analysis

The Sieve net-60 mm installed trawl has shown significantly higher exclusion rates in terms of eleven bycatch species *viz*., *Alepes djedaba* (P=0.016), *Ambassis ambassis* (P=0.000), *Cynoglossus macrostomus* (P=0.008), *Johnius carouna* (P=0.007), *Johnius caroutta* (P=0.042), *Lactarius lactarius* (P=0.000), *Leiognathus splendens* (P=0.026), *Lepturacanthus savala* (P=0.000), *Megalaspis cordyla* (P=0.013), *Otolithes ruber* (P=0.042) and *Sardinella longiceps* (P=0.034) and in the exclusion rate of *Metapenaeus dobsoni* (P=0.002).

7.3.1.2 Selectivity studies

The results of selectivity analysis in respect of 8 species *viz*, *Alepes djedaba, Ambassis ambassis, Johnius carouna, Lactarius lactarius, Leiognathus splendens* and *Lepturacanthus savala* are given in Table 7.5 and Fig. 7.3 to 7.8.

Table 7.5: Selectivity parameters of Sieve net-60 mm BRD

Species	L_{25}	L_{50}	L_{75}	Selection Range, mm	Selection factor, mm	Length at first maturity TL, mm
Alepes djedaba	86.98	103.52	120.06	33.08	1.73	180-189 (Fishbase, 2008)
Ambassis ambassis	75.67	99.41	123.15	47.48	1.66	NA
Johnius carouna	91.75	110.49	129.23	37.48	1.84	NA
Lactarius lactarius	42.46	113.49	184.52	142.06	1.89	168 (Fishbase, 2008)
Leiognathus splendens	144.32	213.66	282.99	138.67	3.56	NA
Lepturacanthus savala	191.21	443.19	695.16	503.95	7.39	NA

L_{50} values lower than length at first maturity (L_m) values indicate better exclusion opportunities for immature fishes below L_m, as the mid-length classes were plotted against excluded fractions in the selectivity estimates. L_{50} values in respect of *Alepes djedaba* and *Lactarius lactarius* was lower than the L_m values reported indicating better juvenile exclusion through sieve net-60 mm BRD.

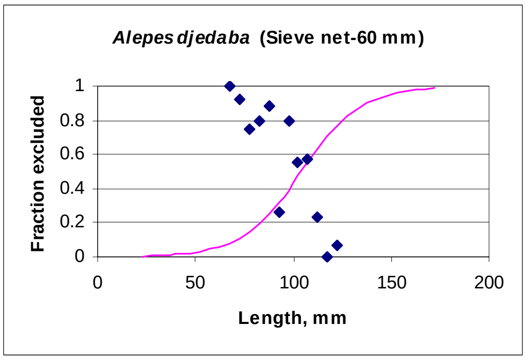


Fig 7.3 Selectivity curve for *Alepes djedaba*

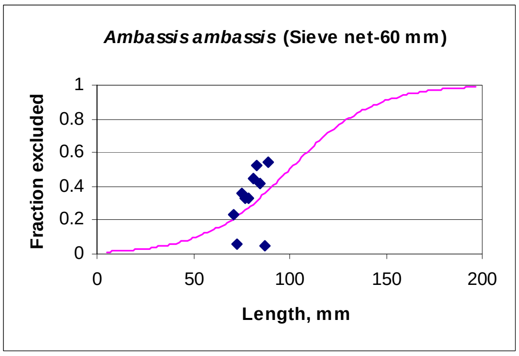


Fig 7.4 Selectivity curve for *Ambassis ambassis*

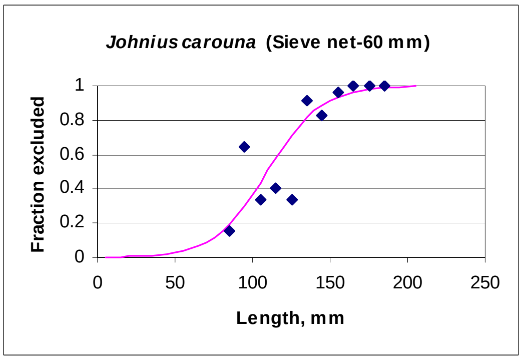


Fig 7.5 Selectivity curve for *Johnius carouna*

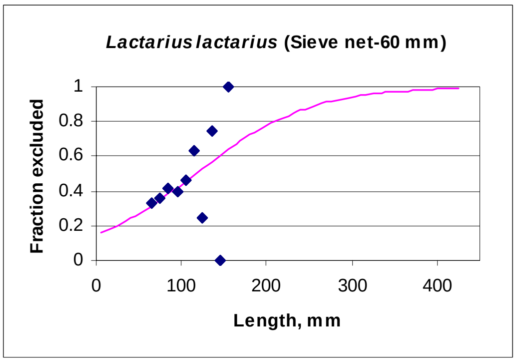


Fig 7.6 Selectivity curve for *Lactarius lactarius*

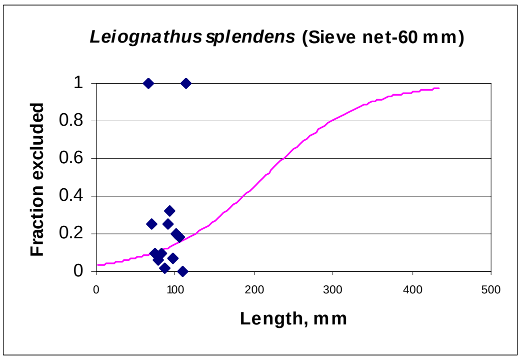


Fig 7.7 Selectivity curve for *Leiognathus splendens*

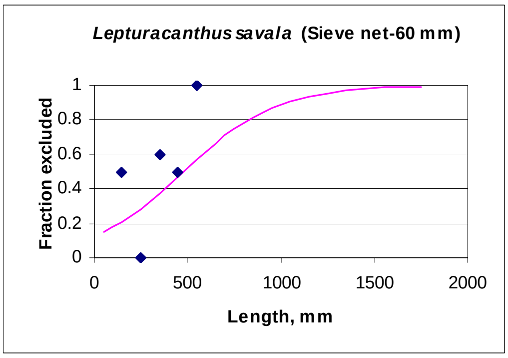


Fig 7.8 Selectivity curve for *Lepturacanthus savala*

Length-wise exclusion characteristics in respect of selected trawl caught species were studied in the Sieve net-60 mm BRD installed operations. Length-wise retention and exclusion results of species *viz., Alepes djedaba, Ambassis ambassis, Johnius carouna, Lactarius lactarius, Leiognathus splendens* and *Lepturacanthus savala* are given in Fig 7.9 to 7.14. In the case of *Alepes djedaba*, length class 65-70 mm was fully excluded and length classes from 71 to 115 mm were retained in the range of 8 to 74%. Length class 67-70 mm in respect of *Ambassis ambassis* was fully retained and length classes from 71 to 90 mm showed an increasing trend in exclusion rate from 25 to 70%.

Length classes of *Johnius carouna* from 81 to 130 mm were retained at the rate of 35 to 85%, length classes from 131 to 160 mm were excluded at rates in excess of 80% and length classes from 161 to 190 mm were fully excluded. *Lactarius lactarius* of length classes from 71 to 150 mm showed an increasing trend in exclusion rate ranging from 35 to 76% and length classes from 151 to 170 mm showed 100% exclusion. *Leiognathus splendens* in the length class 65-68 mm was fully excluded, length classes from 69 to 108 mm were retained at levels in excess of 65%. Length classes from 281 to 440 mm of *Lepturacanthus savala* were retained in the range of 50 to 60% and length classes from 441 to 520 mm were fully excluded through the Sieve net-60 mm BRD.

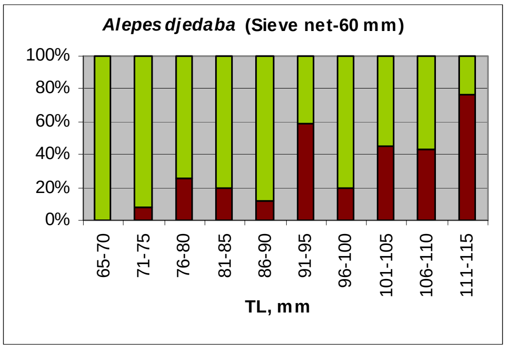


Fig.7.9 Length-wise retention and exclusion of *Alepes djedaba*

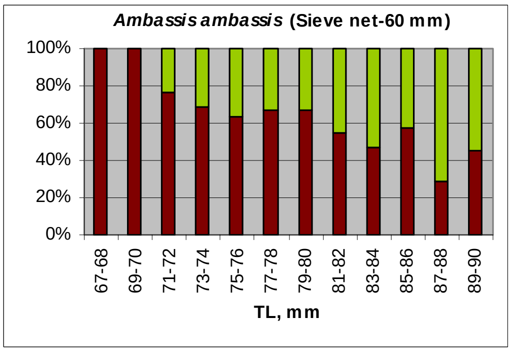


Fig.7.10 Length-wise retention and exclusion of *Ambassis ambassis*

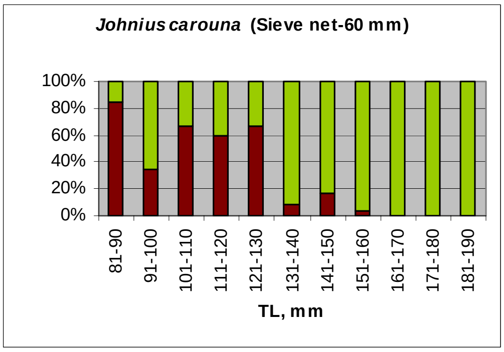


Fig.7.11 Length-wise retention and exclusion of *Johnius carouna*

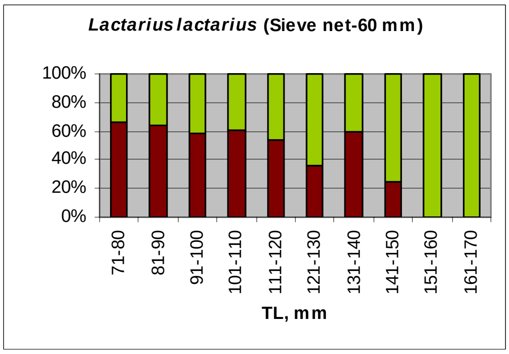


Fig.7.12 Length-wise retention and exclusion of *Lactarius lactarius*

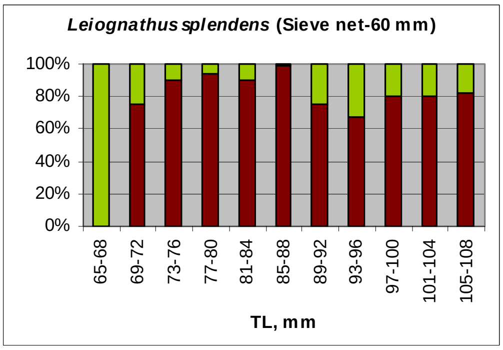


Fig.7.13 Length-wise retention and exclusion of *Leiognathus splendens*

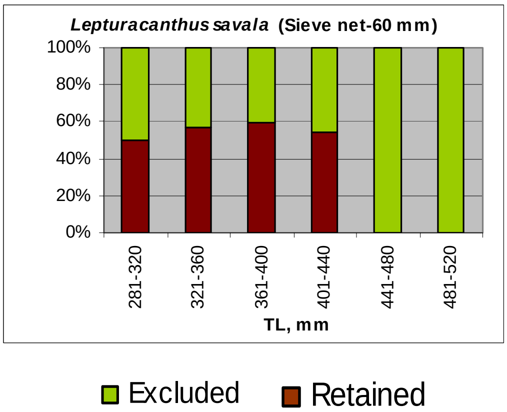


Fig.7.14 Length-wise retention and exclusion of *Lepturacanthus savala*

7.3.2 Performance of Sieve net- 40 mm

The second set of experiments was conducted with Sieve net-40 mm having square mesh funnel and outlet codnend to assess the effect of square mesh funnel on sorting and exclusion characteristics. Eight hauls of 1-1.25 h duration were undertaken during the month of December 2006, off

Cochin, using 28.8 m shrimp trawl. The performance of the BRD during field trials was not satisfactory and heavy blockage in the sorting area was observed leading to poor catch separation and bycatch exclusion. Hence further trials using this design was discontinued.

7.3.3 Performance of Sieve net-50 mm

The third set of experiments was conducted using Sieve net-50 mm, and consisted of 16 hauls, taken using 28.8 m shrimp trawl, during March 2007. Total catch obtained was 290.03 kg with a CPUE of 17.58 kg.h-1, of which 60.65% was retained in the main codend, 9.80% in the outlet codend and 29.55% predominantly consisting of juveniles were excluded. The overall catch during this period consisted of 62 species of finfishes, 6 species of shrimps, 5 species of crabs, 2 species of cephalopod, 5 species of molluscan shells and 1 species of stomatopod. Excluded bycatch (catch other than shrimp) was 33.09% of total catch and shrimp loss was 19.52% (Table 7.5). Views from field trials of Sieve net-50 mm are represented in Fig 7.15 to 7.17.

