Final Report on ICAR Ad-hoc Project

Bycatch Reduction Devices
for Selective Shrimp Trawling

Central Institute of Fisheries Technology
(Indian Council of Agricultural Research)
Cochin India

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Bycatch Reduction Devices for Selective Shrimp Trawling

(Project Code No. 0644003)

Principal Investigator

Dr. M.R. Boopendranath

Co-Investigator

Dr. P. Pravin

Sr. Research Fellows

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Central Institute of Fisheries Technology

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"Present exploitation patterns are unsustainable…Fishing down food webs (that is, at lower trophic levels) leads at first to increasing catches, then to a phase transition associated with stagnating or declining catches."

- Fishing Down Marine Food Webs (D. Pauly, Christensen, J. Dalsgaard, R. Froese and F. Torres), Science 279, February 1998: 861-863

"Our data highlight the societal consequences of an ongoing erosion of diversity that appears to be accelerating on a global scale. This trend is of serious concern because it projects the global collapse of all taxa currently fished by the mid–21st century"

"Our analyses suggest that business as usual would foreshadow serious threats to global food security, coastal water quality, and ecosystem stability, affecting current and future generations."

- Impacts of Biodiversity Loss on Ocean Ecosystem Services (Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi , S.R., Sala, E., Selkoe, K., Stachowicz, J.J., Watson, R.), Science 314, November 2006: 787-790

"The right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources"

- Code of Conduct for Responsible Fisheries, Article 6 General Principles, Food and Agriculture Organization of the United Nations, 1995.

Contents

Foreword

Commercial fishing in India is generally shrimp oriented and large quantities of finfish bycatch including significant amount of juveniles are landed during shrimp trawling. In the context of the current emphasis on responsible fishing, this is not acceptable. Central Institute of Fisheries Technology has done pioneering work in the design and development as well as popularization of shrimp trawls and accessories like otter boards and flexible sheer devices in India. In recent years, the Institute has been focussing attention on developing responsible fishing techniques and practices, in order to minimise the ecological and environmental impacts of fishing. Improving the selectivity of fishing gear systems is one of the priority areas in fisheries research, globally. The Institute has developed an indigenous Turtle Excluder Device (CIFT-TED) which is a specialized form of bycatch reduction device for protecting sea turtles. This device is for use by the commercial trawling industry in order to prevent incidental death of sea turtles in trawl nets.

Development of selective shrimp trawls which catch shrimps and exclude non-shrimp resources will significantly support long-term sustainability of non-shrimp fishery resources and protection of biodiversity. The work carried out under the Ad-hoc Research Scheme under the A.P. Cess Fund of ICAR titled *Bycatch Reduction Devices for Selective Shrimp Trawling* conducted at Central Institute of Fisheries Technology, Cochin, from 3.5.2004 to 2.8.2007, assumes special significance in this context.

A number of bycatch reduction devices with potential for adoption by the commercial shrimp trawling industry have been developed under the project. If and when adopted by the industry, these will reduce the negative impacts of shrimp trawling on marine community, including incidental mortality of vulnerable and endangered species. It is pertinent to mention here that the CIFT research team consisting of Dr. M.R. Boopendranath (Principal Scientist and Principal Investigator), Dr. P. Pravin (Sr. Scientist and Co-Investigator), Mr. T.R. Gibinkumar (Sr. Research Fellow) and Mr. S. Sabu (Sr. Research Fellow) of Fishing Technology Division, has won the coveted International Smart Gear Award-2005, in the category 'Other Non-target Species (Including fish), for one of the bycatch reduction concepts developed under the project. The World Wildlife Fund (WWF) and its partners instituted this award to find solutions for the problem of accidental catch of non-target species in order to reverse the decline of vulnerable species accidentally caught in nets and other fishing gears. The award has been a major fillip to CIFT's efforts in promoting responsible fishing in India and has brought both national and international acclaim for the Institute's effort in fisheries resource conservation.

The research team has done commendable work under the Project in an area which is of great significance in resource conservation and sustainability in fisheries. It is hoped that the bycatch reduction technologies developed under the project will find immediate application in the conservation of trawl resources in Indian waters and elsewhere in the world. It is also hoped that adoption of the bycatch reduction technologies by the trawler fishermen will be facilitated by introduction of an appropriate regime of legislation, incentives and education. This will need the support of the governments, non-governmental agencies and fishermen cooperatives interested in the sustainability of fisheries ecosystem, in a participatory mode.

Cochin-29
19 May 2008

Dr. K. Devadasan
Director
Central Institute of Fisheries Technology

Preface

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 trawls in general and shrimp trawls in particular are fishing gears of poor selectivity that commonly have an associated catch of non-targeted finfish and miscellaneous invertebrates. In addition to the non-targeted finfishes and invertebrates, bycatch also involve protected and charismatic species like sea turtles and significant quantities of juveniles and sub-adults. While the discards are very less in small trawlers engaged in daily fishing, more discards have been reported from vessels engaged in multi-day fishing, mainly due to the shortage of storage facilities and high-grading. The FAO Code of Conduct for Responsible Fisheries, stresses the need for developing selective fishing gears in order to conserve resources, protect non-targeted resources and endangered species like sea turtles. Trawl fisheries in different parts of the world are now being required to use bycatch reduction technologies and strategies as a result of pressure from conservation groups and legal regimes introduced by the governments. The increasing focus on bycatch reduction and mitigation of ecosystem effects of fishing has resulted in responsible fishing practices, in different parts of the world.

The project on Bycatch Reduction Devices for Selective Shrimp Trawling was formulated and proposed in this context. The project was fully funded under A.P. Cess Fund Ad-hoc Research Scheme of ICAR (Project Code No. 0644003), and operated at the Central Institute of Fisheries Technology, Cochin from 3.5.2004 to 2.8.2007. The Project has resulted in the development of a number of bycatch reduction devices including an International Award winning design (Juvenile Excluder cum Shrimp Sorting Device) which are appropriate for adoption and implementation in trawl fisheries of India and elsewhere in the tropical fisheries of the world. Large-scale adoption of such devices by the trawler fishermen would reduce the negative impacts of shrimp trawling on marine community, including incidental mortality of vulnerable and endangered species. In addition, fishers could benefit economically from higher catch values due to improved catch quality, shorter sorting time, longer tow duration, higher catch and lower fuel costs.

The Project Team takes this opportunity to thank the Council, for the funding support for the project under the A.P. Cess Fund Ad-hoc Research Scheme. We are grateful to Dr. S. Ayyappan, Deputy Director General (Fisheries) and Dr. A.D. Diwan, former Asst. Director General (Marine Fisheries), Indian Council of Agricultural Research for their goodwill and encouragement.

We are most grateful to Dr. K. Devadasan, Director, Central Institute of Fisheries Technology for his invaluable guidance, sustained encouragement in every facet of project activity including those leading to the International Smart Gear Award and for providing all facilities for the operation of the project. We would like to thank Dr. B. Meenakumari, Head of Division (Fishing Technology) for her whole hearted support and facilitation of the project work. We wish to acknowledge Mr. C.O. Mohan, Scientist, for his assistance in the drag calculations of shrimp trawl and bycatch reduction devices. We are grateful to all our fellow scientists in the Fishing Technology Division for their good will and cooperation.

We are grateful to Mr. Anil Agarwal, Principal Scientist (Marine Fisheries) for his good will and sensitive support at critical stages, contributing to the smooth operation of the project.

We wish to acknowledge the skippers and crew members of the research vessels MFB Matsykumari and MFV Sagar Shakthi for their courteous cooperation and support. We also would like to acknowledge the technical, administrative and supporting staff who have contributed to the successful operation and completion of the project, for their good will.

The Principal Investigator and Co-Investigator would like to acknowledge the unstinted support and cooperation given by Mr. T.R. Gibinkumar and Mr. S. Sabu, Sr. Research Fellows, during the entire period of project operations, contributing significantly to its success.

M.R. Boopendranath and **P. Pravin**

19 May 2008

Final Report on ICAR Ad-hoc Project

1.	**Project Title**	:	**Bycatch Reduction Devices for Selective Shrimp Trawling**
2.	**Sanction Order No.**	:	F. No. 4(67) / 2003-ASR-I dated 8. 12. 2003 **Project code: 0644003**
3.	**Date of start**	:	3.5.2004
4.	**Date of termination**	:	2.8.2007
5.	**Institution's Name**	:	Central Institute of Fisheries Technology (CIFT)
	Place	:	Cochin -682 029
	District	:	Ernakulam
	State	:	Kerala
	Division	:	Fishing Technology Division
	Actual location of research scheme	:	Fishing Technology Division Central Institute of Fisheries Technology, P. O. Matsyapuri, Cochin- 682 029, Kerala
6.	**Principal Investigator**		
	Name	:	Dr. M. R. Boopendranath
	Designation	:	Principal Scientist
	Division	:	Fishing Technology Division
	Experience	:	30 years
	Address	:	Central Institute of Fisheries Technology, P. O. Matsyapuri, Cochin- 682 029, Kerala
7.	**Co-Investigator**		
	Name	:	Dr. P. Pravin
	Designation	:	Sr. Scientist
	Division	:	Fishing Technology Division
	Address	:	Central Institute of Fisheries Technology, P. O. Matsyapuri, Cochin- 682 029, Kerala
8.	**Senior Research Fellows**	:	(i) Mr. T.R. Gibin Kumar (ii) Mr. S. Sabu

9. Objectives: :

i. Design, development and evaluation of Bycatch Reduction Devices (BRDs) appropriate for shrimp trawls operated in small-scale mechanized sector;
ii. Development of selective shrimp trawls, incorporating optimized Bycatch Reduction Devices;
iii. Evaluation of the effect of BRD incorporated trawl systems in operational fuel consumption;
iv. Characterization of shrimp trawl bycatch.

10.	**Duration of Scheme**	:	3 Years and 3 Months
11.	**Total cost of the scheme**	:	Rs. 17,23,000/- (Please see Annexure-1 for details)
11.1	**Recurring expenditure**		
11.1.1	**Pay of Officers**	:	
	Year	:	3.5.2004 –2.8.2007

Name of Post	Pay scale	Number of Posts	Total (Rs.)
Senior Research Fellows	Rs.8000+15%HRA (1st & 2nd yr) Rs.9000+15%HRA (from 3rd yr)	Two	752100

11.1.2	**Other recurring expenditure**		
	Year	:	3.5.2004 –2.8.2007
	Recurring contingencies	:	Rs. 308817
	Contract labour	:	Rs. 94380
	Institutional service charges		Rs. 93,000
	Total		Rs. 496197

Year	Fellowship (Rs.)	Recurring Contingencies (Rs.)	Contract labour (Rs.)	Institutional charges (Rs.)	Total (Rs.)
I year (3.5.2004 - 2.5.2005)	219614	37477	13065	0	270156
II year (3.5.2005 - 28.2.2006)	220800	240380	45050	60160	566390
III year + 3 months (1.3.2006 - 2.8.2007)	311686	30960	36265	32840	411751
Total project period (3.5.2004-2.8.2007)	752100	308817	94380	93000	1248297

11.2 Non-recurring expenditure : Rs. 469396

Year	Recurring (Rs.)	Non-recurring (Rs.)	Total (Rs.)
I year (3.5.2004 - 2.5.2005)	270156	-	270156
II year (3.5.2005- 28.2.2006)	566390	469396	1035786
III year + 3 months (1.3.2006 - 2.8.2007)	411751	-	411751
Total project period (3.5.2004-2.8.2007)	1248297		1717693

12. Total amount sanctioned : Rs. 17,23,000.00

13. Total amount spent : Rs. 17,17,693.00

14. Results of practical / scientific value:

i. Bycatch Reduction Devices (BRDs) are essential for reducing the negative impacts of trawling on sustainability of marine resources and biodiversity. Use of BRDs need to be made mandatory in shrimp trawl nets and proper awareness generated in trawling industry about its necessity. Effective legislation and incentive schemes may be necessary for their popularisation among fishermen.

ii. Once the Bycatch Reduction Devices are made mandatory for the shrimp trawlers, it will lead to responsible trawling with significant reduction in bycatch volume and growth overfishing, with consequent beneficial impact on the long-term sustainability and biodiversity of the marine resources.

iii. Designs of Hard Bycatch Reduction Devices *viz*., Rectangular Grid BRD, Oval Grid BRD, Fisheye BRD have been developed. Among Hard BRDs evaluated, Fisheye BRD with 300x200 mm semicircular exit opening and rigid Oval Grid BRD with 26 mm bar-spacing performed better in terms of bycatch exclusion and target catch retention and hence can be recommended for use in shrimp trawling.

iv. Designs of Soft Bycatch Reduction Devices *viz*., Radial Escapement Device (RED), Sieve Net BRD, Separator Panel BRD and Bigeye BRD have been developed. Soft BRDs have the advantages such as simplicity in design, ease of construction and installation, low cost, ease of handling, amenability to be taken in a net drum and safety in operation onboard. Among the Soft BRDs tested Big eye BRD positioned at 1.5 m from the distal end of the codend and Sieve Net BRD with 60 mm diamond mesh funnel are potential candidates for bycatch reduction from shrimp trawl and can be popularized among trawler fishermen.

v. A unique International award winning design of Juvenile Bycatch Excluder cum Shrimp Sorting Device (JFE-SSD) has been developed. Juvenile fish Excluder cum Shrimp sorting Device, which is designed to exclude juveniles and in situ shrimp sorting during trawling, has potential for popularization among fishermen. Non-governmental agencies with interest in mitigating negative impacts of trawling have evinced interest in popularizing bycatch reduction devices.

vi. Two patent applications are under preparation: (i) Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD), which is designed to exclude juveniles and in situ shrimp sorting during trawling; and (ii) Juvenile Fish and Turtle Excluder cum Shrimp Sorting Device (JFTE-SSD) which combines the functions of JFE-SSD and Turtle Excluder Device and excludes both juveniles of fish and sea turtles, while performing in situ shrimp sorting.