Among the species, which were excluded through this Sieve net, 9 finfish species *viz*., *Alectis ciliaris, Alectis indicus, Arius jella, Drepene punctuata, Epinepheleus diacanthus, Leiognathus dussumieri, Scombroides lysan, Scomberomorus commerson* and *Scomberomorus guttatus*, 2 shellfish species *(Bufunaria echiniata* and *Turetella acutangula)* and 1 species of crab (*Charybdis natator*) showed 100% exclusion. Nineteen species *viz., Rastrelliger kanagurta, Dussumieria acuta, Johnius dussumieri, Alepes djedaba, Cynoglossus dubius, Pampus argenteus, Siganus canaliculatus, Caranx ignobilis, Leiognathus equulus, Sphyraena jello,* *Secutor insidiator, Terapon theraps, Megalaspis cordyla, Metapenaeus affinis, Sepiella inermis, Turritella attenuata Babylonia spirata, Terapon jarbua* and *Oratosquilla nepa* showed exclusion rates above 50% (Table 7.8). Out of a total of 81 species, 33 species consisting of 26 species of fin fishes, 3 species of shrimps, 2 species of crabs, 1 species of cephalopod and 1 species of molluscan shell showed exclusion up to 50 %. Ten species *viz., Gazza minuta, Congresox talabanoides, Nemipterus japonicus, Pscidinophis cancrivorus, Sillago sihama, Thryssa setirostris, Secutor ruconius, Gerrus erythrorus, Upeneus vittatus* and *Penaeus semisulcatus* did not show any exclusion through this sieve net.

In the 60 mm outlet codend, four species *viz., Charybdis lucifera, Charybdis feriatus, Carangoides armatus* and *Upeneus sulphurus* were fully retained. Seven species *viz., Portunus pelagicus, Portunus sanguinolentus, Mene maculata, Leiognathus brevirostris, Nemipterus japonicus, Saurida undosquamis* and *Dolcia ovis* showed more than 50% exclusion and out of a total of 50 species encountered in outlet codend, 39 species showed retention up to 50% (Table 7.7).

The Sieve net-50 mm excluded more than 90% of gastropod bycatch and more than 70% of squilla (*Oratosquilla nepa*) bycatch. However target catch loss from this sieve net was higher (19.52%). Percentage loss was observed to be high for all shrimp species *viz*., *Metapenaeus dobsoni* (16.92%), *Parapenaeopsis stylifera* (42.17%), *Metapenaeus monoceros* (35.53%) and *Metapenaeus affinis* (59.07%) (Table 7.8), indicating that 50 mm mesh size in the Sieve net funnel is inadequate for letting the shrimps to the main codend.

Fig. 7.15 A view of unsorted catch in the main codend of Sieve net-50 mm

Fig. 7.16 A view of excluded catch through Sieve net-50 mm

Fig. 7.17 A view of the silver pomfret (*Pampus argenteus*) juveniles excluded through Sieve net-50 mm

Table 7.6: Results of Sieve net-50 mm installed trawl operations

	Sieve net- 50 mm
No. of hauls	16
Total catch (kg)	290.03
CPUE ($kg.h^{-1}$)	17.58
Retained catch in main codend (%)	60.65
Retained catch in outlet codend (%)	9.80
Excluded catch (%)	29.55
Total shrimp catch (kg)	75.64
Retained shrimp catch (%)	80.48
Excluded shrimp catch (%)	19.52
Bycatch (catch other than shrimps) (kg)	214.39
Retained bycatch (%)	66.91
Excluded bycatch (%)	33.09
Species encountered (No.)	81

Fish species (No.)	62
Shrimp species (No.)	6
Other species (No.)	13
100% exclusion (No.)	12
>50% exclusion (No.)	19
Up to 50% exclusion (No.)	33
0% exclusion (No.)	17

Table 7.7: Catch composition and exclusion from Sieve net-50 mm

Species	Total catch, kg	Retained catch lower, %	Retained catch upper, %	Excluded catch, %
Alectis ciliaris	0.03	0.00	0.00	100.00
Alectis indicus	0.10	0.00	0.00	100.00
Arius jella	0.03	0.00	0.00	100.00
Bufonaria echiniata	0.03	0.00	0.00	100.00
Charybdis natator	0.08	0.00	0.00	100.00
Drepene punctata	0.04	0.00	0.00	100.00
Epinepheleus diacanthus	0.13	0.00	0.00	100.00
Leiognathus dussumieri	0.06	0.00	0.00	100.00
Scomberoides lysan	1.30	0.00	0.00	100.00
Scomberomorus commerson	0.45	0.00	0.00	100.00
Scomberomorus guttatus	0.20	0.00	0.00	100.00
Turritella acutangula	0.50	0.00	0.00	100.00
Turritella attenuata	0.58	0.00	5.17	94.83
Rastrelliger kanagurta	6.70	2.99	11.19	85.82
Sepiella inermis	1.71	14.08	6.16	79.77
Dussumieria acuta	0.21	23.81	0.00	76.19
Johnius dussumieri	2.12	0.00	28.30	71.70
Babylonia spirata	0.07	0.00	28.57	71.43
Oratosquilla nepa	7.50	28.00	0.93	71.07
Alepes djedaba	1.09	29.36	0.00	70.64
Cynoglossus dubius	0.09	0.00	33.33	66.67
Pampus argenteus	17.47	10.71	24.94	64.36
Siganus canaliculatus	0.11	38.10	0.00	61.90

Caranx ignobilis	2.11	0.00	39.34	60.66
Leiognathus equulus	1.00	21.00	19.50	59.50
Metapenaeus affinis	1.33	29.35	11.59	59.07
Sphyraena jello	4.39	3.42	38.77	57.81
Secutor insidiator	3.43	21.61	21.61	56.79
Terapon theraps	0.96	16.67	28.13	55.21
Megalaspis cordyla	3.18	46.54	0.31	53.14
Terapon jarbua	1.70	3.53	45.88	50.59
Valamugil cunnesius	3.53	39.66	12.75	47.59
Otolithes ruber	3.62	34.02	19.36	46.61
Saurida undosquamis	0.27	0.00	55.56	44.44
Parapenaeopsis stylifera	4.66	41.85	15.99	42.17
Apagon fasciatus	1.78	53.93	4.21	41.85
Dolcia ovis	0.05	0.00	60.00	40.00
Stolephorus waitei	2.58	58.82	1.86	39.32
Nemipterus japonicus	1.00	4.00	60.00	36.00
Uroteuthis duvauceli	7.79	44.70	19.59	35.71
Metapenaeus monoceros	1.30	43.75	20.72	35.53
Pomadasis maculatus	1.34	25.37	41.04	33.58
Leiognathus bindus	0.35	60.80	5.68	33.52
Scomberoides tala	0.26	69.23	0.00	30.77
Thryssa mystax	1.38	54.55	16.36	29.09
Lepturacanthus savala	1.75	67.43	5.71	26.86
Johnius carouna	2.17	47.58	28.87	23.56
Leiognathus splendens	0.17	47.06	29.41	23.53
Opisthopterus tardoore	0.98	74.49	4.59	20.92
Oxiurichthys paulae	0.56	80.36	0.00	19.64
Sardinella longiceps	95.23	80.38	0.92	18.70
Metapenaeus dobsoni	68.35	79.03	4.05	16.92
Lactarius lactarius	0.91	83.52	0.00	16.48
Portunus sanguinolentus	5.50	0.00	84.35	15.65
Cynoglossus macrostomus	1.33	86.47	0.00	13.53
Portunus pelagicus	0.83	0.00	86.67	13.33
Stolephorus indicus	0.32	81.25	6.25	12.50
Leiognathus brevirostris	0.14	7.14	82.14	10.71
Lagocephalus spadiceus	1.79	90.50	0.00	9.50

Encrasicholina heteroloba	3.56	89.28	1.40	9.32
Anadontostoma chacunda	0.11	81.82	9.09	9.09
Stolephorus commersonnii	13.79	87.82	3.55	8.63
Johnius amblycephalus	0.43	93.02	0.00	6.98
Mene maculata	1.19	0.00	97.89	2.11
Carangoides armatus	0.02	0.00	100.00	0.00
Charybdis feriatus	0.15	0.00	100.00	0.00
Charybdis lucifera	0.08	0.00	100.00	0.00
Upeneus sulphurus	0.03	0.00	100.00	0.00
Fenneropenaeus indicus	0.04	50.00	50.00	0.00
Trypouchen vagina	0.50	60.00	40.00	0.00
Scatophagus argus	0.84	71.43	28.57	0.00
Congresox talabonoides	0.10	100.00	0.00	0.00
Gazza minuta	0.23	100.00	0.00	0.00
Gerres erythrourus	0.02	100.00	0.00	0.00
Nemipterus mesoprion	0.10	100.00	0.00	0.00
Penaeus semisulcatus	0.01	100.00	0.00	0.00
Psidinophis cancrivorus	0.10	100.00	0.00	0.00
Secutor ruconius	0.03	100.00	0.00	0.00
Sillago sihama	0.08	100.00	0.00	0.00
Thryssa setirostris	0.04	100.00	0.00	0.00
Upeneus vittatus	0.02	100.00	0.00	0.00
All species	**290.03**	**60.65**	**9.80**	**29.55**

Table 7.8: Species-wise exclusion rates in Sieve net-50 mm BRD

Species	Encountered catch, kg	Exclusion rate, %
Alectis ciliaris	0.03	100.00
Alectis indicus	0.10	100.00
Arius jella	0.03	100.00
Bufonaria echiniata	0.03	100.00
Charybdis natator	0.08	100.00
Drepene punctata	0.04	100.00
Epinepheleus diacanthus	0.13	100.00
Leiognathus dussumieri	0.06	100.00
Scomberoides lysan	1.30	100.00
Scomberomorus commerson	0.45	100.00
Scomberomorus guttatus	0.20	100.00

Turritella acutangula	0.50	100.00
Turritella attenuata	0.58	94.83
Rastrelliger kanagurta	6.70	85.82
Sepiella inermis	1.71	79.77
Dussumieria acuta	0.21	76.19
Johnius dussumieri	2.12	71.70
Babylonia spirata	0.07	71.43
Oratosquilla nepa	7.50	71.07
Alepes djedaba	1.09	70.64
Cynoglossus dubius	0.09	66.67
Pampus argenteus	17.47	64.36
Siganus canaliculatus	0.11	61.90
Caranx ignobilis	2.11	60.66
Leiognathus equulus	1.00	59.50
Metapenaeus affinis	1.33	59.07
Sphyraena jello	4.39	57.81
Secutor insidiator	3.43	56.79
Terapon theraps	0.96	55.21
Megalaspis cordyla	3.18	53.14
Terapon jarbua	1.70	50.59
Valamugil cunnesius	3.53	47.59
Otolithes ruber	3.62	46.61
Saurida undosquamis	0.27	44.44
Parapenaeopsis stylifera	4.66	42.17
Apagon fasciatus	1.78	41.85
Dolcia ovis	0.05	40.00
Stolephorus waitei	2.58	39.32
Nemipterus japonicus	1.00	36.00
Uroteuthis duvauceli	7.79	35.71
Metapenaeus monoceros	1.30	35.53
Pomadasis maculatus	1.34	33.58
Leiognathus bindus	0.35	33.52
Scomberoides tala	0.26	30.77
Thryssa mystax	1.38	29.09
Lepturacanthus savala	1.75	26.86
Johnius carouna	2.17	23.56
Leiognathus splendens	0.17	23.53
Opisthopterus tardoore	0.98	20.92
Oxiurichthys paulae	0.56	19.64

Sardinella longiceps	95.23	18.70
Metapenaeus dobsoni	68.35	16.92
Lactarius lactarius	0.91	16.48
Portunus sanguinolentus	5.50	15.65
Cynoglossus macrostomus	1.33	13.53
Portunus pelagicus	0.83	13.33
Stolephorus indicus	0.32	12.50
Leiognathus brevirostris	0.14	10.71
Lagocephalus spadiceus	1.79	9.50
Encrasicholina heteroloba	3.56	9.32
Anadontostoma chacunda	0.11	9.09
Stolephorus commersonnii	13.79	8.63
Johnius amblycephalus	0.43	6.98
Mene maculata	1.19	2.11
Carangoides armatus	0.02	0.00
Charybdis feriatus	0.15	0.00
Charybdis lucifera	0.08	0.00
Upeneus sulphurus	0.03	0.00
Fenneropenaeus indicus	0.04	0.00
Trypouchen vagina	0.50	0.00
Scatophagus argus	0.84	0.00
Congresox talabonoides	0.10	0.00
Gazza minuta	0.23	0.00
Gerres erythrourus	0.02	0.00
Nemipterus mesoprion	0.10	0.00
Penaeus semisulcatus	0.01	0.00
Psidinophis cancrivorus	0.10	0.00
Secutor ruconius	0.03	0.00
Sillago sihama	0.08	0.00
Thryssa setirostris	0.04	0.00
Upeneus vittatus	0.02	0.00
All species	**290.03**	**29.55**