15. List of publications and papers presented in Seminars and Symposia; animation and video films produced:

i. Boopendranath, M.R. (2008) Possibilities of bycatch reduction from trawlers in India, In: Indian Fisheries – A Progressive Outlook, CMFRI, Cochin: 12-29 pp.

ii. CIFT (2007) Bycatch Reduction Devices, In: Responsible fishing-contributions of CIFT (M.R. Boopendranath, Ed.), CIFT Golden Jubilee Series, Central Institute of Fisheries Technology, Cochin: 32-40

iii. Boopendranath, M.R., Pravin, P. Gibinkumar, T.R. and Sabu, S. (2006) Development of Bycatch Reduction Devices and Turtle Excluder Devices in the Context of Sustainable Seafood Production. Paper presented at *National Seminar on Seafood Production: Reflections, Alternatives and Environmental Control*, 23-24 February 2006, Goa.

iv. Gibinkumar, T.R., Sabu, S., Pravin. P., Boopendranath, M.R. (2005) Trawling systems operated off Quilon, Kerala, India, In: Kurup, B.M., Ravindran, K., (Eds.), Sustain Fish, School of Industrial Fisheries, CUSAT, Cochin, India: 462-481 pp.

v. Sabu, S., Gibinkumar, T.R., Pravin, P., Boopendranath, M.R. (2005) Trawl for whelk (*Babylonia spirata*) off Quilon, Kerala, India. In: Kurup, B.M., Ravindran, K., (Eds.) Sustain Fish, School of Industrial Fisheries, CUSAT, Cochin, India: 496-501 pp.

vi. Gibinkumar, T.R., Sabu, S., Pravin, P., Boopendranath, M.R. (2005) Hard Bycatch Reduction Devices for Trawls Paper presented at the 7th Indian Fisheries Forum, 8-12 November 2005, Bangalore.

vii. Sabu, S., Gibinkumar, T.R., Boopendranath, M.R. and Pravin, P. (2005) Soft Bycatch Reduction Devices for Trawling, Paper presented at the 7th Indian Fisheries Forum, 8-12 November 2005, Bangalore.

Animation and video films produced:

i. Animation film on principles of JFE-SSD operation (57 sec)

ii. Video film on JFE-SSD (7 min 21 sec)

16.	**Detailed progress report**	:	**Please see Chapters 1-16 and Annexures 1-3**

Dr. M. R. Boopendranath
Principal Investigator

Dr. K. Devadasan
Director
Central Institute of Fisheries Technology

Cochin-29
19 May 2008

17. Comments of the Project Co-coordinator/Referee:

18. Remarks of the Council:

1.0 Introduction

The importance of reducing bycatch and minimizing ecological impacts of fishing operations has been emphasized by scientists and fishery managers and recognized by fishermen (e.g. Andrew & Pepperell, 1992; Alverson et al., 1994; Bostock & Ryder,1995; FAO, 1995; Prado & Rahman, 1995; FAO, 1996; FAO, 1997; Hameed & Boopendranath, 2000; Kelleher, 2004; Hall and Mainprize, 2005; Kennelly, 2007). The FAO Code of Conduct for Responsible Fisheries (FAO, 1995), has given priority status to development and improvement of fishing technology that minimizes bycatch and stresses the need for developing selective fishing gears in order to conserve resources, protect non-targeted resources, juveniles and endangered species like sea turtles. Trawl nets are towed gear consisting of funnel shaped body of netting closed by a bag or codend and having extended sides in the front to form wings. The trawls in general and shrimp trawl in particular exhibit poor gear selectivity and commonly have an associated catch of non-targeted organisms such as finfish and miscellaneous invertebrates. 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, particularly trawling.

Trawling provides a major portion of the supply of marine fish in India. Trawling was first attempted in Indian waters during exploratory surveys conducted from S.T. Premier, off Bombay coast, in 1902 (Chidambaram, 1952) and by Ceylon Company for Pearl Fishing Survey, during 1906-07 (Hornell, 1916). The erstwhile Indo-Norwegian Project which was formed as a result of a tripartite technical co-operation agreement signed in 1952, between India, the USA and the United Nations, for fisheries development, has made important contributions in traditional craft motorisation and mechanisation. Central Institute of Fisheries Technology (formerly Central Fisheries Technological Research Station) was established in Cochin in 1957, with the objective of development of fishing industry in India. The programme for mechanisation of the existing traditional crafts began with the posting of FAO Naval Architects to the Research Station.

In 1955, experimental shrimp trawling was conducted with 6.6 m L_{OA}, 10 hp open motor boat, off Malabar coast using a Gulf of Mexico type flat trawl of 9.6 m head line and consistently impressive catches of shrimp was obtained from the shallow coastal waters of 4-18 m depth (Kristjonsson, 1967). This finding gave a major fillip in commercial shrimp trawling in India and increasing demand for shrimps for the processing industry, subsidy and incentive schemes of Government agencies caused rapid development of the otter trawling in Indian waters. This was soon followed by various technological developments and policy changes such as adoption of synthetic gear materials, expansion in mechanized fleet in terms of numbers, size, installed hp and capacities, improvement in efficiency and diversification of trawl systems, adoption of modern technologies such as echo sounder and GPS, chartering and joint venture schemes and expansion of the fishing grounds to deeper waters.

The number of trawlers operating in Indian waters has been recently estimated at 29,241 (CMFRI, 2006), 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. The number of trawlers operating in Indian waters has been recently estimated at 29,241(CMFRI, 2006) against an estimated optimum fleet size of 10996 (Kurup and Devaraj, 2000). The existing capacity is 2.7 times the optimum fleet size, estimated by Kurup and Devaraj (2000). Actual excess capacity could be much higher, as the fishing power of the individual trawlers have significantly grown, during last few decades, due to advances in technology and enhancement in horsepower and capacities of the trawler.

1.1 Bycatch and trawling

The term bycatch refers to non-targeted species retained, sold or discarded for any reason (Alverson et al., 1994). Catch process and production of bycatch during trawling are represented in Fig. 1.1. 'Target catch' is the species or species assemblage primarily sought in a fishery (e.g. shrimps), 'incidental catch' is the retained catch of non-targeted species and 'discarded catch' is that portion of catch returned to the sea because of economic, legal or personal considerations. Bycatch includes both discarded and incidental catch. In addition to the non-targeted finfishes and invertebrates, bycatch also involve threatened and protected species like sea turtles.

Quantum of bycatch landed or discarded may depend on factors affecting selectivity of trawl (such as codend mesh size, mesh sizes of the wings and belly, vertical opening of the trawl mouth, ground rope rigging and bottom contact, overall length of the trawl, otter boards and bridle arrangements, speed and duration of tow, the trip duration (single-day or multi-day fishing), storage and preservation facilities onboard, variation in seasonal abundance of bycatch species and juveniles and variations in export and domestic market demands for target and bycatch species.

Some of the advantages in reducing the amount of unwanted bycatch caught in trawls are: (i) reduction in impact of trawling on non-targeted marine resources and ecosystem, (ii) reduction in damage to shrimps due to absence of large animals in codend, (iii) shorter sorting times, (iv) longer tow times and (v) lower fuel costs due to reduced net drag.

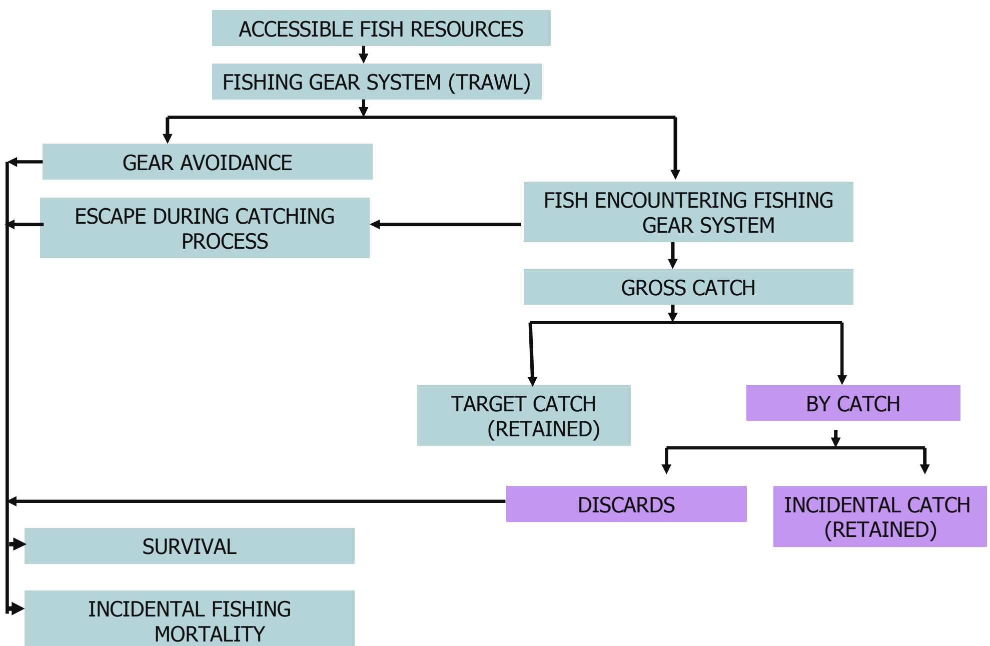


Fig. 1.1 Catch process and bycatch production in trawling

1.2 Bycatch in world fisheries

Global bycatch by the world's marine fishing fleets was estimated at 28.7 million tonnes in 1994, of which 27.0 million tonnes (range : 17.9-39.5 million t) were discarded annually and shrimp trawling alone accounted for 9.5 million t (35 %) of discards annually (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). The reduction in bycatch discards in recent years could be attributed to (i) increased use of bycatch reduction technologies, (ii) anti-discard regulations and improved enforcement of regulatory measures, and (iii) increased bycatch utilization for human consumption or as animal feed, due to improved processing technologies and expanding market opportunities. 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).

1.3 Bycatch in Indian fisheries

Commercial fishing in India is generally shrimp oriented and large quantities of finfish bycatch including significant amount of juveniles are landed during shrimp trawling. Bycatch was estimated at 79.18% (3,15,902 t) of the total shrimp trawl landings in India, during 1979 (George et al., 1981). The quantum of bycatch was maximum 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). Annual bycatch discards of the fleet of 150 large trawlers, 80 mini-trawlers, 70 *sona* boats and 350 small trawlers, based at Visakhapatnam (East coast of India), during 1988-99, was estimated to be between 99,000 to 1,30,000 t (Gordon, 1991). Rao (1998) re-assessed the estimate of bycatch by the fleet based at Visakhapatnam at 40,410 t, of which 32,421 t was discarded and 8258 t was retained.

Menon (1996) observed that in the states of Kerala, Karnataka and Tamil Nadu, 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 states of Kerala, Karnataka and Tamil Nadu, 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 was estimated to be discarded (Menon, 1996).

Pillai (1998) estimated that bycatch formed 70-90%of the landings by shrimp trawlers in different maritime states. About 15-20% of bycatch discards has been reported at Cochin and Visakhapatnam from vessels engaged in multi-day fishing and negligible discards from the fleet based at Saurashtra (Gujarat) where the bycatch is utilized for production of fish meal and manure. Target catch : bycatch ratios along the southwest (Karwar, Mangalore, Cochin) and southeast (Mandapam and Kakinada) regions of India was estimated as 1:4.6 and 1:1.26 respectively, during 1999 (Menon, 2000).

In Karnataka, bycatch quantity from trawlers was estimated 56,083 t during 2001 and 52,380 t in 2002, which formed 54.4% and 47.9% of total trawl catch, respectively. The quantity of discards was 34,958 t (33.9%) in

2001 and 38,318 t (35.1% of total catch) in 2002 (Zacharia et al., 2006). In Kerala, the discarded quantity estimated during 2000-2001 was 2,62,000 t and during 2001-2002 it was 2,25,000 t, of which 33.3 and 35.5%, respectively, were edible constituents. The dominant varieties among the discards were finfishes, crabs and stomatopods (Kurup et al., 2003; 2004). Sujatha (1995) studied the catch composition of the low value bycatch off Visakhapatnam, and identified 228 species belonging to 68 families, constituting about 11% of the total trawl landings.

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.