Table 7.9: Sorting effect on trawl caught species in Sieve net-50 mm BRD

Species	Encountered catch, kg	Main codend, % retention	Outlet codend, % retention
Congresox talabonoides	0.10	100.00	0.00
Gazza minuta	0.23	100.00	0.00
Gerres erythrourus	0.02	100.00	0.00
Nemipterus mesoprion	0.10	100.00	0.00
Penaeus semisulcatus	0.01	100.00	0.00
Psidinophis cancrivorus	0.10	100.00	0.00
Secutor ruconius	0.03	100.00	0.00
Sillago sihama	0.08	100.00	0.00
Thryssa setirostris	0.04	100.00	0.00
Upeneus vittatus	0.02	100.00	0.00
Johnius amblycephalus	0.43	93.02	6.98
Lagocephalus spadiceus	1.79	90.50	9.50
Encrasicholina heteroloba	3.56	89.28	10.72
Stolephorus commersonnii	13.79	87.82	12.18
Cynoglossus macrostomus	1.33	86.47	13.53
Lactarius lactarius	0.91	83.52	16.48
Anadontostoma chacunda	0.11	81.82	18.18
Stolephorus indicus	0.32	81.25	18.75
Sardinella longiceps	95.23	80.38	19.62
Oxiurichthys paulae	0.56	80.36	19.64
Metapenaeus dobsoni	68.35	79.03	20.97
Opisthopterus tardoore	0.98	74.49	25.51
Scatophagus argus	0.84	71.43	28.57
Scomberoides tala	0.26	69.23	30.77
Lepturacanthus savala	1.75	67.43	32.57
Leiognathus bindus	0.35	60.80	39.20
Trypouchen vagina	0.50	60.00	40.00
Stolephorus waitei	2.58	58.82	41.18
Thryssa mystax	1.38	54.55	45.45
Apagon fasciatus	1.78	53.93	46.07
Fenneropenaeus indicus	0.04	50.00	50.00
Johnius carouna	2.17	47.58	52.42

Leiognathus splendens	0.17	47.06	52.94
Megalaspis cordyla	3.18	46.54	53.46
Uroteuthis duvauceli	7.79	44.70	55.30
Metapenaeus monoceros	1.30	43.75	56.25
Parapenaeopsis stylifera	4.66	41.85	58.15
Valamugil cunnesius	3.53	39.66	60.34
Siganus canaliculatus	0.11	38.10	61.90
Otolithes ruber	3.62	34.02	65.98
Alepes djedaba	1.09	29.36	70.64
Metapenaeus affinis	1.33	29.35	70.65
Oratosquilla nepa	7.50	28.00	72.00
Pomadasis maculatus	1.34	25.37	74.63
Dussumieria acuta	0.21	23.81	76.19
Secutor insidiator	3.43	21.61	78.39
Leiognathus equulus	1.00	21.00	79.00
Terapon theraps	0.96	16.67	83.33
Sepiella inermis	1.71	14.08	85.92
Pampus argenteus	17.47	10.71	89.29
Leiognathus brevirostris	0.14	7.14	92.86
Nemipterus japonicus	1.00	4.00	96.00
Terapon jarbua	1.70	3.53	96.47
Sphyraena jello	4.39	3.42	96.58
Rastrelliger kanagurta	6.70	2.99	97.01
Carangoides armatus	0.02	0.00	100.00
Charybdis feriatus	0.15	0.00	100.00
Charybdis lucifera	0.08	0.00	100.00
Upeneus sulphurus	0.03	0.00	100.00
Mene maculata	1.19	0.00	100.00
Portunus pelagicus	0.83	0.00	100.00
Portunus sanguinolentus	5.50	0.00	100.00
Dolcia ovis	0.05	0.00	100.00
Saurida undosquamis	0.27	0.00	100.00
Caranx ignobilis	2.11	0.00	100.00
Cynoglossus dubius	0.09	0.00	100.00
Babylonia spirata	0.07	0.00	100.00
Johnius dussumieri	2.12	0.00	100.00
Turritella attenuata	0.58	0.00	100.00

Alectis ciliaris	0.03	0.00	100.00
Alectis indicus	0.10	0.00	100.00
Arius jella	0.03	0.00	100.00
Bufonaria echiniata	0.03	0.00	100.00
Charybdis natator	0.08	0.00	100.00
Drepene punctata	0.04	0.00	100.00
Epinepheleus diacanthus	0.13	0.00	100.00
Leiognathus dussumieri	0.06	0.00	100.00
Scomberoides lysan	1.30	0.00	100.00
Scomberomorus commerson	0.45	0.00	100.00
Scomberomorus guttatus	0.20	0.00	100.00
Turritella acutangula	0.50	0.00	100.00
All species	**290.03**	**60.65**	**39.35**

7.3.3.1 Statistical analysis

The Sieve net-50 mm installed trawl has shown significantly higher exclusion rates in terms of eleven species *viz*., *Cynoglossus macrostomus* (P=0.030), *Gazza minuta* (P=0.031), *Lactarius lactarius* (P=0.045), *Lagocephalus spadiceus* (P=0.007), *Leiognathus bindus* (P=0.028), *Lepturacanthus savala* (P=0.004), *Megalaspis cordyla* (P=0.012), *Metapenaeus affinis* (P=0.034), *Metapenaeus monoceros* (P=0.018), *Otolithes ruber* (P=0.034) and *Pampus argenteus* (P=0.024).

7.3.3.2 Selectivity studies

The results of selectivity analysis in respect of 9 species *viz, Lepturacanthus savala, Megalaspis cordyla, Metapenaeus dobsoni, Otolithes ruber, Pampus argenteus, Parapenaeopsis stylifera, Secutor insidiator, Stolephorus waitei* and *Thryssa mystax* are given in Table 7.10 and Fig 7.18 to 7.27.

L_{50} values lower than length at first maturity (L_m) values indicate better exclusion opportunities for immature fishes below L_m, as the mid-length classes were plotted against excluded fractions in the selectivity estimates. L_{50} values in respect of *Megalaspis cordyla, Otolithes ruber* and *Pampus argenteus* were found to be lower than L_m values reported indicating better opportunity for exclusion of juveniles through this BRD.

Table 7.10: Selectivity parameters of Sieve net-50 mm BRD

Species	L_{25}	L_{50}	L_{75}	Selection range, mm	Selection factor, mm	Length at first maturity TL, mm
Lepturacanthus savala	220.32	288.09	355.86	135.66	5.76	NA
Megalaspis cordyla	136.71	203.62	270.53	133.81	4.07	250 (Fishbase, 2008)
Metapenaeus dobsoni	78.78	95.85	112.93	34.15	1.92	88.6 (Rao, 1967)
Otolithes ruber	122.61	160.76	198.90	76.29	3.22	221-230 (Fishbase, 2008)
Pampus argenteus	90.58	310.18	520.78	43.19	0.62	320 (Bal & Rao, 1990)
Parapenaeopsis stylifera	81.44	133.83	186.22	104.78	2.68	63.2 (Rao, 1967)
Secutor insidiator	72.42	83.43	94.44	22.03	1.67	NA
Stolephorus waitei	116.95	192.56	268.17	151.22	3.85	77.5 (Fishbase, 2008)
Thryssa mystax	93.48	141.52	189.56	96.07	2.83	130 (Fishbase, 2008)

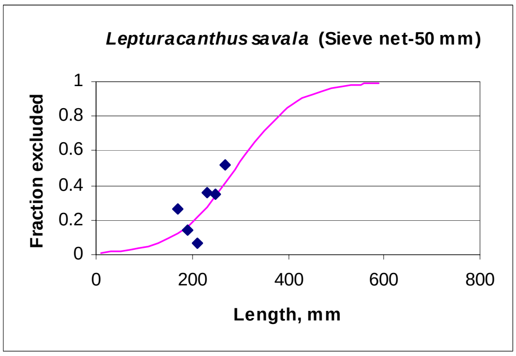


Fig 7.18 Selectivity curve for *Alepes djedaba*

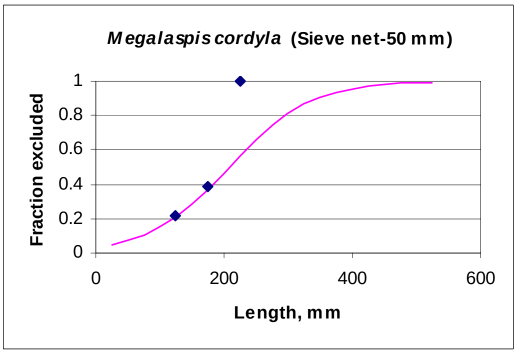


Fig 7.19 Selectivity curve for *Megalaspis cordyla*

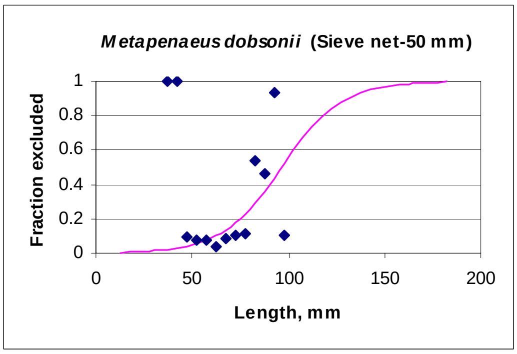


Fig 7.20 Selectivity curve for *Metapenaeus dobsoni*

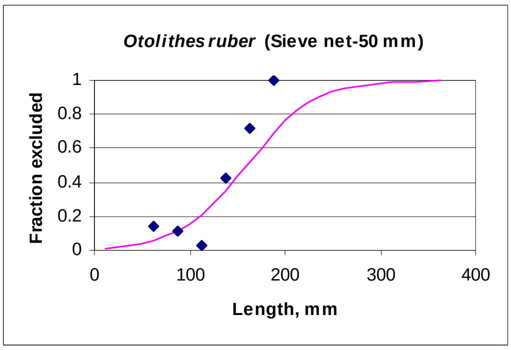


Fig 7.21 Selectivity curve for *Otolithes ruber*

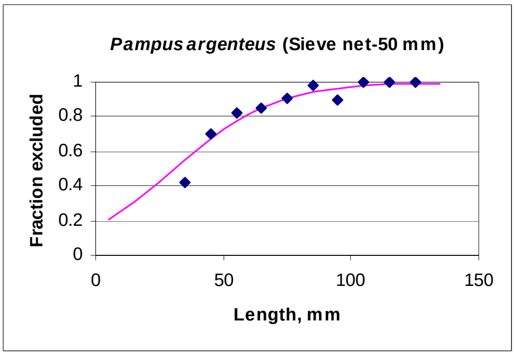


Fig 7.22 Selectivity curve for *Pampus argenteus*

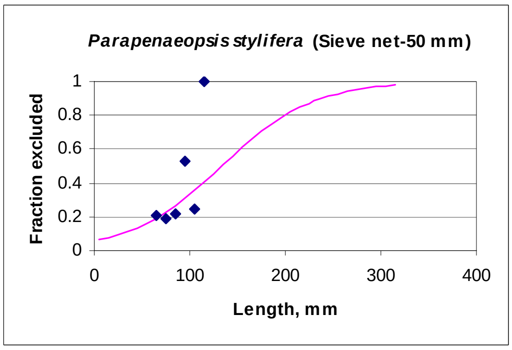


Fig 7.23 Selectivity curve for *Parapenaeopsis stylifera*

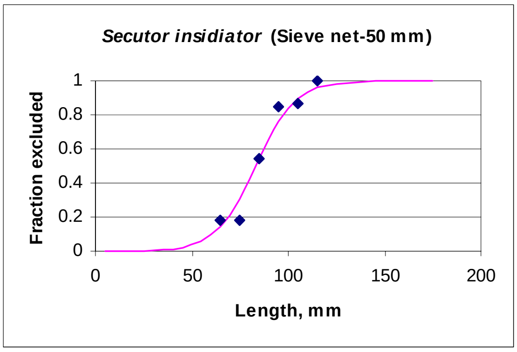


Fig 7.24 Selectivity curve for *Secutor insidiator*

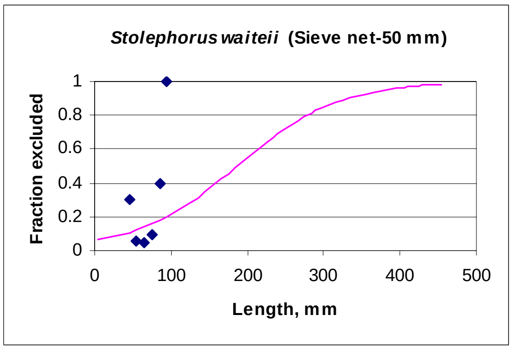


Fig 7.25 Selectivity curve for *Stolephorus waitei*

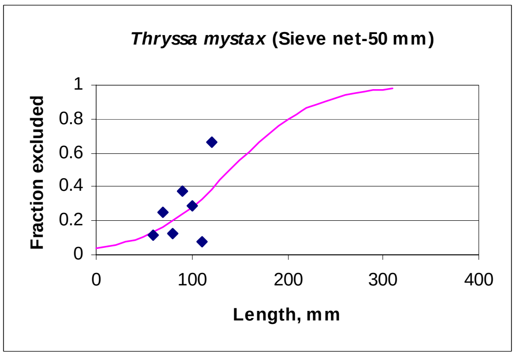


Fig 7.26 Selectivity curve for *Thryssa mystax*

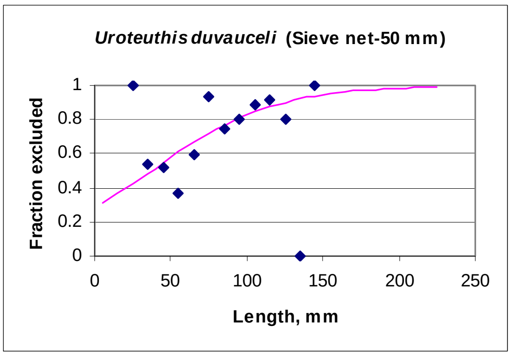


Fig 7.27 Selectivity curve for *Uroteuthis duvauceli*

Length-wise retention and exclusion characteristics in respect of eight species *viz*., *Lepturacanthus savala, Megalaspis cordyla, Thryssa mystax, Otolithes ruber, Pampus argenteus, Parapenaeopsis stylifera, Secutor insidiator* and *Uroteuthis duvauceli* are given in Fig. 7.28 to 7.35. Length class of 101-120 mm of *Lepturacanthus savala* showed 100% exclusion; 141-160 mm length class showed full retention and length classes from 161 to 280 mm showed retention in the range of 43 to 96%. *Megalaspis cordyla* in the length class of 51-100 mm was fully excluded and there was an increasing trend in the exclusion of length classes from 101 to 300 mm. *Thryssa mystax* in the length classes of 56 to 125 mm showed exclusion in the range of 10 to 38% while length classes from 126 to 155 mm showed 100% retention.