1.4 Juveniles in trawl bycatch

Trawl bycatch is known to be constituted by high proportion of juveniles and sub-adults, particularly of commercially important fishes, which needs serious attention in development and adoption of bycatch reduction technologies. Luther and Sastry (1993) found that the bulk of landings in different fisheries in all maritime states comprised of juveniles. Sivasubramaniam (1990) reported that more than 50% of the bycatch samples studied were immature fish and attributed the significant declines in longer-living species such as snappers, groupers and croakers in the Asian region to the capture of juveniles. Pillai (1998) estimated that about 40% of the bycatch landings by shrimp trawlers in different maritime states were juveniles.

Pravin and Manohardoss (1996) identified 87 species belonging to 42 families in the low value bycatch off Veraval, Gujarat, which included juveniles of commercial finfish and shellfish. Pravin et al. (1998) found that juveniles of many commercial varieties of fish, along with low value fish, constituted more than half (52.2%) of the total catch by trawlers off Veraval coast in Gujarat, during 1988-93. Rohit et al. (1993) reported that during the peak fishing season, 23% of the landings of the bull trawlers operating off South Kannada coast in Karnataka consisted of juveniles of commercially important fishes. Menon (1996) estimated that about 1.5% of the trawl landings in the states of Kerala, Karnataka and Tamil Nadu, was constituted by juveniles of commercially important food fishes and shellfishes and average quantity of juveniles of fish and shrimp during 1980-84 was about 6200 t, which, if allowed to grow to marketable sizes, would have yielded 0.155 million t of fishes. Sujatha (1995; 1996; 2005) has reported the low value finfish bycatch landed by small trawlers based at Visakhapatnam contained significant quantity of juveniles.

1.5 Approaches for bycatch reduction in trawling

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 (i) a reduction in the overall fishing effort by removal of excess capacity, regulatory bans (e.g. area and seasonal closures), trade related measures (e.g. US embargo on shrimp imports linked to TED use in trawls) and consumer behaviour (e.g. establishment of ecolabelling schemes); (ii) a reduction in bycatch per unit effort by technological interventions (e.g. installation of Bycatch Reduction Devices and Turtle Excluder Devices; fishing gear modifications and substitutions) and operational changes (reduction in speed and duration of trawling, avoiding areas of high bycatch); and (iii) management actions (e.g. setting bycatch limits for individual vessels; providing incentives to fishermen for success in bycatch reduction).

1.5.1 Bycatch Reduction Devices

Devices developed to exclude the endangered species like turtles, and reduce the non-targeted species and other unwanted catch in shrimp trawling are collectively known as Bycatch Reduction Devices (BRDs). These devices have been developed taking into consideration the variations in the size, and differential behaviour pattern of shrimp and other animals inside the net. Various types of BRDs have been developed in the fishing industry around the world (Gibinkumar et al., 2005; Sabu et al., 2005; Boopendranath et al., 2006). 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. Combination BRDs use more than one BRD, usually hard BRD in combination with soft BRD, integrated to a single system.

Use of Bycatch Reduction Devices is one of the widely used approaches to reduce bycatch in trawls. About 50 designs of BRDs and TEDs developed for different resource groups and fishing areas are in vogue either in experimental or commercial operations (Boopendranath et al., 2006). BRDs and TEDs most appropriate for the regional fishery conditions should be developed, adopted and enforced legally, after careful scientific evaluation and commercial trials, in order to ensure long-term sustainability of fishery resources, protect biodiversity and safeguard sea turtles from accidental mortality associated with shrimp trawling. Juvenile mortality could be reduced by using specially designed BRDs for juvenile exclusion such as Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) (Anon 2006) and Juvenile and Trash Excluder (JTED) (Chokesanguan et al., 2000).

1.6 Trawl bycatch reduction in India

Bycatch reduction in fishing and the accompanying issues, though recognized, have not been adequately addressed in Indian fisheries (Boopendranath, 2006; Kumar and Deepthi, 2006). Discards is not as serious a problem in India at present, compared to earlier years of shrimp oriented multi-day fishing, as most of the bycatch is now-a-days landed and utilized for either human consumption or manufacture of animal feed. However, poor resource specificity of trawls and dominance of juveniles in the bycatch have serious ecological impacts, affecting long-term sustainability of resources and biodiversity. A recent analysis of time series data of marine landings has shown that 'the fishing down marine food webs' is visible in all maritime states of India and this is more pronounced on the west coast (Bhathal, 2004). A National Plan of Action for bycatch reduction in fishing gears, particularly targeting trawling sector, is a necessity for sustainability of Indian fisheries.

1.7 Project objectives

Main objectives of the Project on *Bycatch Reduction Devices for Selective Shrimp Trawling* (Project Code No. 0644003) sanctioned under A.P. Cess Fund Ad-hoc Research Scheme of ICAR have been the following:

- Design, development and evaluation of Bycatch Reduction Devices (BRDs) appropriate for shrimp trawls operated in small-scale mechanized sector;
- Development of selective shrimp trawls, incorporating optimized Bycatch Reduction Devices;
- Evaluation of the effect of BRD incorporated trawl systems in operational fuel consumption;
- Characterization of shrimp trawl bycatch.

2.0 Review of Bycatch Reduction Devices

Devices developed to reduce the non-targeted species and other unwanted catch in shrimp trawling and exclude the endangered species like turtle, and are collectively known as Bycatch Reduction Devices (BRDs). BRDs have been developed taking into consideration the differential behavior patterns or size of shrimp and fish inside the net. Various types of BRDs have been developed in the fishing industry around the world. The salient features and operational features of some of the important BRDs are reviewed below.

Bycatch reduction devices and technologies have been reviewed by Broadhurst (2000), Eayers (2005), Gibinkumar et al. (2005), Sabu et al (2005), Boopendranath et al (2006), Eayers (2007), Kennelly (2007) Boopendranath et al (2008) and others. 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. Combination BRDs use more than one BRD, usually hard BRD in combination with soft BRD, integrated to a single system.

2.1 Escape windows

Escape windows made of large square mesh netting (square mesh window) or parallel ropes (rope BRD) provided on the upper side of the codend or belly and function based on the differential behaviour of fishes and shrimps (Broadhurst and Kennely, 1994; Pillai, 1998; Boradhurst et al., 1999) (Fig. 2.1). Fishes that have entered the codend tend to swim back and escape through the openings, at the top in the front section of the codend. 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). 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). 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).

Attachment of square mesh windows has been proved to be a very simple and low cost bycatch reduction technique. The size of the square mesh is determined according to the size and species of fish to be excluded. 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). The use of square mesh in codend of trawl net increases the filtering efficiency, facilitating the escape of juvenile fishes.

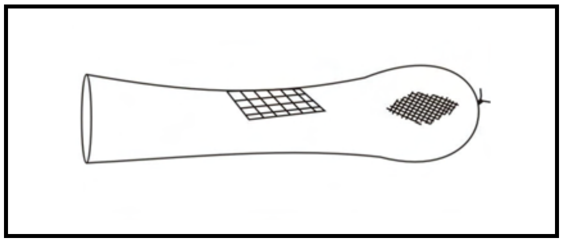


Fig. 2.1 Square Mesh Window

2.2 BRDs with differently shaped slits

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) (Fig. 2.2). 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). 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. The Big eye BRD in this category is a very simple 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).

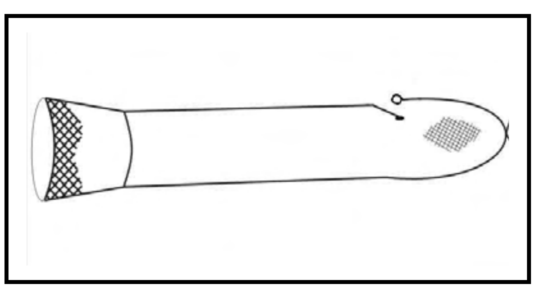


Fig. 2.2 Bigeye BRD

2.3 Radial Escapement Section

A radial section of netting with large meshes or parallel ropes is provided between hind belly and codend. Small sized fishes, jelly fish and other bycatch components which have low swimming ability are expelled due to enhanced water flow through large mesh section. Often, a funnel made of small netting is provided to accelerate the water flow inside the trawl and carry 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 (Watson and Taylor, 1988; Brewer et al., 1998; Robins et al., 1999). Experiments in India, has indicated a finfish bycatch exclusion of about 18% (Pillai et al., 2004).

2.3.1 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.

2.3.2 Radial Escapement Devices with funnel

Radial Escapement Devices with funnel (Fig. 2.3) is 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). 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).

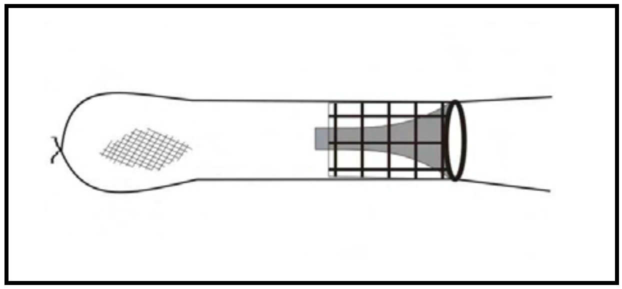


Fig. 2.3 Radial Escapement Device

2.4 BRDs with guiding/separator panels

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 (e.g. Authement-Ledet Excluder) (Fig. 2.4). 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 (Rogers et al., 1997). 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).

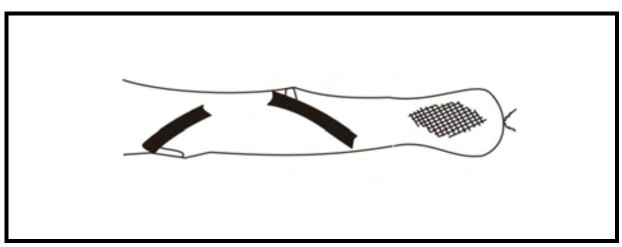


Fig. 2.4 Authement-Ledet Excluder

2.5 BRDs with rigid escape slots

BRDs with rigid escape slots are designed to facilitate the escapement of fish from the codend (2.5). Fisheye is the most important BRD coming under this category (Pillai, 1998; Brewer et al., 1998; Hannah et al., 2003; Burrage, 2004). It consists of an oval shaped rigid structure of about 80 - 150 mm in height and 300 - 400 mm in width, with supporting frames made of stainless steel rods. This is attached at the top of the codend so as to provide an escape opening. This opening facilitates the escape of fish which swim backward from the end of the codend). There are several design variations of fisheye such as Florida Fish Eye (FFE) used in the Southeast US Atlantic (NCDMF, 1997) and in the Gulf of Mexico (Wallace and Robinson, 1994) and 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, 2004) are other designs in this category.

Performance of fisheye is depending on the shape, size, position, light and water current. Fisheye experiments conducted in Florida and in coastal Australian waters showed enhanced bycatch reduction when used in combination with other BRDs (Brewer et al., 1998; Steele et al., 2002). During experiments using Fish slot in North Carolina, USA an average reduction of weak fish was about 30% and shrimp loss was about 55%. This model is prone to hang on the bumper rails of the vessels sides and can damage the tail bag or BRD (Morris, 2001). Experiments using Popeye fish excluder or fish box BRD in Queensland waters showed 29-60% reduction in bycatch (Anon, 2004)

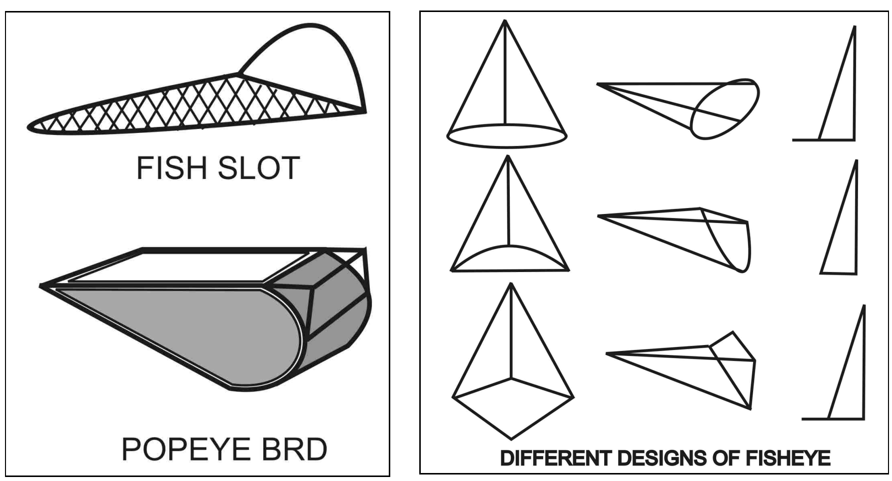


Fig. 2.5 BRDs with rigid escape slots

2.6 Rigid grid sorting devices

Several designs of rigid grid sorting devices (Fig. 2.6) have been developed for separation of shrimp from non-shrimp resources, such as Nordmore grid (Isaksen et al., 1992) and Juvenile and Trash Excluder Device (JTED) (Chokesanguan et al., 2000). Operations with Nordmore grid, in Norwegian waters, has shown a low shrimp loss of 2-5%.