Length classes of *Otolithes ruber* from 51 to 175 mm showed an increasing trend in exclusion rate from 10 to 70% and length classes from 176 to 250 mm were fully excluded. *Pampus argenteus* in the length class 21-30 mm was fully retained, length classes from 31 to 100 mm showed an increasing trend in exclusion rate in the range of 41 to 98% and length classes from 101 to 130 mm showed 100% exclusion. *Parapenaeopsis stylifera* in the length classes from 51 to 60 mm were retained completely, length classes from 61 to 70 mm showed retention in the range of 50 to 80% and length classes from 111 to 120 mm showed 100% exclusion. Length classes from 61 to 110 mm of *Secutor insidiator* showed an increasing trend in exclusion in the range of 18 to 87% and length classes from 111 to 120 mm were fully excluded. *Uroteuthis duvauceli* in the length classes from 21 to 140 mm showed exclusion in the range of 42 to 98% and length classes from 141 to 160 mm were completely excluded.

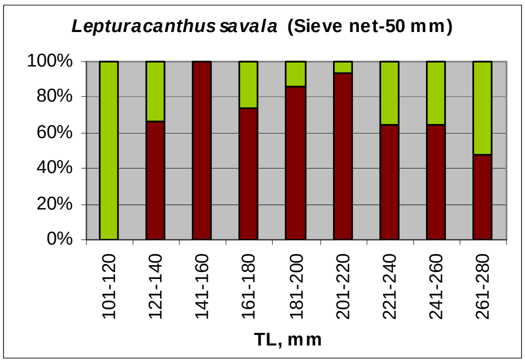


Fig.7.28 Length-wise retention and exclusion of *Lepturacanthus savala*

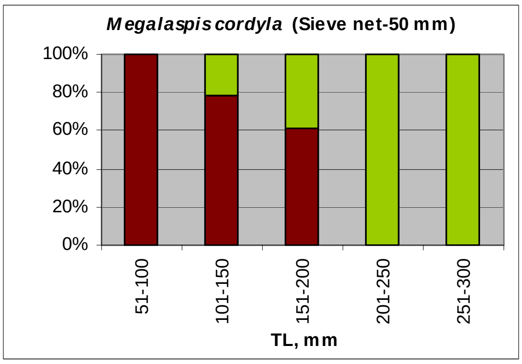


Fig.7.29 Length-wise retention and exclusion of *Megalaspis cordyla*

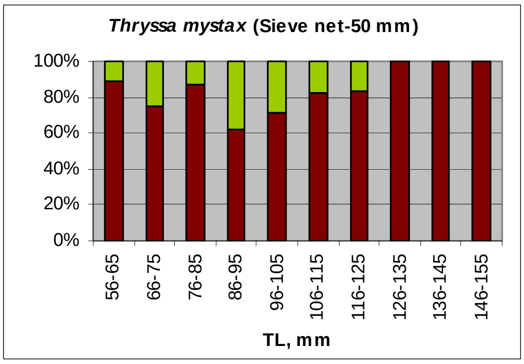


Fig.7.30 Length-wise retention and exclusion of *Thryssa mystax*

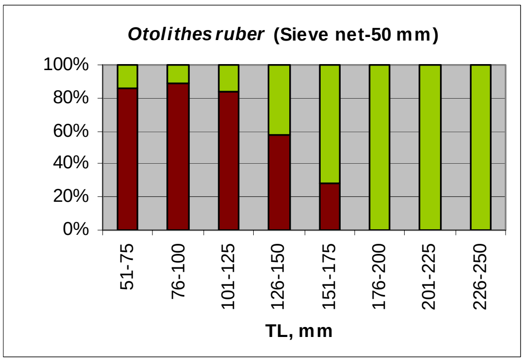
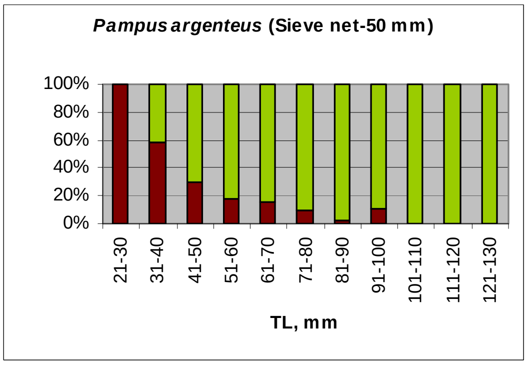


Fig.7.31 Length-wise retention and exclusion of *Otolithes ruber*



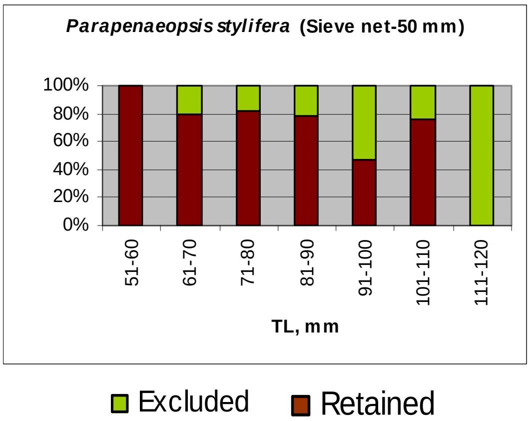
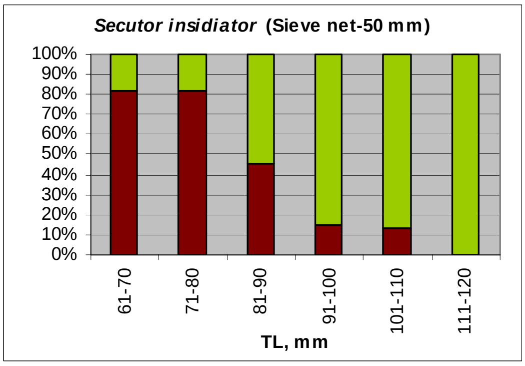
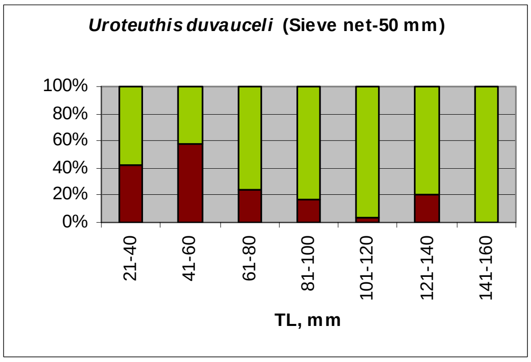


Fig.7.32 Length-wise retention and exclusion of *Pampus argenteus*

Fig.7.33 Length-wise retention and exclusion of *Parapenaeopsis stylifera*



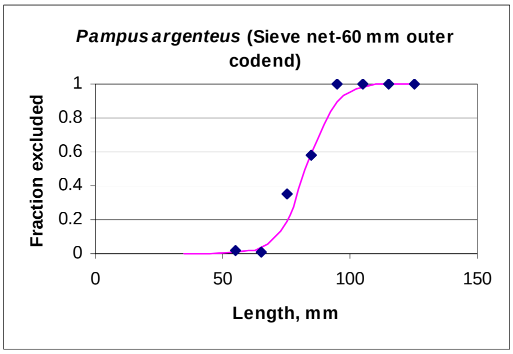


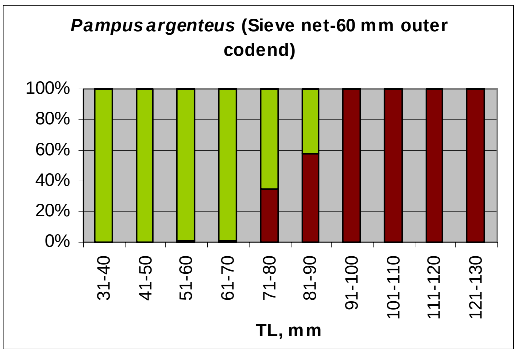
Excluded Retained

Fig.7.34 Length-wise retention and exclusion of *Secutor insidiator*

Fig.7.35 Length-wise retention and exclusion of *Uroteuthis duvauceli*

Mesh size of outlet codend determines the size at retention of the species. Selectivity curve and length-wise catch retention and exclusion of *Pampus argenteus* in the 60 mm outlet codend of Sieve net-50 mm are presented in Fig 7.36 and Fig 7.37. Mean selection length (L_{50}), L_{25}, L_{75} and selection range obtained for *Pampus argenteus* was 83.24 mm, 77.02 mm, 89.47 mm and 12.45 mm, respectively (Fig 7.36). Length classes from 31 to 50 mm was completely excluded, length classes from 51 to 90 mm were excluded at levels ranging from 42 to 98% and length classes above 91mm was fully retained in the 60 mm diamond mesh outlet codend (Fig 7.37).





Excluded Retained

Fig: 7.36 Selectivity curve for *Pampus argenteus*

Fig.7.37 Length-wise retention and exclusion of *Pampus argenteus*

7.4 Catch diversity analysis

The diversity indices calculated for sieve net with 50 mm funnel and sieve net with 60 mm funnel are given in the table 7.6.1. From the results, the catch excluded from the sieve net-50 mm was found to have more diversity in terms of S, d, J', H, H', N1 and E1/D. Higher dominance (Simpson's dominance index, λ') was observed in Sieve net-50 mm compared to Sieve net-60 mm. Diversity parameters and the k-dominance curve for the Sieve net BRDs are given in Table 7.11 and Fig. 7.38, respectively.

The cumulative ranked abundances of the species obtained from the k-dominance curve when plotted against the species rank, the curve for Sieve net-50 mm was observed to begin lower than Sieve net-60 mm, indicating higher diversity in the catch excluded from the Sieve net-50 mm.

Table 7.11: Mean diversity indices of species excluded from Sieve net- 50 mm and sieve net- 60 mm

Sieve net	S	d	J'	H	H'	N1	λ'	E1/D
50 mm	80	10.32	0.54	2.33	2.39	10.86	0.20	0.06
60 mm	44	7.14	0.43	1.49	1.62	5.03	0.44	0.05

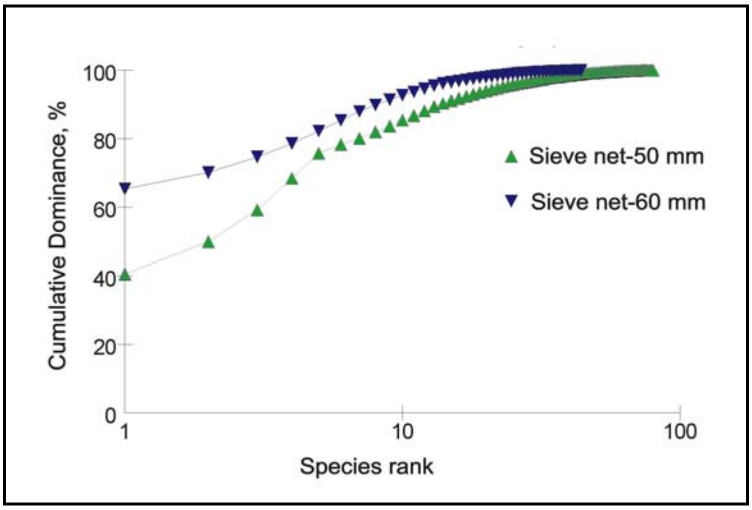


Fig 7.38 k-dominance curve for Sieve net BRDs

7.5 Conclusion

Among the two Sieve nets evaluated, Sieve net-60 mm performed comparatively better in terms of shrimp retention. Bycatch exclusion in Sieve net-60 mm was about 37% (without jellyfish) and 15% (with jellyfish) compared to Sieve net-50 mm (33%). Shrimp loss in Sieve net-60 mm was about 4.5%, compared to a shrimp loss of 20% in Sieve net-50 mm. Number of species excluded at levels exceeding 50% and species diversity of the excluded catch were higher in respect of Sieve net-50 mm, compared to Sieve net-60 mm.

Complete exclusion of bycatch fishes from shrimp trawls may not be always acceptable to the fishermen, as a part of the bycatch constituted by large marketable species often contribute to the profitability of trawl operations in the tropical fisheries. Sieve net designs which are appropriately adapted to regional fisheries in terms of mesh sizes of the outlet and main codends, is expected to be acceptable and could lead to significant reduction in the mortality of juveniles during shrimp trawling. Among the two sieve nets evaluated, Sieve net with 60 mm diamond mesh funnel inside the net with 80 mm diamond mesh outlet codend, has been able to exclude significant quantities of bycatch including juveniles while keeping shrimp loss at about 4.5% and retaining larger marketable bycatch species. Sieve nets are comparatively easier to handle onboard and are less prone to blockage due to larger sorting area, compared to rigid grid BRDs.

In addition, it is also possible to adapt the Sieve net to retain the shrimp catch and efficiently exclude jellyfish when they abound in the shrimp fishing grounds, by keeping the outlet codend open. Trawl fishermen can thus reduce the sorting time onboard resulting in an increase in the useful fishing time and can enhance the profitability of trawl operations. Sieve net is effectively used by many fisheries around the world to reduce fish, jelly fish and other bycatch species in shrimp trawling.

Sieve net-60 mm has potential for adoption in tropical trawl fisheries, in order to minimize the impact of shrimp trawling on juveniles and non-targeted bycatch species.

Chapter 8

Separator Panel Bycatch Reduction Devices

8.1 Introduction

Separator panels physically separate the catch according to the size, with the use of netting panels of appropriate mesh size. Shrimps pass through the mesh openings of the separator panel to the codend while bycatch such as fishes and sea turtles are directed towards the exit opening. These devices are advantageous as they are cheap, simple to construct, easy to handle and repair, compared to rigid grid devices, which work on similar principles. The separator designs use panels of netting placed in the mouth, throat, or along the wings of the trawl to lead the fish toward escape openings, allowing shrimp to pass through relatively large panel meshes in to the codends (FAO, 1973, Watson *et al*., 1986). Separation of shrimp and fish with netting panels has been successful in fisheries where the difference between sizes of shrimp and fish is significant (Prado, 1993). Large mesh triangular netting panels placed in the trawl net in upward sloping position to exclude turtles from the nets are called soft Turtle Excluder Devices (TED). The Morrison TED, Parker TED and Andrews TED are efficient soft TEDs prevailing in the world (Christian *et al*., 1988; Andrew *et al*., 1993; Anon, 2002b).

In Norway, oblique separator panels with 50 to 60 mm mesh size in 40° angle, placed in the aft belly were tested during mid-1970s by Norwegian Institute of Fishery Technology. From the fishing trials, it was found that upward sloping separating panel is very efficient than other designs and in 1984, the oblique panel was approved by the fishery legislative authorities for use in shrimp fisheries (Prado, 1993). In 1980s, Norwegian Institute of Fishery Technology developed and tested a vertical side-sorting panel installed in the aft belly which has given promising results with respect to the fish release with minimum shrimp loss (Isaksen, 1984). An oval shaped separator panel of 3 to 8 inches was used in USA fisheries and the performance of this device was reported to be less consistent than grids with exclusion rates of 30-80% for fish and shrimp loss of 2-30% (Anon, 2004a). Proper installation of the soft TEDs is essential in order to ensure their efficient performance. Morrison soft TED has been used successfully to exclude sea turtles in Gulf of Mexico. In addition to sea turtles, it reduced other bycatch species, particularly fish. The biggest drawback regarding this category of BRDs is the possibility of clogging with debris (Christian *et al*., 1988; Kendall, 1990).

Studies in Moreton Bay, Queensland, Australia using Morrison soft TED has given reduction in bycatch by 32% (Andrew *et al*., 1993; Robins-Troeger, 1994). Results of studies conducted in the Gulf of Mexico and South Atlantic shrimp fisheries has shown that Andrews soft TED is very effective in excluding the red snapper bycatch up to 77% with a shrimp loss of 16% and Morrison soft TED excluded 20 to 40% of fish bycatch with a shrimp loss of 13%. Andrews soft TED was successfully used in West Florida shelf area without excessive clogging (Anon, 2002b). Turtle exclusion rate from Parker soft TED, which is approved for use in US waters, has been reported to be 97% (Anon, 1998).

8.2 Materials and Methods

Two designs of Separator panel BRDs *viz*., (i) Separator panel with 40 mm square mesh netting (Separator panel-40S) and (ii) Separator panel with 60 mm diamond mesh netting (Separator panel-60D) were constructed and operated using 28.8 m shrimp trawl, during February-March 2007, off Cochin. Details of materials and methods adopted for the study are described in Chapter section 2.1.4.

8.3 Results and Discussion

Results of ten paired comparative experimental hauls undertaken with two designs of separator panel BRDs are given in Table 8.1 to 8.4 and Fig. 8.1 to 8.2.

Table 8.1: Results of experiments with Separator panel BRDs

	Separator panel- 40S	Separator panel- 60D
No. of hauls	10	10
Total catch (kg)	42.92	35.25
CPUE ($kg.h^{-1}$)	4.31	3.54
Retained catch (kg)	9.76	12.53
Retained catch (%)	22.73	35.55
Excluded catch (kg)	33.16	22.72
Excluded catch (%)	77.27	64.45
Retained shrimp catch (kg)	1.84	1.91
Retained shrimp catch (%)	47.29	56.01
Excluded shrimp catch (kg)	2.05	1.50
Excluded shrimp catch (%)	52.71	43.99
Retained bycatch (catch other than shrimps) (kg)	7.92	10.62
Retained bycatch (catch other than shrimps) (%)	20.29	33.36

Excluded bycatch (catch other than shrimps) (kg)	31.12	21.22
Excluded bycatch (catch other than shrimps) (%)	79.71	66.64
No. of species caught	77	81
Fish species	64	66
Shrimp species	5	5
Other species	8	10
100% exclusion (No. of species)	22	19
>50% exclusion (No. of species)	36	23
Up to 50% exclusion (No. of species)	6	25
0% exclusion (No. of species)	13	14

Table 8.2: Group-wise exclusion rate of Separator panel BRDs

BRD type	Species groups	Encountered catch, kg	Retained catch, %	Excluded catch, %
Separator panel-40S	**All species**	**42.92**	**22.73**	**77.27**
	Finfishes	34.39	17.81	82.19
	Shrimps	3.88	47.29	52.71
	Crabs	1.59	31.00	69.00
	Cephalopods	2.38	37.39	62.61
	Miscellaneous	0.68	61.03	38.97
Separator panel-60D	**All species**	**35.25**	**35.55**	**64.45**
	Finfishes	28.19	30.28	69.72
	Shrimps	3.41	56.01	43.99
	Crabs	1.43	60.84	39.16
	Cephalopods	1.33	32.45	67.55
	Miscellaneous	0.90	87.78	12.22

8.3.1 Performance of Separator panel-40S

Total catch obtained during the field trials of Separator panel-40S was 42.92 kg, with an average CPUE of 4.31 $kg.h^{-1}$ of which 22.73% was retained in the codend and 77.27% was excluded. Excluded bycatch (catch other than shrimp) from this BRD was 79.71% and the shrimp loss was 52.71%. The overall catch during this period consisted of 64 species of finfishes, 5 species of shrimps, 4 species of crabs, 2 species of cephalopod, 1 species of molluscan shell and 1 species of stomatopod (Table 8.1).

Among the species which excluded from Separator panel-40S, 22 species *viz., Caranx sexfasciatus, Dussumieria acuta, Epinepheleus diacanthus, Gerrus oyena, Ilisha filigera, Johnius amblycephalus, Liza parsia, Mene maculata, Nemipterus mesoprion, Parastromateus niger, Pellona ditchella, Platycephalus indicus, Sardinella albella, Sardinella fimbriatus, Scomberoides tala, Selar crumenophthalmus, Therapon jarbua, Uroconger lepturus, Valamugil cunnesius, Valamugil speigleri, Fenneropenaeus indicus* and *Scylla serrata* showed 100% exclusion and 36 species *viz., Rastrelliger kanagurta, Pampus argenteus, Alepes djedaba, Siganus canaliculatus, Scomberomorus commersoni, Leiognathus equulus, Megalaspis cordyla, Leiognathus dussumieri, Sardinella longiceps, Lactarius lactarius, Secutor insidiator, Stolephorus indicus, Thryssa mystax, Leiognathus brevirostris, Encrasicholina devisi, Lepturacanthus savala, Ambassis ambassis, Otolithes cuvieri, Stolephorus waitei, Lagocephalus inermis, Gazza minuta, Sphyraena forsteri, Uroteuthis duvauceli, Apogon fasciatus, Sphyraena jello, Stolephorus commersonnii, Otolithes ruber, Thryssa puruva, Lagocephalus spadiceus, Gerres filamentosus,* *Metapeneaeus dobsoni, Metapenaeus affinis, Metapeneaeus monoceros Portunus pelagicus, Portunus sanguinolentus* and *Charybdis lucifera* showed more than 50% exclusion (Table 8.3). Out of total 77 species, 6 species showed exclusion up to 50% and 13 species *viz., Alectis ciliaris, Congresox talabonoides, Cynoglossus bilineatus, Filimanus heptadactylus, Johnius carouna, Kathala axillaris, Leiognathus splendens, Oxyurichthys paulae, Secutor ruconius, Sillago sihama, Thryssa malabarica, Upeneus sulphureus* and *Turitella acutangula* did not show any exclusion from this BRD.

Juveniles of *Pampus argenteus* and *Uroteuthis duvauceli* were excluded at rates of 97.34% and 65.09%, respectively. Occasional clogging of the separator panel was observed in the case of Separator panel-40S, which could be contributing to the poor sorting effect (Fig 8.1).

Among the species groups encountered, finfishes showed an overall exclusion of 82.19%, followed by crabs (69.0%), cephalopods (62.61%), shrimps (52.71%) and miscellaneous species (38.97%) (Table 8.2).

Fig 8.1 Blockage in the Separator panel-40 S

Table 8.3: Species-wise exclusion rate in Separator panel-40S

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
Caranx sexfasciatus	0.030	0.00	100.00
Dussumieria acuta	0.070	0.00	100.00
Epinepheleus diacanthus	0.020	0.00	100.00
Fenneropenaeus indicus	0.010	0.00	100.00
Gerres oyena	0.010	0.00	100.00
Ilisha filigera	0.020	0.00	100.00
Johnius amblycephalus	0.050	0.00	100.00
Liza parsia	0.025	0.00	100.00
Mene maculata	0.215	0.00	100.00
Nemipterus mesoprion	0.010	0.00	100.00
Parastromateus niger	0.945	0.00	100.00
Pellona ditchella	0.050	0.00	100.00
Platycephalus indicus	0.025	0.00	100.00
Sardinella albella	0.010	0.00	100.00
Sardinella fimbriatus	0.010	0.00	100.00
Scomberoides tala	0.040	0.00	100.00
Scylla serrata	0.250	0.00	100.00
Selar crumenophthalmus	0.250	0.00	100.00
Terapon jarbua	0.025	0.00	100.00
Uroconger lepturus	0.035	0.00	100.00
Valamugil cunnesius	0.215	0.00	100.00
Valamugil speigleri	0.030	0.00	100.00
Rastrelliger kanagurta	1.615	1.86	98.14
Pampus argenteus	5.188	2.66	97.34
Alepes djedaba	0.400	7.50	92.50
Siganus canaliculatus	0.105	9.52	90.48
Scomberomorus commersoni	0.140	10.71	89.29
Leiognathus equulus	0.081	13.58	86.42
Megalaspis cordyla	7.715	15.42	84.58
Leiognathus dussumieri	2.940	18.20	81.80
Sardinella longiceps	5.185	18.51	81.49
Charybdis lucifera	0.025	20.00	80.00

Lactarius lactarius	0.098	23.47	76.53
Portunus sanguinolentus	0.960	24.48	75.52
Secutor insidiator	0.620	25.00	75.00
Stolephorus indicus	0.100	25.00	75.00
Thryssa mystax	2.055	27.49	72.51
Leiognathus brevirostris	0.018	27.78	72.22
Encrasicholina devisi	0.035	28.57	71.43
Lepturacanthus savala	0.790	29.75	70.25
Ambassis ambassis	0.415	31.33	68.67
Otolithes cuvieri	0.460	32.61	67.39
Stolephorus waitei	0.272	33.09	66.91
Lagocephalus inermis	0.015	33.33	66.67
Gazza minuta	0.023	34.78	65.22
Sphyraena forsteri	0.115	34.78	65.22
Uroteuthis duvauceli	2.220	34.91	65.09
Apogon fasciatus	0.032	37.50	62.50
Sphyraena jello	0.165	39.39	60.61
Metapenaeus affinis	0.050	40.00	60.00
Stolephorus commersonnii	0.505	40.59	59.41
Otolithes ruber	1.395	40.86	59.14
Portunus pelagicus	0.602	41.86	58.14
Thryssa puruva	0.210	42.86	57.14
Lagocephalus spadiceus	0.660	44.70	55.30
Metapeneaeus monoceros	0.055	45.45	54.55
Gerres filamentosus	0.065	46.15	53.85
Metapeneaeus dobsoni	3.550	46.48	53.52
Encrasicholina heteroloba	0.006	50.00	50.00
Oratosquilla nepa.	0.530	50.00	50.00
Opisthopterus tardoore	0.300	56.67	43.33
Parapenaeopsis stylifera	0.215	65.12	34.88
Sepiella inermis	0.160	71.88	28.13
Leiognathus bindus	0.036	72.22	27.78
Alectis ciliaris	0.100	100.00	0.00
Miscellaneous species	0.348	100.00	0.00
All species	**42.92**	**22.73**	**77.27**

8.3.2 Performance of Separator panel-60D

The total catch obtained during this period using Separator panel-60D BRD was 35.25 kg with an average CPUE of 3.54 kg.h^{-1} of which 35.55% was retained in the codend and 64.45% was excluded. Excluded bycatch (catch other than shrimp) from this BRD was 66.64% of total catch and the shrimp loss was 43.99%. The overall catch during this period consisted of 66 species of finfishes, 5 species of shrimps, 4 species of crabs, 2 species of cephalopods, 3 species of molluscan shells and 1 species of stomatopod (Table 8.1).