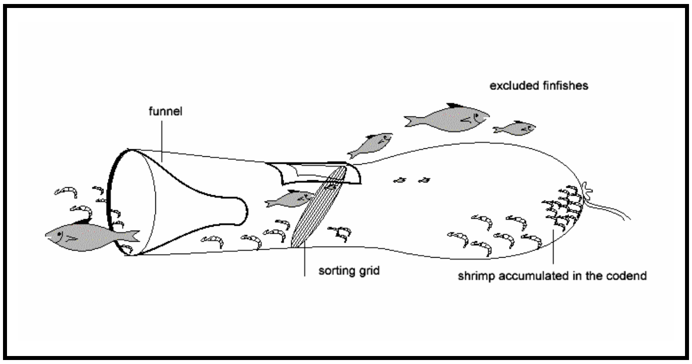


Fig. 2.6 Principle of operation of Rigid grid sorting device

2.6.1 Flat grid BRDs

Flat grid BRDs are mostly rectangular in shape without any bend in the grid bars (Fig. 2.7). This type of design was developed in Norway originally to exclude jelly fish (Isaksen et al., 1992). The grids are made of either aluminium or steel. The grid is usually mounted in the throat section at an angle 45-50° from the horizontal. The grid is usually associated with an accelerator funnel for guiding the catch to the grid. Escape openings are provided either on top or bottom and are either kept open or covered with a flap of netting. Examples for flat grid BRDs are 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).

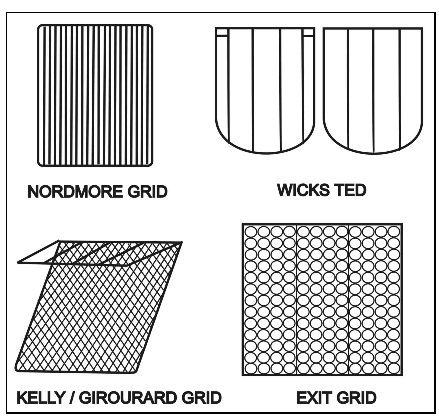


Fig. 2.7 Flat Grid BRDs

Experiments with Nordmore grid, in Norwegian waters, have shown a low and fairly constant shrimp loss of 2-5% (Isaksen et al., 1992). Fishes above 200 mm size were observed to escape. Experiments using

Nordmore grid in Nova Scotia, Canada showed target catch loss of 2-5% and bycatch reduction of 48-98% (Halliday and Cooper, 1999). Nordmore grid experimented in Clarence river of New South Wales showed 77% reduction in bycatch with no reduction in prawns (Broadhurst et al., 1999). Experiments with Nordmore grid in Portuguese continental waters showed up to 78.5% exclusion of large bycatch species with negligible target catch loss (Fonseca et al., 2005a). Experiments using modified versions of Nordmore grids made of plastic, conducted in the North sea reduced >70% fish and 65% benthos with a target catch loss of 15% (Polet, 2002). Maartens et al. (2002) observed the escapements of juveniles up to 95%, during experiments with rigid sorting grid EX-it grid, in coastal waters off Namibia.

2.6.2 Bent grid BRDs

Bent grid BRDs are either rectangular or elliptical in shape. In this group of BRDs, the grid bars and, in some cases, grid frame are bent at one end near the exit opening (Fig. 2.8). This is to facilitate the easy ejection of the debris, seaweeds, and bycatch components and prevent clogging of the grid. Exit holes are guarded with flap of netting. The grid is mounted in the aft section of the trawl just in front of the codend at an angle between 45 and 55° from horizontal. Material used for its construction is steel or aluminium. Super Shooter TED (Mitchell et al., 1995), Seymour TED (Robins et al., 1999), Juvenile and Trash Excluder Device (JTED) (Chokesanguan et al., 2000) NAFTED (Brewer et al., 1998; Eayrs, 2004) are BRDs coming under this category.

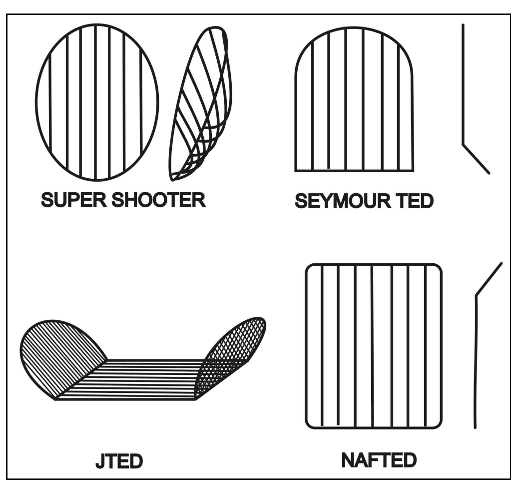


Fig. 2.8 Bent Grid BRDs

2.6.3 Oval grid BRDs

These are flat grids, which are either oval or circular in shape. The grids are made of steel and are mounted in a netting section between throat and codend of the trawl net (Fig. 2.9). Grid angle varies from 45 to 55° from horizontal. Exit openings are at either the top or the bottom of the section. Various grid designs of this type are used worldwide, which include 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).

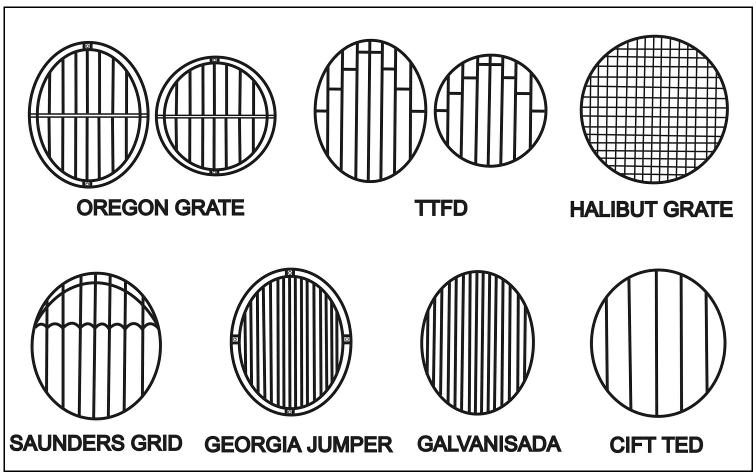


Fig. 2.9 Oval Grid BRDs

2.6.4 Slotted grid BRDs

These are flat grids mostly rectangular in shape made of either aluminium or steel. Slotted grid BRD is inserted in the aft section of the trawl just in front of the codend (Fig. 2.10). The main characteristic of this category of BRDs is that they are provided with slots for allowing the passage of targeted species other than shrimp. The slots may be either at top or at bottom, made by welding cross bars or by leaving one end of the bars without joining to the frame. Steel, aluminium and polyamide are used to construct the grids. The important grids under this category are Flounder TED (Mitchell et al*.,* 1995), Johns TED (Boopendranath, 2003), Hinged grid (Eigaard and Holst, 2004) and Anthony Weedless (Talavera, 1997).

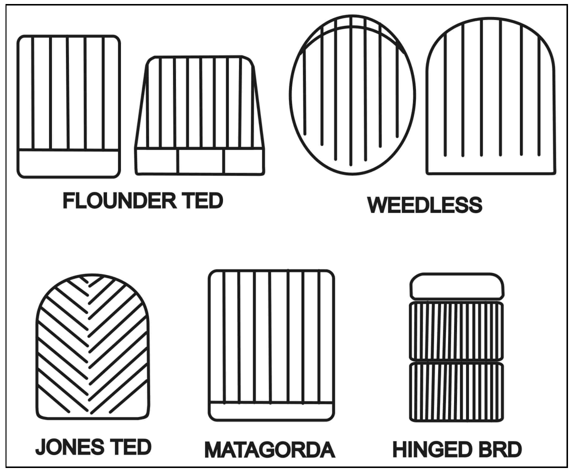


Fig. 2.10 Slotted Grid BRDs

2.6.5 Hooped and Fixed angle BRDs

Hooped and Fixed angle BRDs have circular, oval or rectangular hoops in front and rear of the deflecting grid, which is rigidly fixed in a framework at the desired angle (Fig. 2.11). Materials used for construction are steel or aluminium. The main advantages of hooped TEDS are (i) sturdier construction for fishing in rugged conditions and (ii) constant angle of the deflector bars unaffected by changes in the elongation of netting. However, these designs are relatively cumbersome in terms of onboard handling and hence are not in popular use. The NMFS Hooped BRD, Cameron shooter BRD and Fixed angle BRD comes under this category (Oravetz and Grant, 1986; Prado, 1993; Mitchell et al., 1995).

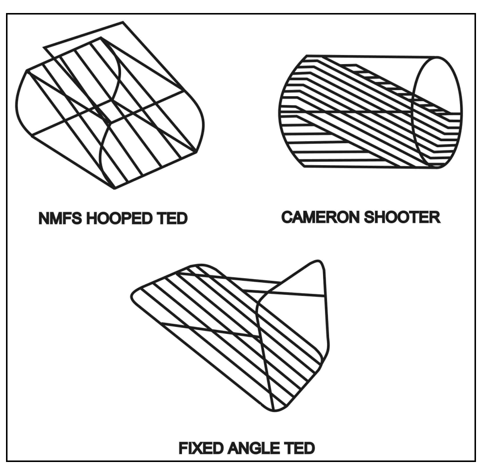


Fig. 2.11 Hooped BRDs

2.7 Semi-flexible BRDs

Semi-flexible BRDs are constructed out of semi flexible or flexible materials such as plastic, polyamide, FRP and rubber (Fig. 2.12). These include (i) flexible plastic grid made of polyethylene and the grid frame consisted of plastic tubes used in the North Sea brown shrimp fishery (Polet, 2002), (ii) Polyamide grid with hinges for operation from net drums used in the Danish experiments in the North Sea shrimp fishery (Madsen and Hanson., 2001) and (iii) Polyamide-rubber grid design from Denmark (Anon, 2002). Flexible polyamide grid experimented in North Sea has been shown to be efficient in fish and lobster exclusion, and also has flexibility to be wound into the net drum (Madsen and Hanson, 2001).

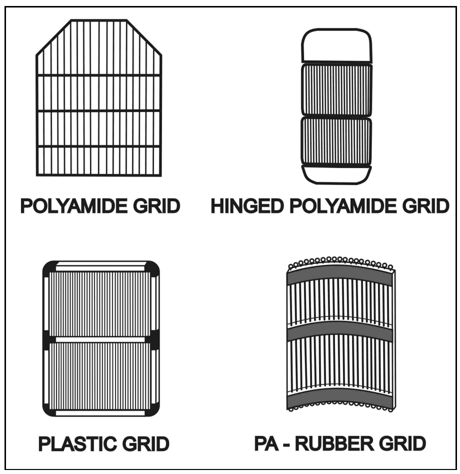


Fig. 2.12 Semi-flexible BRDs

2.8 Turtle Excluder Devices (TEDs)

Sea turtles are ancient and widely distributed species whose migratory pattern extends throughout the oceans of the world. Due to harvesting of sea turtles and their eggs and accidental mortality associated with shrimp trawling and other fishing operations, turtles have been threatened with extinction in all parts of the world. Marine turtles are endangered species. They are also protected under the international conventions such as Convention on Migratory Species (CMS) and Convention on International Trade on Endangered Species of Wild Flora and Fauna (CITES) and under various national regulations.

Turtle Excluder Devices (TEDs) are specially designed BRDs for protecting sea turtles. TEDs consist of panels of large mesh netting (soft TED) or a frame consisting of grid of deflector bars (hard TED) installed before the codend of the trawl net at an angle leading upward or downward to an escape opening. Small animals such as shrimp, slip through the mesh lumen of netting panel or gap between the deflector bars and are retained in the codend while large animals such as turtles, large fishes and large elasmobranchs are stopped by the netting panel or the grid of deflector bars and can escape through the opening (Fig. 2.13). Thus sea turtles which breathe air are prevented from incidental capture and death due to prolonged entrapment in the trawl. TEDs were introduced in US shrimp fishery in late 1980s. Several improvements have taken in TED design, fabrication and operational techniques, since then.

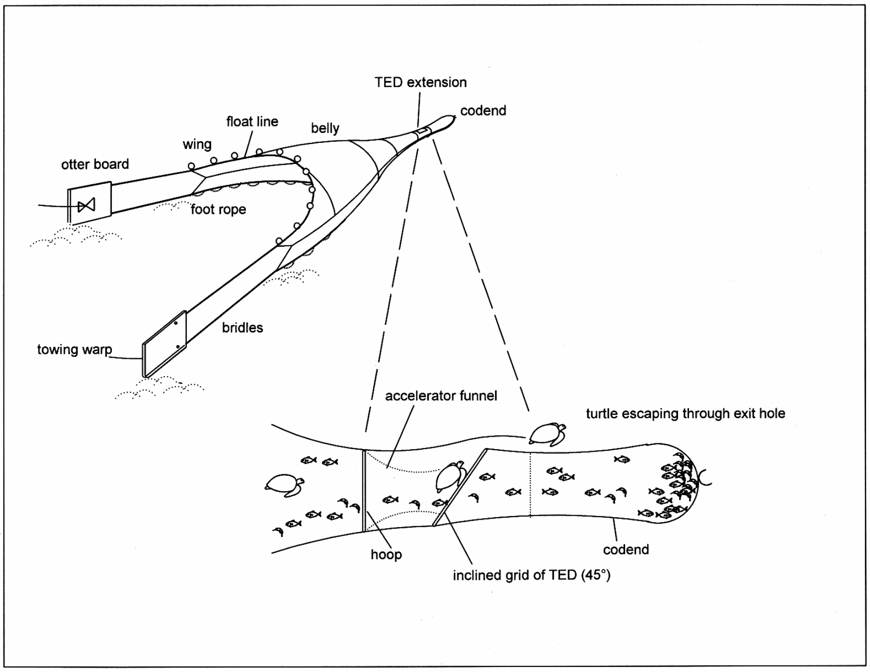


Fig. 2.13 Principles of TED operation

Turtle Excluder Devices (TEDs) are recognized internationally as a convenient and effective measure for protecting sea turtles from trawling-related mortality and also for reducing bycatch in shrimp landings. TEDs are acknowledged as an important conservation tool by the United Nations Food and Agriculture Organization, fisheries biologists and sea turtle conservationists. Many trawl fisheries throughout the world are now required to use TEDs. Over 18 nations are now having TED regulations for their shrimp trawlers.

Hard TEDs generally consists of a metallic grid, an escape opening, a guiding funnel and flapper. The grid may be of oval, spherical or rectangular shape made of stainless steel or aluminium rods (Fig. 2.15). A guiding funnel is provided before the grid and the escape opening is provided either at the top or bottom of the grid. This grid is attached ahead of the codend at an angle of 45° to 55°. During fishing, shrimps are taken along with the flow of the water to the codend, the fish swim upwards and try to escape through the opening provided. In the case of turtles and other large animals when obstructed by grid/separating panel move upward or downward as the case may be and escape through the opening.

2.8.1 Variations in TED Designs

There are a variety of TED designs available today, which vary with regard to construction details, principle of operation, materials for construction and depending on the target resource groups and conditions of fishing. There are primarily two types of TEDs – soft TED and hard TED. Soft TED consists of a large mesh selective front panel fitted at an angle, inside the trawl leading to an escape chute at the hind end. Hard TEDs are rigid frame devices installed ahead of codend to separate and exclude turtles from trawl catch components.

2.8.2 Soft-TEDs

Examples of soft TEDs are Morrison TED, Taylor TED, Andrews TED and Parker TED. Soft TED, in general, is difficult to install properly in different types of trawls oriented towards catching different species whose behaviour requires the shape of the trawl opening to be changed by adjusting the rigging. The soft TEDs are also known to produce higher shrimp losses (about 15%) and their performance is reported to be inferior to hard TEDs (Christian et al., 1988; Kendall, 1990; Andrew et al., 1993; Robins-Troeger, 1994). In view of this, hard TEDs are more popular among trawler operators compared to soft TEDs. However, they are generally simple in construction, cheaper and easy to handle and maintain onboard.

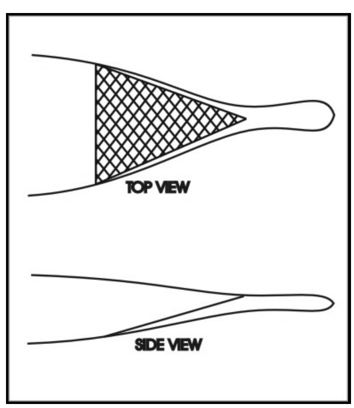


Fig. 2.14 Morrison soft TED

In Morrison soft TED (Fig. 2.14), a triangular netting panel of 203 mm mesh size is placed inside the net, in a gradually slanting orientation, in order to lead sea turtles and large animals to a top opening, while shrimps pass through the mesh openings of the panel, to the codend (Christian et al., 1988; Kendall, 1990).

2.8.3 Hard TEDs

There are several designs of hard TED in use (Fig. 2.15). In the first category, viz., Hooped hard TEDs, deflector bars are rigidly fixed in a framework at the desired angle. NMFS hooped TED, Cameron TED and Fixed angle TED fall under this category. NMFS hooped TED design was the first TED design to be introduced. It has a rectangular-oval frame in the front and rear and deflector bars are fixed and its angle remains unchanged. However, NMFS hooped TED is relatively cumbersome in terms of onboard handling compared to recently introduced TED designs and for this reason it is not in common use, presently. Fixed angle TED and Cameron TED are similar designs with a simplified framework for fixing the deflector bars and they maintain a fixed angle during operation. (Oravetz and Grant, 1986; Prado, 1993; Mitchell et al., 1995; Talavera, 1997, Rogers et al., 1997).

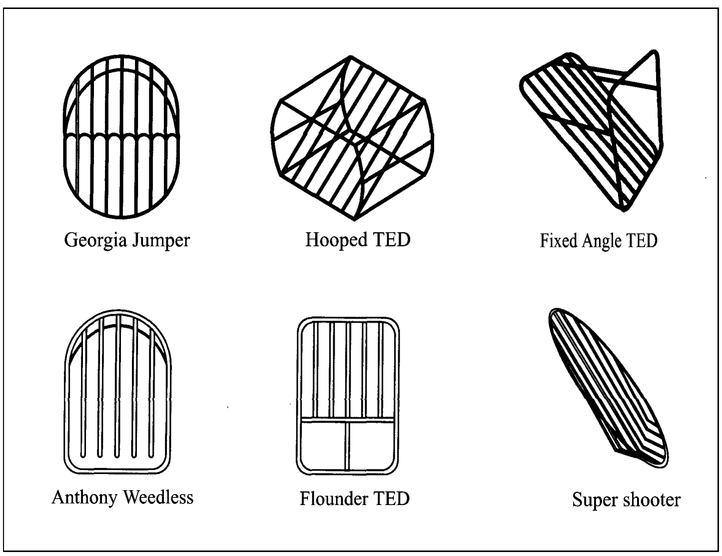


Fig. 2.15 Different hard TED designs

The second category viz., Single-grid Hard TEDs includes the Matagorda TED, Georgia-Jumper, Super Shooter, Anthony Weedless and Jones TED (CIFT, 2003). Flounder TED has a 102 mm wide horizontal slot at the bottom end of the TED frame, which permit flounder and other fishes to pass through into the codend. It is used in areas where flounder is the targeted catch (Talavera, 1997; Mitchell et al., 1995; Dawson, 2000; Belcher, 2001). Georgia-Jumper is one of the simplest of hard TED designs, which is widely used in different fisheries. It consists of an oval frame with deflector bars with horizontal braces and is constructed of stainless steel rod (Mitchell et al., 1995; CIFT, 2003; Committee on Sea Turtle Conservation, 1990).

Super Shooter is a popular design of TED, originally designed for use in Gulf of Mexico, in which deflector bars are bent at an angle at a distance from the escape opening, in order to facilitate elimination of debris from the TED (Mitchell et al., 1995; Brewer et al., 1998; Steele et al., 2002). Anthony Weedless is a patented design of TED, which is designed to reduce the accumulation of debris and sea grass by specially designed deflector bar, which is free at the bottom end and is kept at an appropriate angle (Talavera, 1997; Mitchell et al., 1995; CIFT, 2003).

2.8.4 CIFT-TED

CIFT-TED is an efficient turtle excluder device developed at Central Institute of Fisheries Technology (Cochin, India) with focus on reducing catch losses, which is a cause of concern for trawler fishermen in adopting the device. The device christened as CIFT-TED, is a simple single grid, hard TED design with top opening (Fig. 2.16). It consists of an oval frame measuring 1000x800 mm and is constructed with 10 mm Ø stainless steel rod. Five vertical grid bars of 8 mm Ø stainless steel rod are welded to the inside of the oval frame. The spacing between the deflector bars is 142 mm and the maximum spacing between the frame and the adjacent deflector bar is 90 mm. The frame was fixed in the TED extension at 45° angle. Catch losses during the experimental operations due to installation of CIFT-TED were in the range of 0.52-0.97% for shrimp and 2.44-3.27% for non-shrimp catch components (Dawson and Boopendranath, 2001; CIFT, 2003).

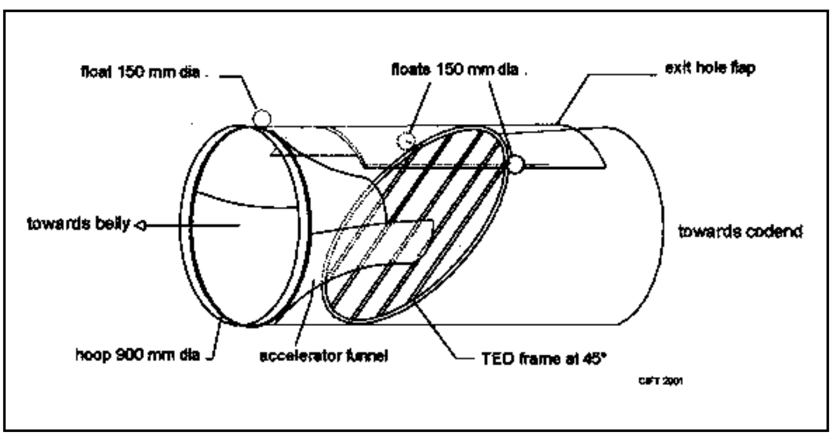


Fig. 2.16 Perspective diagram of CIFT-TED

2.9 Combination BRDs

Sometimes, two or more BRDs are combined in a single gear to enhance the efficiency of bycatch exclusion (Fig. 2.17 and 2.18). 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 efficiences (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.

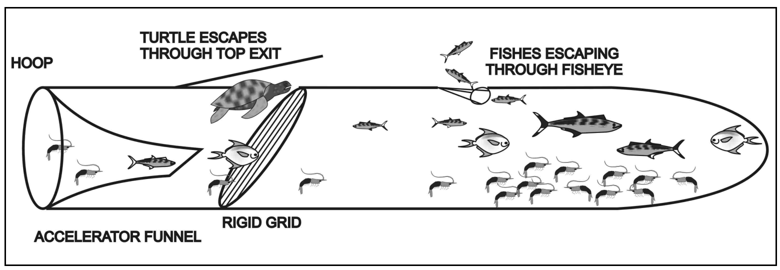


Fig. 2.17 Principles of Combination BRD operation (combination of rigid grid and fisheye BRDs)

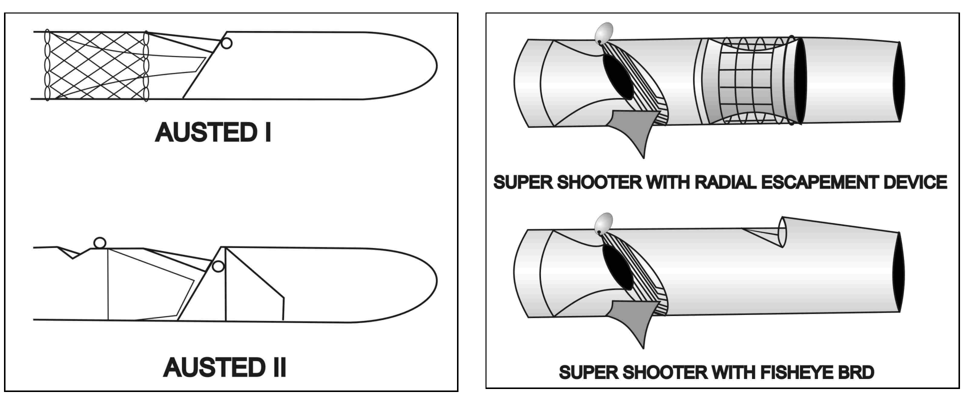


Fig. 2.18 Combination BRDs

2.10 Conclusions

About 50 designs of BRDs and TEDs developed for different resource groups and fishing areas are in vogue either in experimental or commercial operations. BRDs and TEDs most appropriate to the regional fishery conditions should be adopted and enforced legally, after careful scientific evaluation and commercial trials, in order to ensure long-term sustainability of fishery resources and protect the biodiversity.

3.0 Materials and Methods

A review of literature on bycatch reduction technologies has shown that about 50 BRD designs are in use either in commercial or experimental operations in different fishing areas of the world for mitigation of regional bycatch issues and increase the selectivity of trawl nets. Most BRDs have been developed through intensive research and constant modifications made in their design based on the operational experience. It is important to take into consideration the regional characteristics of the fishery and geographical peculiarities, in the design process for development of BRDs.

3.1 Experimental BRD Designs

The selection of BRDs for the experiments was mainly 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 fishing industry.

3.1.1 Rectangular grid BRD

The rectangular grid design has rectangular frame of 1000 mm in height and 800 mm in width and has a grid bar spacing of 22 mm. It is fabricated out of stainless steel rods of 8 mm dia for the frame and 4 mm dia for grid bars. The grid is fixed at an angle of 45° from the horizontal, inside the trawl extension. Two floats of adequate extra buoyancy are provided on the top of the grid on either side, to compensate the weight of the grid and to keep the grid always in the upright position. An exit opening of triangular shape having dimensions 600 mm at base and 450 mm at sides is provided at the top of the trawl extension in front of the grid. This triangular opening is made by cutting all bars from the corners of the grid. The opening is reinforced by a 4 mm rope frame at its edges. An accelerator or guiding funnel is provided in front of the grid at a distance of 0.5 m from the bottom of the grid. The funnel is inclined towards the bottom so that the water flow will be directed towards the bottom of the grid. Design details of Rectangular grid BRD are given in Chapter 6.