Among the species excluded from the separator panel-60D, 19 species *viz., Mene maculata, Acanthurus* sp.*, Saurida undosquamis, Therapon jarbua, Drepene punctata, Sphyraena fosteri, Ilisha filigera, Pellona ditchella, Encrassicholina heteroloba, Johnius dussumieri, Sardinella fimbriatus, Scomberoides tala, Sardinella albella, Secutor ruconius, Sillago sihama, Alectis indicus, cynoglossus macrostomus, Pelatus quadrilineatus* and *Bufunaria echiniata* showed 100% exclusion. Twenty three species *viz., Parastromateus niger, Secutor insularis, Megalaspis cordyla, Alepes djedaba, Anadontostoma chacunda, Leiognathus dussumieri, Platycephalus indicus, Stolephorus indicus, Lactarius lactarius, Sphyraena jello, Uroteuthis duvauceli, Pampus argenteus, Johnius carouna, Rastrelliger kanagurta, Scomberomorus commersoni, Stolephorus waitei, Stolephorus commersonnii, Thryssa mystax, Secutor insidiator, Sardinella longiceps, Ambassis ambassis, Metapenaeus affinis,* and *Metapeneaeus monoceros,* showed more than 50% exclusion from this BRD (Table 8.4) and 25 species showed upto 50% exclusion. Out of total 81 species 14 species *viz., Apogon* *fasciatus, Caranx ignobilis, Thryssa dussumieri, Thryssa malabarica Leiognathus brevirostris, Encrassicholina punctifer, Upeneus sulphureus Upeneus vittatus, Lagocephalus inermis, Oxyurichthys paulae, Charybdis lucifera, Fenneropenaeus indicus, Dolcia ovis* and *Turitella attenuata* did not show any exclusion through this BRD. Juveniles of *Pampus argenteus* and *Uroteuthis duvauceli* were found to be excluded at levels exceeding 73.15% and 75.86% respectively.

Among the species groups encountered, finfishes showed an overall exclusion of 69.72%, followed by cephalopods (67.55%), shrimps (43.99%) crabs (39.16%) and miscellaneous species (12.22%) (Table 8.2).

Table 8.4: Species-wise exclusion rate from Separator panel-60D

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
Mene maculata	0.460	0.00	100.00
Acanthurus spp.	0.170	0.00	100.00
Saurida undosquamis	0.100	0.00	100.00
Terapon jarbua	0.075	0.00	100.00
Drepene punctatus	0.050	0.00	100.00
Sphyraena forsteri	0.040	0.00	100.00
Ilisha filigera	0.030	0.00	100.00
Bufonaria echinata	0.025	0.00	100.00
Pellona ditchella	0.020	0.00	100.00
Encrassicholina heteroloba	0.010	0.00	100.00
Johnius dussumieri.	0.010	0.00	100.00
Sardinella fimbriatus	0.010	0.00	100.00
Scomberoides tala	0.010	0.00	100.00
Alectis indicus	0.008	0.00	100.00
Cynoglossus macrostomus	0.005	0.00	100.00
Pelates quadrilineatus	0.005	0.00	100.00
Sardinella albella	0.005	0.00	100.00
Secutor ruconius	0.005	0.00	100.00

Sillago sihama	0.005	0.00	100.00
Parastromateus niger	2.570	2.72	97.28
Metapenaeus affinis	0.038	7.89	92.11
Secutor insularis	0.045	11.11	88.89
Megalaspis cordyla	3.435	11.21	88.79
Alepes djedaba	2.375	14.11	85.89
Anadontostoma chacunda	0.065	15.38	84.62
Leiognathus dussumieri	0.065	15.38	84.62
Platycephalus indicus	0.090	16.67	83.33
Stolephorus indicus	0.125	20.00	80.00
Metapeneaeus monoceros	0.013	23.08	76.92
Sphyraena jello	0.125	24.00	76.00
Uroteuthis duvauceli	1.160	24.14	75.86
Pampus argenteus	3.985	26.85	73.15
Johnius carouna	0.350	27.14	72.86
Rastrelliger kanagurta	0.835	27.54	72.46
Scomberomorus commersoni	0.320	28.13	71.88
Stolephorus waitei	0.250	29.20	70.80
Stolephorus commersonnii	0.325	33.85	66.15
Thryssa mystax	2.090	35.65	64.35
Secutor insidiator	2.083	36.39	63.61
Sardinella longiceps	2.825	37.88	62.12
Ambassis ambassis	0.225	44.44	55.56
Lactarius lactarius	0.045	44.44	55.56
Siganus canaliculatus	0.020	50.00	50.00
Lepturacanthus savala	0.675	53.33	46.67
Johnius amblycephalus	0.220	54.55	45.45
Otolithes cuvieri	0.045	55.56	44.44
Encrasicholina devisi	0.076	56.58	43.42
Metapenaeus dobsoni	3.225	56.59	43.41
Gazza minuta	0.353	56.66	43.34
Gerres filamentosus	0.070	57.14	42.86
Parapenaeopsis stylifera	0.131	58.02	41.98
Portunus sanguinolentus	1.100	59.09	40.91
Portunus pelagicus	0.250	60.00	40.00
Scomberoides lysan	0.025	60.00	40.00
Scomberomorus guttatus	0.025	60.00	40.00

Lagocephalus spadiceus	1.115	60.99	39.01
Leiognathus splendens	0.028	64.29	35.71
Opisthopterus tardoore	0.160	65.63	34.38
Leiognathus bindus	0.073	65.75	34.25
Thryssa puruva	0.125	68.00	32.00
Valamugil cunnesius	0.095	73.68	26.32
Otolithes ruber	1.435	76.31	23.69
Dussumieria acuta	0.140	78.57	21.43
Leiognathus equulus	0.063	79.37	20.63
Charybdis natator	0.050	80.00	20.00
Oratosquilla nepa.	0.665	87.22	12.78
Sepiella inermis	0.165	90.91	9.09
Apogon fasciatus	0.008	100.00	0.00
Miscellaneous species	0.434	100.00	0.00
All species	**35.25**	**35.55**	**64.45**

Fig 8.2 Operation of Separator panel-60D, off Cochin

Fig 8.3 A view of catch excluded from Separator panel-40S

8.3.3 Statistical analysis

Statistical analysis using Student's *t*-test has shown that the difference in exclusion rates, in respect of *Lactarius lactarius* (P=0.037), *Opisthopterus tardoore* (P=0.019), *Siganus canaliculatus* (P=0.028) and *Valamugil cunnesius* (P=0.020) was significantly higher in Separator panel-40S, compared to Separator panel-60D.

8.3.4 Selectivity analysis

The results of selectivity analysis of Separator panel-40S and Separator panel-60 D in respect of six species *viz.*, *Lepturacanthus savala, , Otolithes ruber, Stolephorus commersoni, Uroteuthis duvauceli, Metapenaeus dobsoni* and *Sardinella longiceps* are presented in Table 8.5 and Figures 8.4 to 8.9 respectively.

L_{50} values lower than length at first maturity (L_m) values indicate better exclusion opportunities for immature fishes below L_m, as the mid-length classes were plotted against excluded fractions in the selectivity estimates. L_{50} values in respect of *Otolithes ruber* and *Uroteuthis duvauceli* were found to be lower than L_m values, for Separator panel-40S and L_{50} values in respect of *Metapenaeus dobsoni* and *Sardinella longiceps* were lower than L_m values for Separator panel-60D. Juvenile exclusion in respect of *Otolithes ruber* and *Stolephorus commersonii* was comparatively better through Separator panel-40S, as indicated by lower L_{50} values.

Table 8.5: Selectivity parameters for Separator Panel BRDs

Species	Separator panel BRD	L_{25}	L_{50}	L_{75}	Selection range, mm	Length at first maturity, mm
Lepturacanthus savala	Separator panel-40S	207.84	263.60	319.37	111.53	NA
Metapenaeus dobsoni	Separator panel-60D	46.02	63.08	80.14	34.12	88.6 (Rao,1967)
Otolithes ruber	Separator panel-40S	83.24	118.97	154.70	71.45	221-230 (Fishbase, 2008)
	Separator panel-60D	220.18	359.24	498.31	278.13	
Sardinella longiceps	Separator panel-60D	0.52	54.38	108.23	107.71	150-162 (Fishbase, 2008)
Stolephorus commersonii	Separator panel-40S	76.34	99.56	122.78	46.44	NA
	Separator panel-60D	115.07	142.59	170.11	55.04	
Uroteuthis duvauceli	Separator panel-40S	10.76	28.70	46.65	35.88	110-120 (Roper *et al.*, 1984)

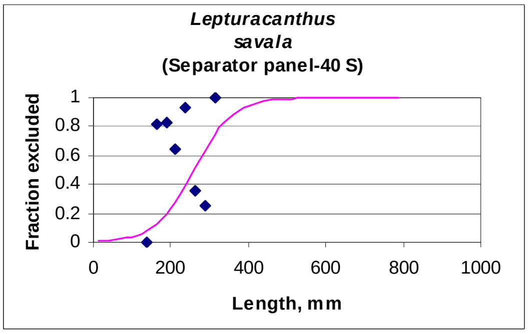


Fig. 8.4 Selectivity curve for *Lepturacanthus savala*

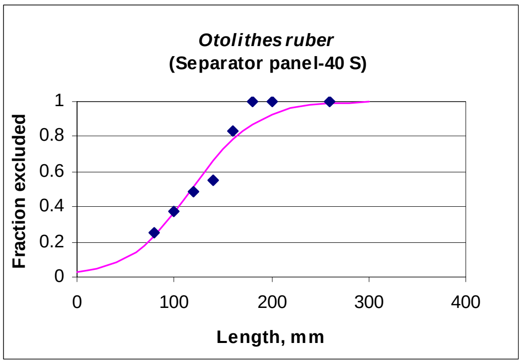


Fig. 8.5 Selectivity curves for *Otolithes ruber*

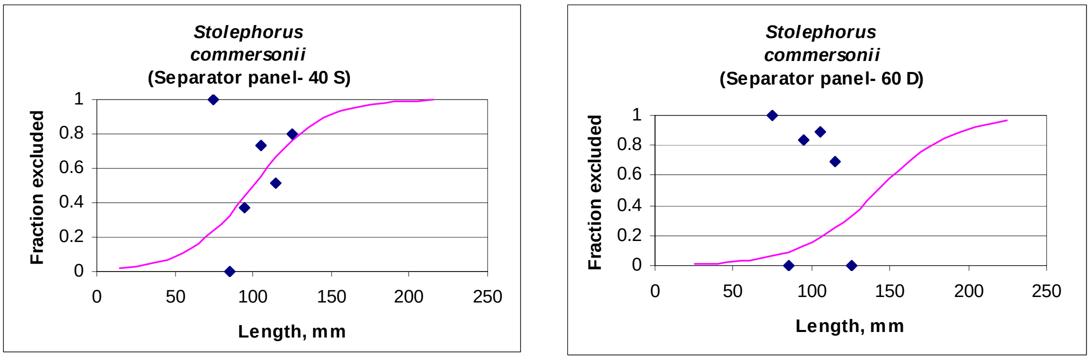


Fig. 8.6 Selectivity curves for *Stolephorus commersoni*

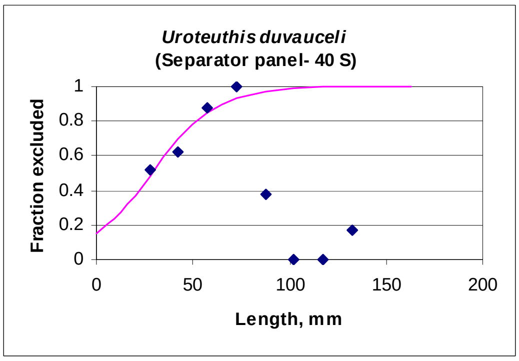


Fig. 8.7 Selectivity curve for *Uroteuthis duvauceli*

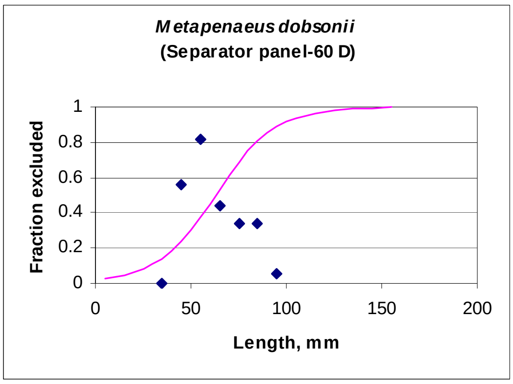


Fig. 8.8 Selectivity curve for *Metapenaeus dobsoni*

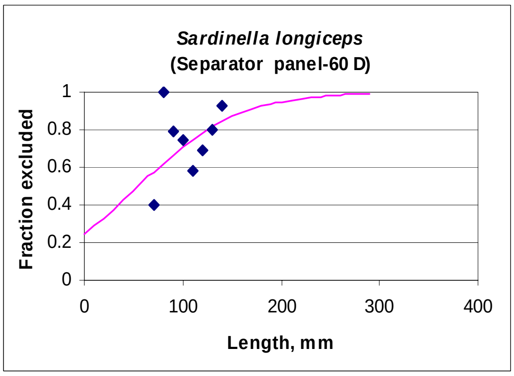


Fig. 8.9 Selectivity curve for *Sardinella longiceps*

Length class-wise exclusion characteristics of *Otolithes ruber, Sardinella longiceps* and *Stolephorus waitei* are given in Fig. 8.10 to 8.12. In Separator panel-40S, length classes of *Otolithes ruber* from 71 to 170 mm showed an increasing trend in exclusion from 25 to 83% and length classes from 171 to 210 mm were fully excluded. In Separator panel-60D, length classes of *Otolithes ruber* from 71 to 110 mm were fully retained, length classes of 111 to 170 mm were retained in the range of 80 to 90% and 171-

190 mm length class was fully excluded. In Separator panel-40S, length classes of *Sardinella longiceps* from 81 to 140 mm showed retention in the range of 6 to 38% and length classes from 141 to 200 mm were 100% excluded. In Separator panel-60D, length classes of *Sardinella longiceps* from 86 to 145 mm were retained in the range of 8 to 42% and length classes from 146 to 205 mm showed 100% exclusion. Length classes of *Stolephorus waitei* from 51 to 85 mm in Separator panel-40S showed an increasing trend in exclusion at levels from 70 to 90% and length classes from 86 to 95 mm were fully excluded. In Separator panel-60D, length classes of *Stolephorus waitei* from 41 to 95 mm were excluded in the range of 62 to 80%.