3.1.2 Oval grid BRD

Oval grid BRD has an oval frame of 1000 mm in height and 800 mm in width and 22 mm bar-spacing. It is fabricated out of stainless steel rods of 8 mm dia for the frame and 4 mm dia for grid bars. The grid is kept at an angle 45° from the horizontal, inside the trawl extension. Two floats of adequate extra buoyancy are provided on the top of the grid on either side, to compensate the weight of the grid and to keep the grid always in the upright position. A triangular exit opening of 600 mm at base and 450 mm at sides is provided at the top of the trawl extension in front of the grid. This triangular opening is made by cutting all bars from the upper sides of the grid. The opening is reinforced by a 4 mm rope frame at its edges. An accelerator or guiding funnel is provided in front of the grid at a distance of 0.5 m from the bottom of the grid. The funnel is inclined towards the bottom so that the water flow will be directed towards the bottom of the grid. Design details of Oval grid BRDs are given in Chapter 6 and 7.

3.1.3 Fisheye BRD

This device facilitates the escapement of actively swimming fishes from the codend. It is fitted at different positions on the upper side of the codend. Three different designs of fisheyes were fabricated for the experiments. Fisheye consists of a stainless steel structure having an oval or semicircular opening with supporting frames made of 6 mm dia stainless steel rods. Design details of Fisheye BRDs are given in Chapter 5.

3.1.4 Radial Escapement Device

Radial Escapement Device (RED) consists of a small mesh funnel surrounded by a radial section of large square mesh netting. Shrimps are retained in the codend while fishes swim back and escape through the radial section of large square meshes. The first design variation of Radial Escapement Device was constructed of 150 mm large square mesh 3 mm dia twine (20 mesh depth and 38 mesh circumference) attached to a 900 mm dia hoop (constructed of 8 mm dia stainless steel rod) at both ends. A small mesh (20 mm) funnel is attached inside the netting cylinder in order to guide the catch towards the codend. The second design variation of Radial Escapement Device is constructed of 100 mm large square mesh netting of 2 mm dia twine (30 mesh depth and 56 mesh circumference) attached to a 900 mm dia hoop (constructed of 8 mm dia stainless steel rod) at both ends. The Radial Escapement Device has an overall length of 1.5 m and is fixed between hind belly and codend of the trawl. The device was attached to a codend of 4.0 m (280 mesh circumference) constructed of netting with 20 mm mesh size and 1.5 mm dia twine. Design details of Radial Escapement Devices are given in Chapter 8.

3.1.5 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. 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 codend. In a modified design of experimental Bigeye BRD, the slit is positioned at the beginning 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 2x 125 g) and four floats with sufficient extra-buoyancy were used to keep the slit vertically open. Further details of Bigeye BRD are given in Chapter 9.

3.1.6 Sieve net

A large mesh funnel positioned inside the net is used to separate shrimps from other non-target organisms. Three design variations were used for performance evaluation. 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 1N 10B) is used for separation of shrimps. The hind end of the funnel is opening to a second 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). 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 a second codend of 4 metre in length 74 bar in circumference, fabricated of 60 mm square mesh netting. 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 a second 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. Further details of Sieve net BRD are given Chapter 11.

3.1.7 Separator panel

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 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 PP) was used. 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 PP) 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. Further details of Separator panel BRDs are given in Chapter 12.

3.2 Fishing operations

3.2.1 Fishing area

The experimental fishing operations were conducted during day-time, in the traditional shrimp fishing grounds at a depth ranging between 9-32 m off Cochin (Fig. 3.1).

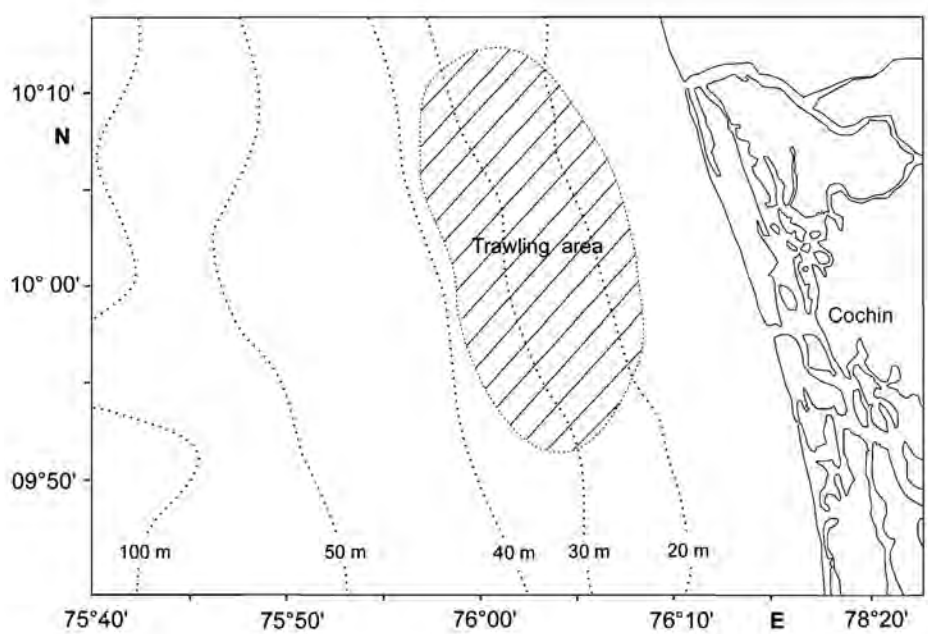


Fig. 3. 1 Fishing area

3.2.2 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. 3.2) and MFV Sagar Shakti (wooden trawler 15.24 m LOA, 30 GRT, 223 bhp @ 1800 rpm Ruston MWM engine) (Fig. 3.3)

Fig. 3.2 MFB Matsyakumari

Fig. 3.3 MFV Sagar Shakthi

3.2.3 Fishing gear

Shrimp trawls of 28.8 and 29.0 headline with 20 mm diamond mesh codend which are widely used in south-west coast of India were used for experimental fishing (Fig. 3.4 and 3.5). The shrimp trawl was rigged with V-type steel otter boards of size 1420x790 mm size (80 kg each) and 20 m double bridles (Fig. 3.6 and 3.7).