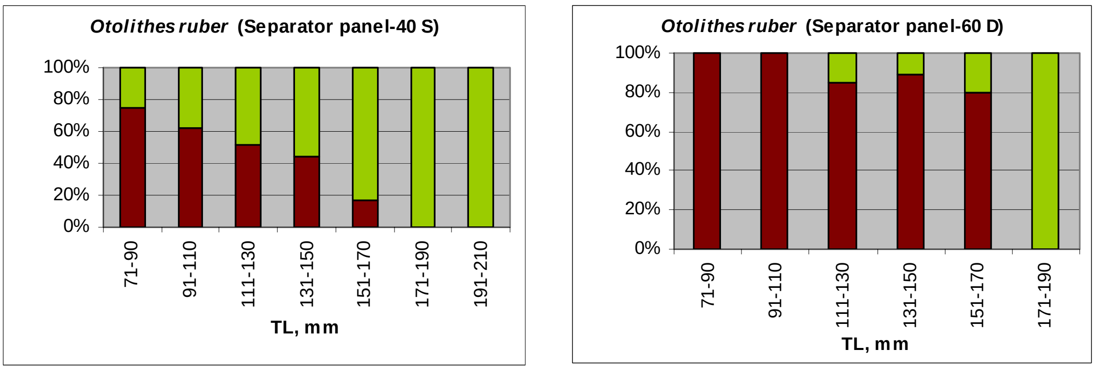


Fig. 8.10 Length-wise retention and exclusion of *Otolithes ruber*

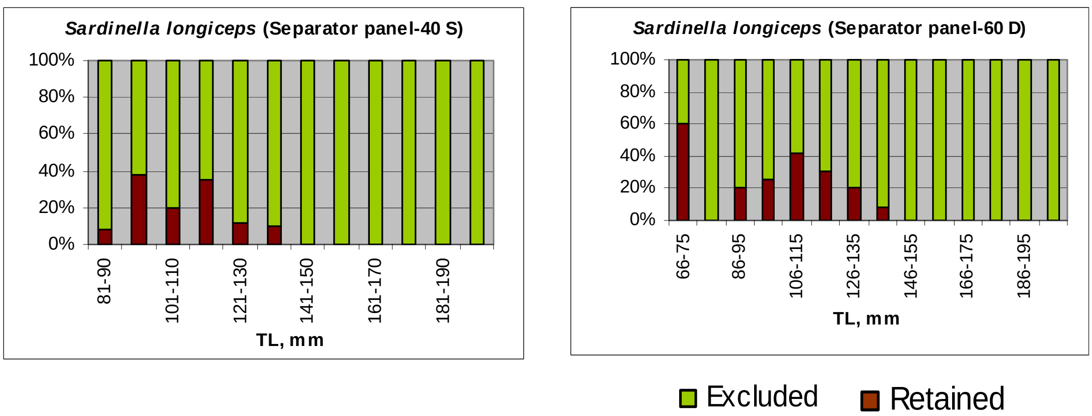


Fig. 8.11 Length-wise retention and exclusion of *Sardinella longiceps*

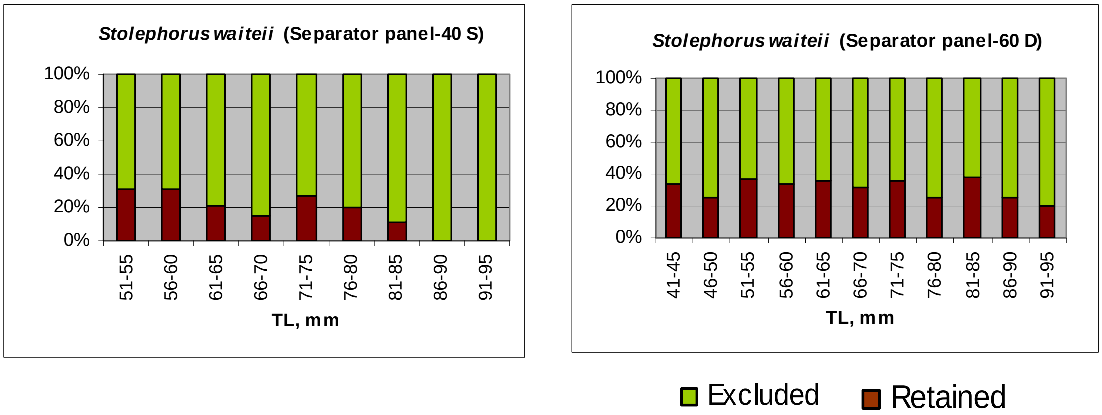


Fig. 8.12 Length-wise retention and exclusion of *Stolephorus waitei*

8.3.5 Catch diversity analysis

The results of diversity analysis has shown that the catch excluded from the Separator panel-40S was more diverse in terms of S, d, J’, H, H’ and N1. Simpson’s dominance index (λ') was observed equal in both the BRDs. Simpson’s evenness measure (E1/D) was higher in separator panel-60D. Diversity parameters and the k-dominance curve for the Separator panel BRDs are given in Table 8.6 and Fig. 8.12, respectively.

The cumulative ranked abundances of the species obtained from the k-dominance curve when plotted against the species rank, the curve for both the Separator panel BRDs starting from same point, indicating similar diversity in excluded catch.

Table 8.6: Mean diversity indices of species excluded through Separator panel BRDs

Separator panel BRDs	S	d	J'	H	H'	N1	λ'	E1/D
Separator panel-40S	57	9.72	0.66	2.50	2.68	14.61	0.12	0.15
Separator panel-60D	53	9.22	0.66	2.43	2.64	13.99	0.12	0.16

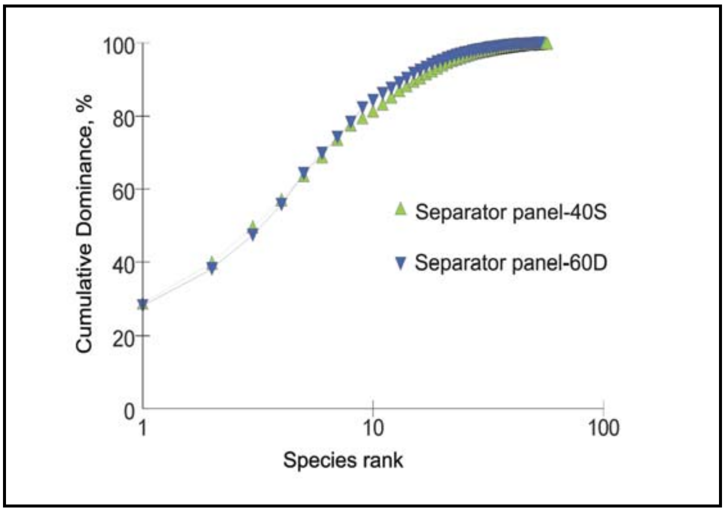


Fig. 8.13 k-dominance curve showing the diversity of excluded catch from Separator panel BRDs

8.4 Conclusion

The two designs of separator panels evaluated did not give promising results. Though bycatch reduction ranging from 67 to 80% was realised, it was accompanied by unacceptably high loss of target catch (44-53%). Exclusion in excess of 50% was observed in respect of 58 species in Separator panel-40S and in respect of 42 species in Separator panel-60D. Selectivity analysis gave comparatively better juvenile exclusion in respect of Separator panel-40S BRD while catch diversity analysis showed similar results in both the Separator panel BRDs. High loss of target catch and vulnerability to clogging leading to ineffectual sorting, the present design of Separator panel BRDs will not be appropriate for Indian fishery conditions.

Summary and Recommendations

Trawling, though an efficient method of fishing, is known to be one of the most non-selective methods of fish capture. The bulk of the wild caught penaeid shrimps landed in India are caught by trawling. In addition to shrimps, the trawler fleet also catches considerable amount of non-shrimp resources. The term bycatch means that portion of the catch other than target species caught while fishing, which are either retained or discarded. Annual bycatch in the world fisheries was estimated to be about 28.7 million tonnes in 1994, of which 27.0 million tonnes were discarded. Shrimp trawling accounted for 37.2% (9.5 million tonnes) of the total world bycatch. Annual world bycatch discards has been re-assessed at 7.3 million tonnes, in 2004. In India, the bycatch in shrimp trawling accounts for 70 to 90% of the catch of which 40% are juveniles.

Bycatch discards is a serious problem leading to the depletion of the resources and negative impacts on biodiversity. In order to minimize this problem, trawling has to be made more selective by incorporating Bycatch Reduction Devices (BRDs). Efforts towards reducing bycatch take advantage of the variation in size of the species and their differential behaviour within and in the proximity of the fishing gear. There are several advantages in using BRDs in shrimp trawling. BRDs reduce the negative impacts of shrimp trawling on marine community. Fishers could benefit economically from higher catch value due to improved catch quality, shorter sorting time, lower fuel costs, and longer tow duration. Adoption of BRDs by fishers would forestall criticism by conservation groups against trawling. The soft Bycatch

Reduction Devices uses soft structures made of netting and rope frames instead of rigid grids, prevalent in hard BRDs, for separating and excluding bycatch. The content of the thesis is organized into 8 Chapters.

Chapter-1

In the first Chapter, an introduction to the topic of study, highlighting its relevance, objectives of the study and a review on Bycatch Reduction Devices used in trawling around the world in general and soft bycatch reduction devices in particular are presented. The main objectives of the study included (i) design and development of soft bycatch reduction devices, incorporating flexible materials, for selective trawling, (ii) study of the existing trawl systems and bycatch issues, off south Kerala, and (iii) comparative field evaluation of prototype BRDs and statistical analysis of data, in order to evolve most appropriate BRD for the small-scale mechanised trawl sector. About twenty soft BRDs are in operation either commercially or on experimental basis around the world. Based on the structure and principles of operation soft BRDs are classified into five categories *viz*., (i) Escape windows (e.g. Square Mesh Window and Rope BRD), (ii) Radial Escapement Section without Funnel (e.g. Trawl Flow Regulative Ecological Friendly Netting Device), (iii) Radial Escapement Section with Funnel (e.g. Radial Escapement Device and Monofilament BRD), (iv) BRDs with differently shaped slits (e.g. Bigeye BRD, Lake Arthur BRD and V-cut BRD) and (v) BRDs with guiding or separator panel (e.g. Separator panel BRD, Sieve net and Morrison Soft TED).

Chapter-2

The second Chapter deals with the materials and methods used for the conduct of investigations on soft bycatch reduction devices for selective trawling, during 2004-2007. Details of soft Bycatch Reduction Devices selected for the study, prototype design and fabrication, trawls and accessories, research vessels, fishing area, field trials, data collection and analysis are elaborated in this Chapter. Soft BRD designs evaluated were Radial Escapement Device, Bigeye BRD, Sieve net BRD and Separator panel BRD. The field trials of BRDs were conducted using commercial shrimp trawl designs of 28.8 m, 29.0 m and 32.4 m head rope length, rigged with V-form otter boards of 80 kg each, in the traditional fishing grounds at a depth range of 9-32 m, off Cochin, onboard research vessels of Central Institute of Fisheries Technology, *viz*., *MFB Matsyakumari* (17.5 m LOA; 57.17 GRT; 277 bhp @ 1000 rpm) and *MFV Sagar Shakti* (15.24 m LOA; 30 GRT; 223 bhp @ 1800 rpm), using statistically designed experiments. Species level data was used for analysis of selectivity and exclusion characteristics of soft BRDs. Student's *t*-test was used to evaluate the significance of difference in exclusion rates between BRDs. Selectivity analysis of soft BRDs was conducted following methods adapted from Sparre *et al*. (1989) and Wileman *et al*. (1996) and BRD-wise diversity analysis of excluded catch was performed using PRIMER Ver. 5.2.9 (Plymouth Routines in multivariate Ecological Research) (Clark and Warwick, 2001).