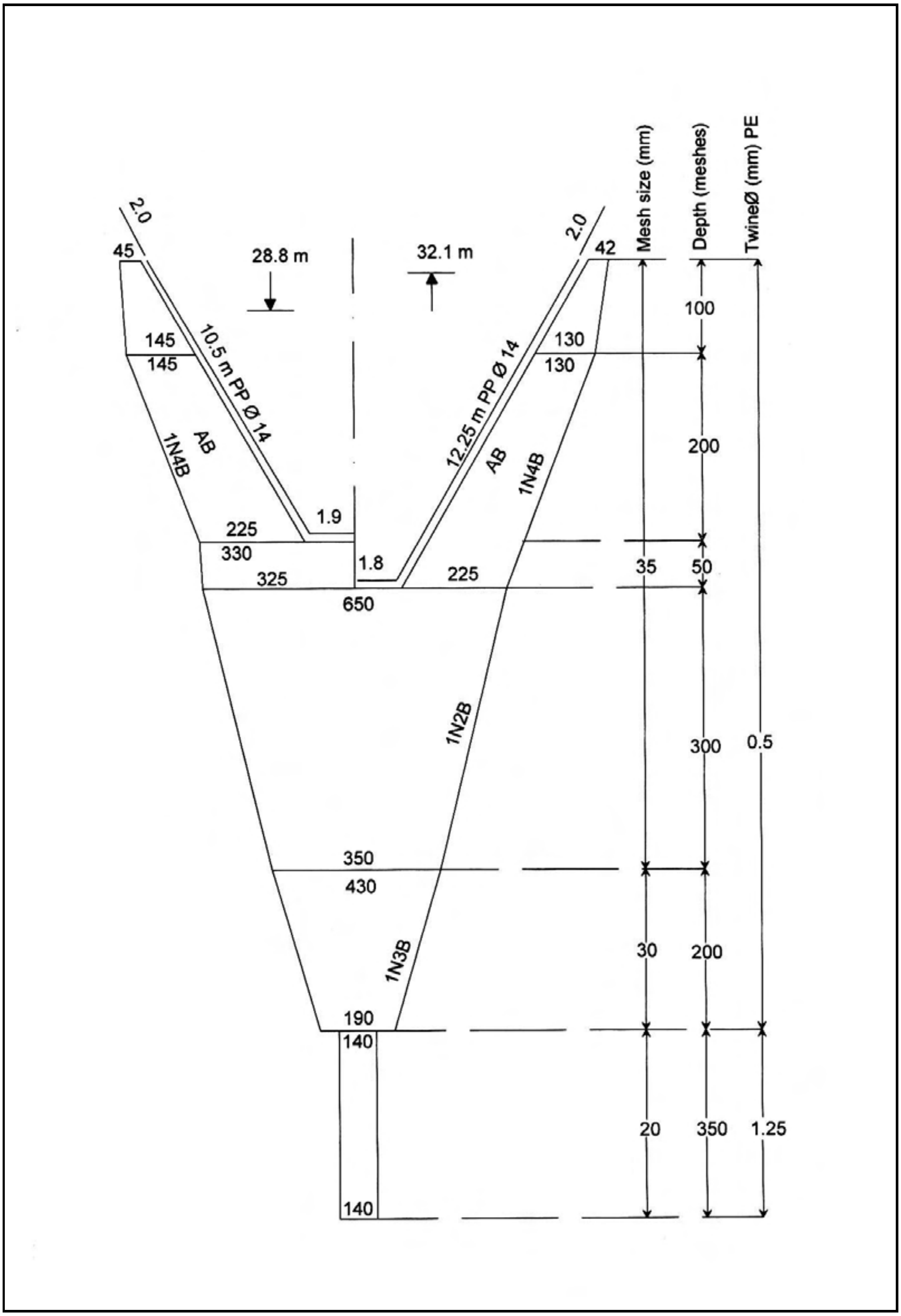


Fig. 3.4 Design of 28.8 m shrimp trawl

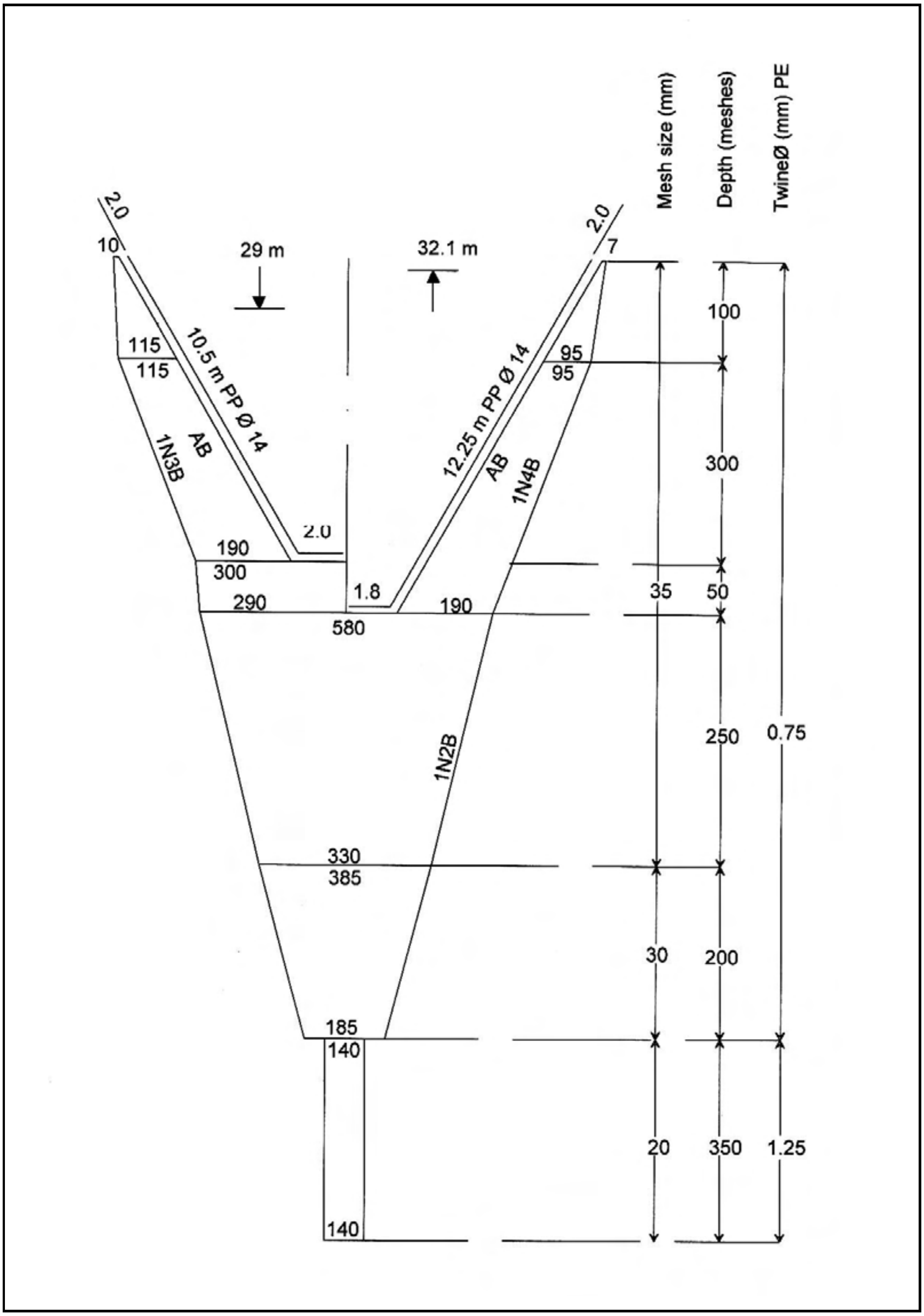


Fig. 3.5 Design of 29.0 m shrimp trawl

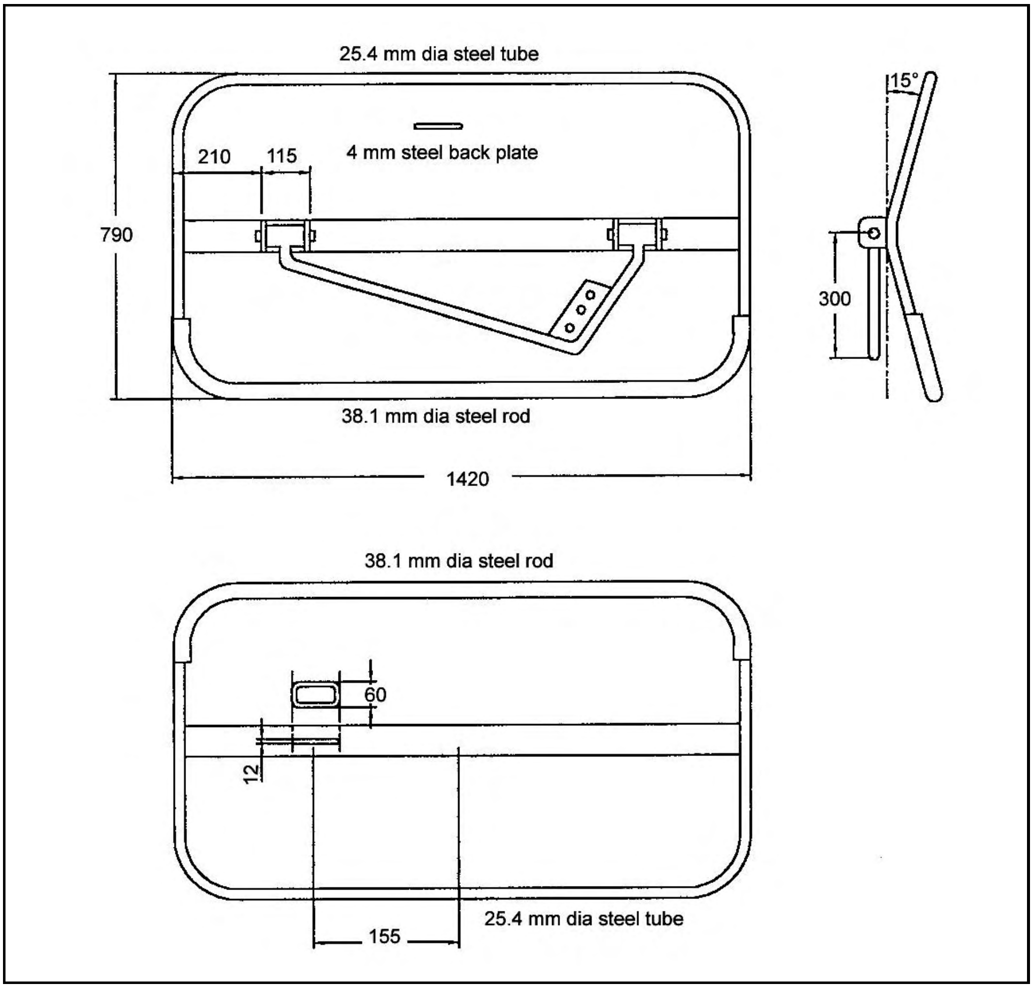


Fig. 3.6 Design details of V-type otter boards (1420x790 mm; 80 kg each)

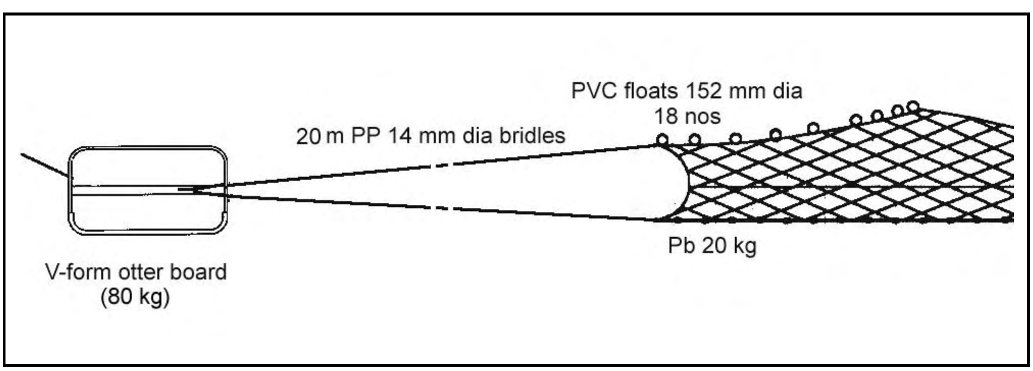


Fig. 3.7 Rigging of a typical shrimp trawl

3.2.4 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 and bycatch exclusion characteristics of 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. Data were subjected to statistical analysis using standard procedures. Detailed methodology for data collection and analysis are given in the respective chapters.

3.3 Survey of trawl systems

Information on trawlers, trawl nets and accessories, bycatch issues and concerns were collected using pre-tested structured Schedules prepared for the purpose, from centres of major trawling activity in Kerala such as Cochin, Munambam and Kollam.. Data on design details and rigging of existing commercial trawls and their accessories were obtained by a survey of trawl systems, using a trawl design template. Design drawings and specifications were prepared as per conventions of FAO (1975, 1978) and recommendations of ISO (1975).

3.4 Characterization of shrimp bycatch

Methodology followed for characterization of shrimp bycatch is given in Chapter 14.

3.5 Evaluation of the effect of BRD incorporated trawl systems in operational fuel consumption

Methodology followed to assess the effect BRD incorporated trawl systems in operational fuel consumption is given in Chapter 15.

4.0 Present Status of Trawl Systems

4.1 Introduction

Trawling is the most important commercial fishing method used in mechanized sector. The marine fish production in Kerala during 2005-06 was estimated at 5.59×10^5 tonnes, of which the mechanized sector accounted for 67.9%. Currently there are about 850 trawlers operating during normal seasons making Cochin and Munambam as their base and during peak seasons more than 1200 trawlers are operated in Cochin – Munambam areas. Such a large number of trawlers operate off Cochin mainly due to its geographic proximity to the fishing harbours at Thoppumpady and Munambam and landing centers such as Malippuram, Murikkumpadam and Puthuvypin. Moreover, Cochin is the most important area of seafood processing in Kerala. As a result of constant efforts to increase the efficiency of fishing, large-scale changes have taken place in both the fishing vessel and gear since its introduction in 1950s. Earlier attempts to study commercially operated trawl systems of Cochin has been made by Mukundan and Hameed (1993) and Boopendranath (2000). About 850 trawlers are operating from Quilon. Trawl systems of Kollam have been studied earlier by Gibinkumar et al. (2006) and Sabu et al. (2006). Though it is the most widely adopted fishing method, there is paucity of accurate information regarding the trawl systems used by the mechanized sector. In the present study, an attempt is made to assess the present status of trawl systems operated in Kerala, in terms of vessel, capacities, fishing gear, accessories, equipment, fishing practices and bycatch issues.

4.2 Materials and Methods

Data for this study was collected from centres of major trawling activity in Kerala such as Cochin, Munambam and Kollam. Information on trawlers, trawl nets and accessories were collected from boat owners, skippers / serangs, engine drivers, deckhands, boat yard engineers, net makers and trawl accessory suppliers, using pre-tested structured Schedules prepared for the purpose. Data on design details and rigging of existing commercial trawls and their accessories were obtained by a survey of trawl systems, using a trawl design template. Design drawings and specifications were prepared as per conventions of FAO (1975, 1978) and recommendations of ISO (1975).

4.3. Results and Discussion

The present status of trawl systems in Kerala was studied in terms of material used for fabrication; LOA of the vessel; installed horse power; crew size; area and depth of operation; number and duration of hauls; capacities such as fish hold, ice, water, and diesel; type of otter boards; availability of electronic and fish finding equipment; details of number, design, construction and appurtenances of different trawl nets onboard.

4.3.1 Trawler details

Vessel categories

Trawlers of both wood and steel construction are available in Kerala. Majority of the recent constructions used steel for hull. Wooden trawlers are in general, more than 5-10 years old and all the new trawlers are made exclusively of steel. The size of the trawlers ranges from 9.8 m L_{OA} winch-less type to 21.6 m large vessels used for multi-day deep-sea fishing. Trawlers can be classified in to (i) Small Trawlers having L_{OA} ranging from 8.5 m to 10.6 m with a resale value between 0.1 to 0.15 million rupees for old vessels and replacement cost of about 0.4 million rupees, (ii) Medium sized Trawlers having L_{OA} between 10.7 m and 15.2 m with a resale value of 0.2 - 0.7 million rupees for old vessels and replacement cost of 1.0 to 2.0 million rupees and (iii) Large Trawlers of 15.3 m L_{OA} and above with an investment of Rs 2.0 to 3.0 million.

Engine details

The most preferred engine used in trawlers of almost all length classes in central Kerala is Ashok Leyland marine diesel engine. The reliable performance and the easy availability of spares made this the most preferred brand by the fishermen, owners and service mechanics. Ruston engines are used in the older winch-less trawlers and other small trawlers having L_{OA} between 8.5 and 9.8 m. A very small percentage of trawlers are using Cummins marine diesel engines. Engine details are given in Table 4.1.

Trawl winch

Trawl winches used are of mechanical type operated using power take-off from the main engine. Steel wire ropes (SWR) of 8-10 mm dia are generally used for trawling. Small and medium sized trawlers use 8-9 mm dia SWR which costs about Rs 26-30 per metre and larger vessels use 10 mm dia SWR which costs about Rs 30-32 per metre. Wire rope length is up to 700 metre/drum for small vessels and 1500-2000 metre/drum for large vessels.

Table 4.1 Details of engine models, their power and vessel type

Vessel L_{OA}	Engine model	hp @ 2000 rpm
8.5 - 9.8 m	Ruston	
8.5 - 12.2 m	Ashok Leyland – 370	90
12.2 - 14.6 m	Ashok Leyland – 400	100
12.2 - 15.2 m	Ashok Leyland - 402	107.5
13.7 - 18.3 m	Ashok Leyland - 411	110
13.7 - 18.3 m	Ashok Leyland - 412	112
13.7 - 18.3 m	Ashok Leyland - 412 TC*	124
15.2 - 19.8 m	Ashok Leyland - 680	158
15.2 - 21.6m	Ashok Leyland - 680 TC*	177

* Turbo charged

Fish hold capacity

Smaller boats conducting daily trips up to 9 h duration, do not have any built-in fish hold facility. However, some vessels carry 1 or 2 boxes of 500 kg capacity. In larger boats, fish hold capacity ranges from 2-10 tonnes. Earlier, the fish hold used to be insulated using thermocol. Currently, puff insulation is used which costs around Rs. $1\text{-}1.5\times10^5$ due to its better thermal insulation properties and durability. Separate compartments are available in the fish hold for storing various categories of finfishes, shrimps and cephalopods. Crushed ice is stored separately in the fish hold.

Quantity of ice and water

Small vessels undertaking single day operation do not carry ice while multi-day fishing vessels carry ice in large quantities for preservation of catch onboard. On an average, vessels of 15.2 m carry 20-30 blocks of ice weighing 25 kg each. Large vessels carry up to 150 blocks of ice for trips up to 5 days. 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 freshwater and large vessels carry 1000-4000 liters depending trip duration.

Electronic and fish detection equipment

Almost all large vessels and 75-80 % of small trawlers are equipped with modern electronic equipments such as echo sounder and Global Positioning System (GPS) and in some cases VHF radiotelephone. Echo sounder is used for monitoring the depth of operation, nature of fishing ground and also to detect fish. GPS is used for locating the exact position speed and course and facilitates location of potential fishing grounds. It also aids the rescue operators to locate the boats in distress after communicating with them through wireless. Radiotelephone and mobile phone help in communicating with the land stations or with the other boats operating in the same area.