Chapter-3

Chapter-3 deals with the present status of trawlers, trawl nets and accessories and bycatch issues related to trawling in South Kerala. Four categories of trawlers *viz*., (i) small vessels up to 9.7 m L_{OA} with 90 hp @ 2000 rpm engine; (ii) medium sized vessels of 9.8-12.1 m L_{OA} with 100-107 hp @ 2000 rpm engine; (iii) medium sized vessels of 12.1-16.7 m L_{OA} with 124-158 hp @ 2000 rpm engine; and (iv) large trawlers above 16.7 m with 177 hp @ 2000 rpm engine were identified. There has been a shift towards steel as the preferred boat building material due to scarcity of good quality wood and its high cost. Most trawlers based at Quilon were engaged in multi-day fishing targeting fish, squids and cuttlefish in addition to shrimps. In view of this multi-species nature of operations, different designs of trawl nets were kept onboard. The large vessels carry between 12 and 15 nets and small vessels carry up to 8 nets, during fishing trips. Ten different designs of trawl nets were observed to be in use in the study area. Among these, five were shrimp trawls, three were fish trawls, one was cephalopod trawl and one was gastropod trawl.

Discard rate by trawlers based at Quilon ranged between 20 and 70% and consisted of 50% of juveniles and sub adults. Bycatch included finfishes such as sciaenids, *Lagocephalus* sp., C*ynoglossus* spp., *Muraenosox* sp., *Conger* sp., *Platycephalus* sp., carangids, cardinal fishes, damsels, leather jackets, sardines, threadfin breams and lizard fishes, Mollsucan species such as *Anadara granosa, Babylonia* spp., *Turritella* spp., *Xancus pyrum* and crustaceans such as *Charybdis cruciata, Charybdis feriatus, Charybdis natator*, *Portunus sanguinolentus*, *Portunus pelagicus, Calappa lophos*

Porphyra sp., stomatopods and echinoderms. The use of Bycatch Reduction Devices was not found to be prevalent in trawl fisheries of southern Kerala.

Chapter-4

Chapter-4 deals with the performance evaluation of Radial Escapement Devices. The Radial Escapement device consists of a small mesh funnel surrounded by a radial section of large square meshes and is positioned between belly and codend of the shrimp trawl. Two design variations of Radial Escapement Device having different mesh sizes *viz*., RED with 150 mm square mesh escapement section (RED-150) and RED with 100 mm square mesh escapement section (RED-100) were evaluated, in terms of selectivity and bycatch exclusion characteristics.

The first set of experiments was conducted with RED-150 using covered codend method. Total catch obtained was 257.67 kg of which 77.61% was retained in the codend and 22.39% was excluded. Seven species of finfishes *viz*., *Uroconger lepturus, Nibea maculata, Scatophagus argus, Selar crumenophthalmus, Trypauchen vagina, Leiognathus brevirostris* and *Penaeus semisulcatus* showed 100% exclusion and eight species showed greater than 50% exclusion. The bycatch exclusion (catch other than shrimps) through RED-150 was 26.04% and the shrimp loss was 8.32%.

The second set of experiments were conducted using RED-100 and RED-150, using modified covered codend. In RED-100, a total catch of 86.65 kg was obtained during the experiments, of which 79.32% was retained in the codend and 20.68% was excluded. Nine species including seven species of finfishes *viz*., *Otolithes ruber, Uroconger lepturus, Selar crumenophthalmus, Cynoglossus biliniatus, Terapon theraps, Leiognathus brevirostris* and *Lagocephalus spadiceus* and two species of crabs *viz*., *Scylla serrata* and *Portunus sanguinolentus* showed 100% exclusion and an additional 14 species showed greater than 50% exclusion, through the RED-100. The excluded bycatch (catch other than shrimp) from RED-100 was 20.09% and the shrimp loss was 24.29%. In RED-150, total catch obtained was 87.69 kg of which 84.40% was retained in the codend and 15.60% was excluded. Nine species of finfishes *viz*., *Valamugil cunnesius, Dasciana albida, Scatophagus argus, Terapon jarbua, Anadontostoma chacunda, Valamugil spiegleri, Alectis indicus, Liza subviridis* and *Terapon theraps* showed 100% exclusion and an additional 10 species showed greater than 50% exclusion through RED-150. The excluded bycatch (catch other than shrimps) from this experiment was 14.60% and the shrimp loss was 20.33%. Statistical analysis using Student's *t*-test showed no significant difference ($p>0.05$) in the exclusion rates between the two RED designs. Selectivity and diversity analysis of the excluded catch have indicated comparatively better juvenile exclusion and higher diversity in the excluded catch through RED-100, compared to RED-150.

Chapter 5

Chapter 5 deals with the performance evaluation of Bigeye BRD. Bigeye BRD consists of a simple horizontal slit in the upper part of codend or hind belly, where the opening is maintained by floats and sinkers. Differences in the behaviour of fish and shrimp are utilized in the design of this category of BRDs. Comparative effectiveness of Bigeye BRDs positioned in two locations in the codend were evaluated. The results showed that the Bigeye BRD was more effective when positioned at 1.5 m from the distal end of the codend (Bigeye-1.5) compared to the BRD positioned at 0.5 m from the leading edge of the codend (Bigeye-0.5). The Bigeye-0.5 facilitated exclusion of 6.13% of the total catch of 71.79 kg. No species showed exclusion above 50% levels from this BRD. The bycatch exclusion from this BRD was 7.83% and the shrimp loss was 0.81%. The Bigeye-1.5, facilitated exclusion of 9.17% of the total catch of 81.49 kg, obtained during the experiment. Six species of finfishes *viz*., *Ambassis ambassis, Gerrus limbatus, Mene maculata, Peletus quadrilineatus, Secutor ruconius* and *Valamugil cunnesius* showed 100% exclusion and five species showed greater than 50% exclusion through Bigeye-1.5. The bycatch exclusion from this BRD was 11.42% and the shrimp loss was 2.27%. Statistical analysis using Student's *t*-test showed no significant difference ($p>0.05$) in exclusion of species between the two Bigeye BRDs. Species excluded from Bigeye-1.5 was observed to be more diverse compared to Bigeye-0.5. Selectivity results has indicated comparatively better exclusion of juveniles from Bigeye-0.5 than the Bigeye-1.5 BRD.

Chapter-6

Chapter-6 deals with the comparative performance of Bigeye BRD and Fisheye BRD. Fisheye consists of rigid escape opening fabricated of stainless steel rods, installed in the top side of the codend. Bigeye BRD positioned at 1.5 m from the distal end of codend (Bigeye) and Fisheye BRD with semicircular 300x200 mm exit opening (Fisheye) were evaluated. The overall catch using Bigeye BRD was 234.76 kg, of which 69.44% was retained in the codend and 30.56% was excluded. Ten species of finfishes *viz, Arius jella, Caranx sexfasciatus, Esculosa thoracata, Selar crumenophthalmus, Valamugil speigleri, Gerres limbatus, Thryssa malabarica, Apogon fasciatus, Ilisha filigera* and *Gerres filamentosus* showed 100% exclusion and five species showed greater than 50% exclusion. The excluded bycatch (catch other than shrimp) from this BRD was 32.54% of total catch and the shrimp loss was 4.25%.

The overall catch obtained using Fisheye BRD was about 223.23 kg, of which 41.97% retained in the codend and 58.03% was excluded. Eleven species including ten species of finfishes *viz., Decapterus russelli, Dasciana albida, Anadontostoma chacunda, Pampus chinenesis, Megalaspis cordyla, Thryssa puruva, Johnius amblycephalus, Parastromateus niger, Sillago sihama, Caranx sexfasciatus* and one species of cephalopod (*Sepiella inermis*) showed 100% exclusion. Seventeen species showed greater than 50% exclusion through the Fisheye. Bycatch (catch other than shrimp) exclusion from this BRD was 62.67% and the shrimp loss was 3.79%. Statistical analysis using Student's *t*-test has indicated significant difference in exclusion rates ($p<0.05$) in respect of five species. Diversity analysis indicated excluded catch from Bigeye was more diverse than Fisheye. Selectivity analysis has indicated comparatively higher levels of juvenile exclusion through Fisheye BRD.

Chapter-7

Chapter-7 deals with the performance evaluation of Sieve net BRD. The Sieve net BRD has a netting funnel inside the net to separate target and non-target catch leading to an outlet codend which retain large sized bycatch components and exclude juveniles. Three sets of experiments were conducted using three design variations of Sieve net BRD to study the selectivity and bycatch exclusion characteristics. Designs tested were Sieve net (i) with 60 mm diamond mesh funnel inside the net and 80 mm diamond mesh outlet codend (Sieve net-60 mm), (ii) with 40 mm square mesh funnel inside the net and 60 mm square mesh outlet codend (Sieve net-40 mm) and (iii) with 50 mm diamond mesh funnel inside the net and 60 mm diamond mesh outlet codend (Sieve net-50 mm). The performance of Sieve net-40 mm was not satisfactory and, hence, experiments using this design was not continued. Experiments with Sieve net-60 mm gave a total catch of 244.4 kg, of which 28.52% was retained in the main codend, 57.25% in the outlet codend and 14.23% was excluded. Jellyfish formed a dominant component of the trawl catch during the period of field trials and 98.19% of total jellyfish catch was diverted and retained in the outlet codend. Analysis excluding jellyfish component in the catch, has shown that out of 106.1 kg obtained, 63.33% was retained in the main codend, 3.89% in the outlet codend and 32.78% consisting mostly of juveniles of fishes, was excluded through the meshes of outlet codend. Among the species excluded, two species of finfishes (*Mene maculata* and *Cynoglossus arel*) showed 100% exclusion and twelve species showed exclusion rates above 50%. Excluded bycatch (catch other than shrimp) was 14.74% (36.45% when jellyfish is excluded from the analysis) and shrimp loss was 4.47%. In the outlet codend of 80 mm mesh, 4 species *viz., Pampus argenteus, Caranx ignobilis, Charybdis feriatus* and 1 species of ray showed 100% retention.

During experiments with Sieve net-50 mm, total catch obtained was 290.03 kg of which 60.65% was retained in the main codend, 9.80% in the outlet codend and 29.55%, mostly juveniles of fishes, was excluded through the meshes of the outlet codend. Twelve species including 9 finfishes *viz*., *Alectis ciliaris, Alectis indicus, Arius jella, Drepena punctuata, Epinepheleus diacanthus, Leiognathus dussumieri, Scombroides lysan, Scomberomorus commerson* and *Scomberomorus guttatus*, 2 species of molluscs (*Bufunaria echiniata* and *Turritella acutangula*) and 1 species of crab (*Charybdis natator*) showed 100% exclusion. In the 60 mm outlet codend, 4 species *viz., Charybdis lucifera, Charybdis feriatus, Carangoides armatus* and *Upeneus sulphureus* showed 100% retention. Excluded bycatch (catch other than shrimp) through Sieve net-50 mm was 33.09% of total bycatch. The Sieve net-50 mm excluded more than 90% of the bycatch of gastropod and more than 70% of squilla (*Oratosquilla nepa*). However, shrimp loss was nearly 20%. Statistical analysis using Student's *t*-test has shown significantly high exclusion rates ($p<0.05$) in respect of 12 species from Sieve net-60 mm and in respect of 11 species from Sieve net-50 mm. Catch diversity analysis indicated that excluded catch from Sieve net-50 mm was more diverse compared to Sieve net-60 mm.

Chapter-8

The final Chapter deals with the performance of Separator panel BRDs. Separator panel physically separate the catch according to the size, with the use of appropriate mesh size in the netting panel. Shrimps and small-sized catch components pass through the panel meshes to the codend while bycatch such as fishes and sea turtles are directed towards the exit opening. Comparative evaluation of two designs of Separator panel BRDs having 40 mm square mesh panel (Separator panel-40S) and 60 mm diamond mesh panel (Separator panel-60D), attached in the throat section of the net at 45° angle was conducted in this study. In the Separator panel-40S, the total catch was 42.92 kg of which 22.73% was retained in the codend and 77.27% was excluded. Twenty-two species showed 100% exclusion, thirty-six species showed more than 50% exclusion. Excluded bycatch (catch other than shrimp) from this BRD was 79.71% and shrimp loss was very high (52.71%).

During field trials with Separator panel-60 mm, a total catch of 35.25 kg was obtained, of which 35.55% was retained in the codend and 64.45% was excluded. Nineteen species showed 100% exclusion, 23 species showed more than 50% exclusion. The bycatch exclusion from this Separator panel-60 mm was 66.64% and shrimp loss was 43.99%. Statistical analysis using Student's *t*-test showed significant levels ($p<0.05$) of exclusion in respect of four species. Selectivity analysis indicated comparatively exclusion of juveniles, in respect of Separator panel-40 mm and catch diversity analysis showed similar results in both the Separator panel BRDs.

Recommendations

- Soft BRDs have the advantages such as simplicity in design, ease of construction and installation, low cost, ease of handling and safety in operation onboard and hence they may be popularized for minimizing the impact of trawling on long-term sustainability of trawl-caught resources and biodiversity.
- The designs of Radial Escapement Devices and Separator panel BRDs evaluated in the present study were not found to be appropriate for Indian fisheries conditions, primarily due to high levels of target catch loss.
- Bigeye BRD positioned at 1.5 m from the distal end of the trawl codend is a soft BRD suitable for bycatch reduction in commercial shrimp trawls with minimal shrimp loss. The design is very simple and can be easily implemented onboard by fishermen themselves.
- Sieve net BRD with 60 mm diamond mesh funnel and 80 mm diamond mesh outlet codend was found to be an efficient device for bycatch reduction in multi-species trawl fishery and may be popularized among trawler fishermen. It excludes juveniles of fishes while retaining shrimps and large sized high value bycatch components.

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