4.3.2 Trawl nets

Earlier trawlers were operated mainly targeting shrimp resources. The scenario has changed in recent years, with the trawlers resorting to fishing trips extending up to 10 days and they are targeting finfish, squids and cuttle fish in addition to shrimps. Multiple numbers of different designs of trawl nets are carried onboard for this purpose. The number of trawl nets ranges between 5 and 15. The large vessels carry 12 to 15 trawl nets and small vessels carry up to 8 nets. Trawl nets are made of high density polyethylene (HDPE) netting and polypropylene ropes. Thirteen different designs of trawl nets including twelve two seam designs and one four seam design, were observed during the survey. Among them seven are shrimp trawl nets (known as *Chemmeen vala*, *Poovalan vala* and *Pullan vala* in vernacular), three are fish trawls (*Meen vala*) for targeting finfishes and one four seam anchovy trawl (*Chooda vala*) for catching anchovies and two cephalopod trawls (*Kanava vala*) for harvesting squids and cuttlefishes. Twenty-three trawl designs were identified from Cochin, Munambam and Kollam centres.

At Cochin and Munambam centres 13 trawl designs were identified, of which 7 were shrimp trawls (Fig. 4.1-4.7), 4 fish trawls and 2 cephalopod trawls. At Kollam centre 10 trawl designs were identified which included 5 shrimp trawl designs (Fig. 4.8-4.12), 3 fish trawls and 2 cephalopod trawls including one used for harvesting whelks (*Babylonia* spp.).

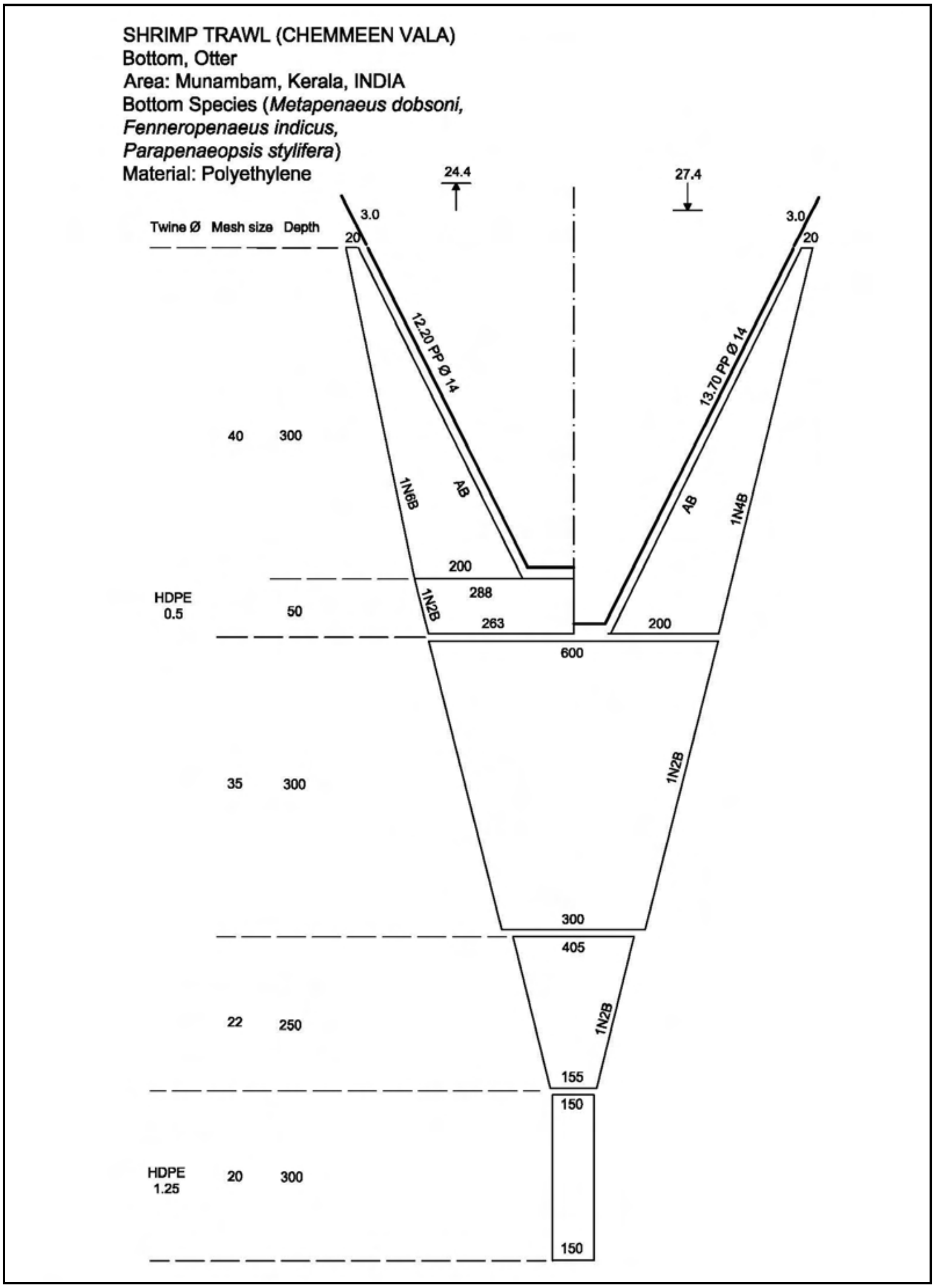


Fig. 4.1 Design of 24.4 m shrimp trawl (Munambam centre)

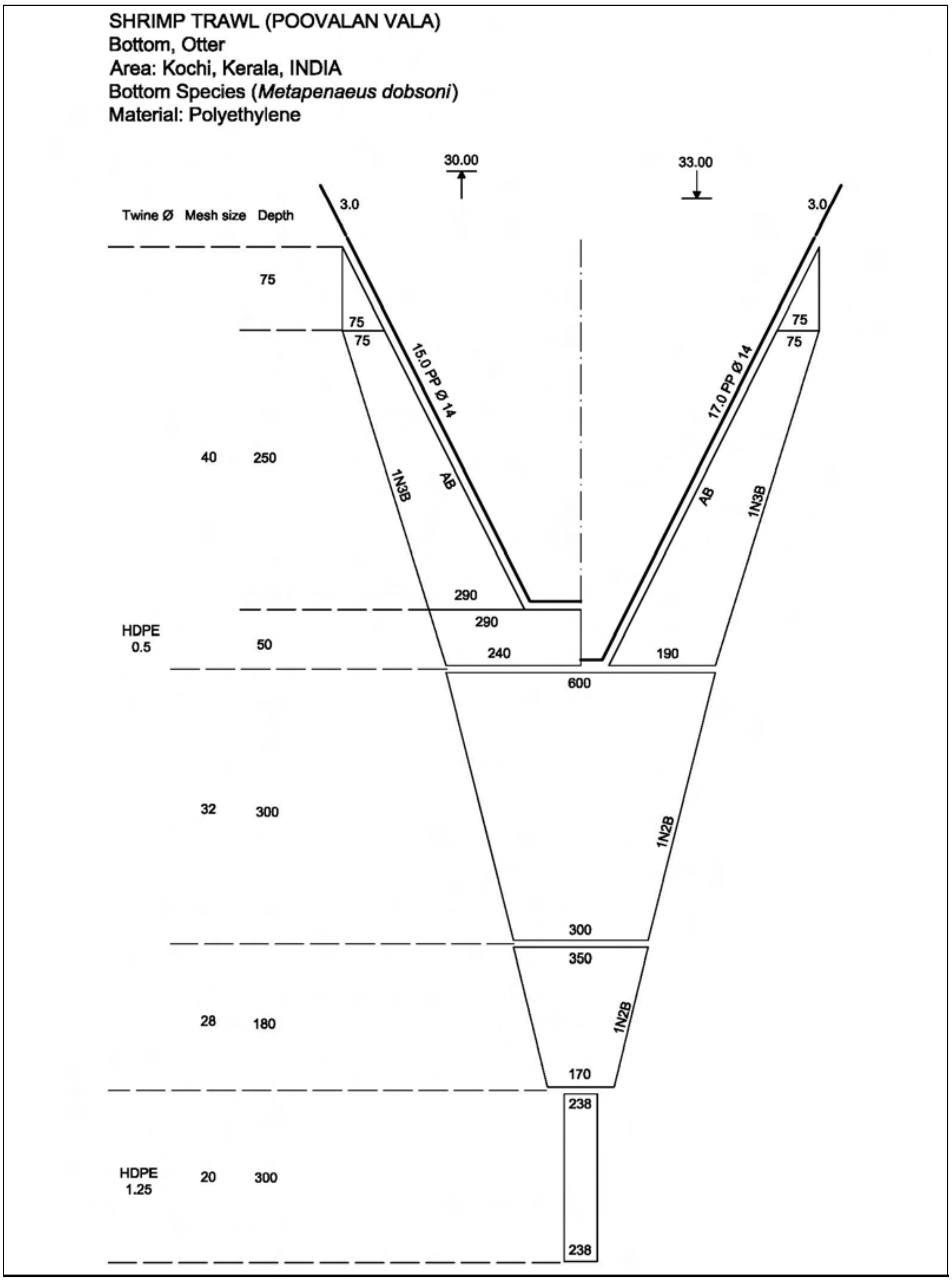


Fig. 4.2 Design of 30.0 m shrimp trawl (Cochin centre)

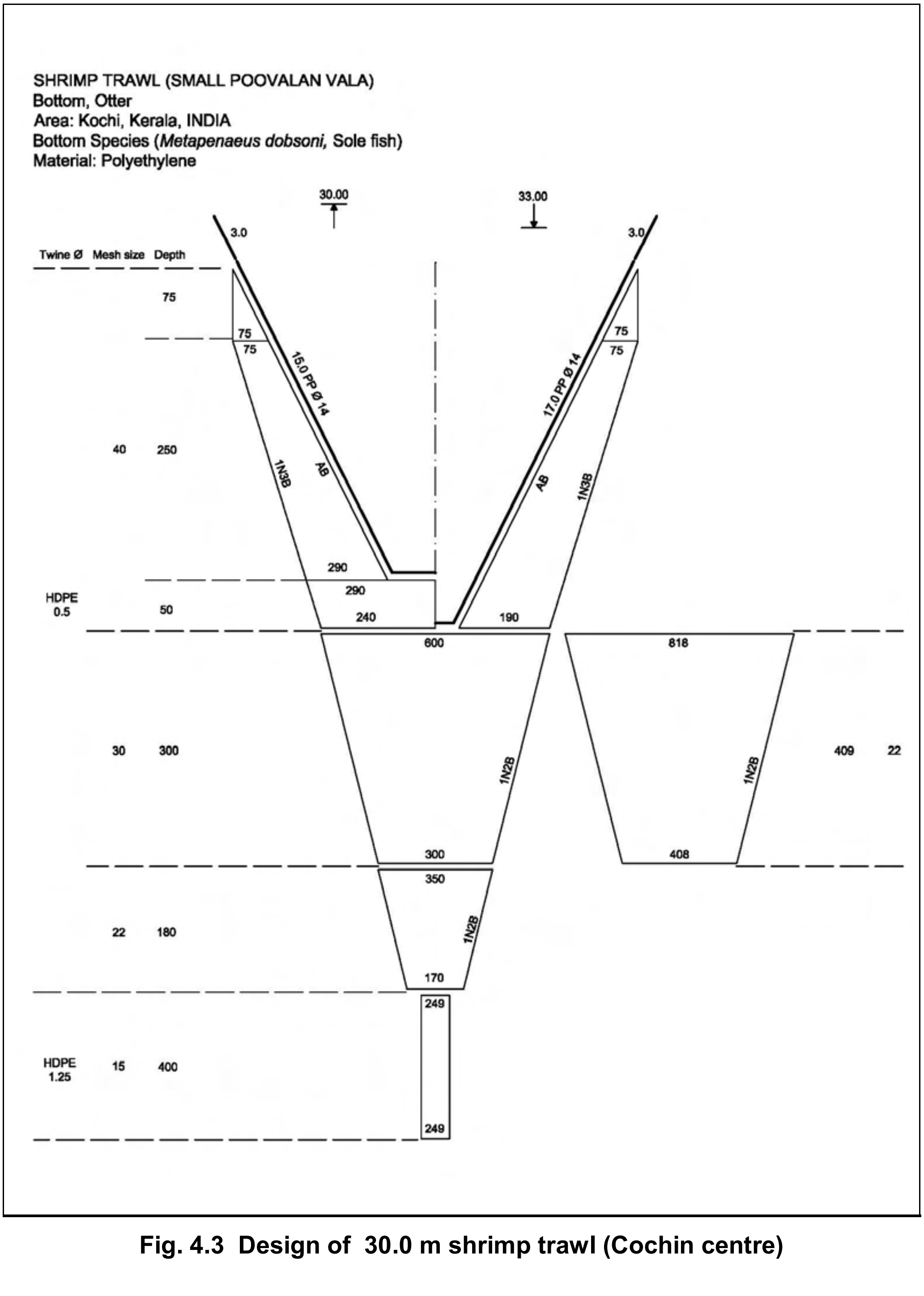


Fig. 4.3 Design of 30.0 m shrimp trawl (Cochin centre)

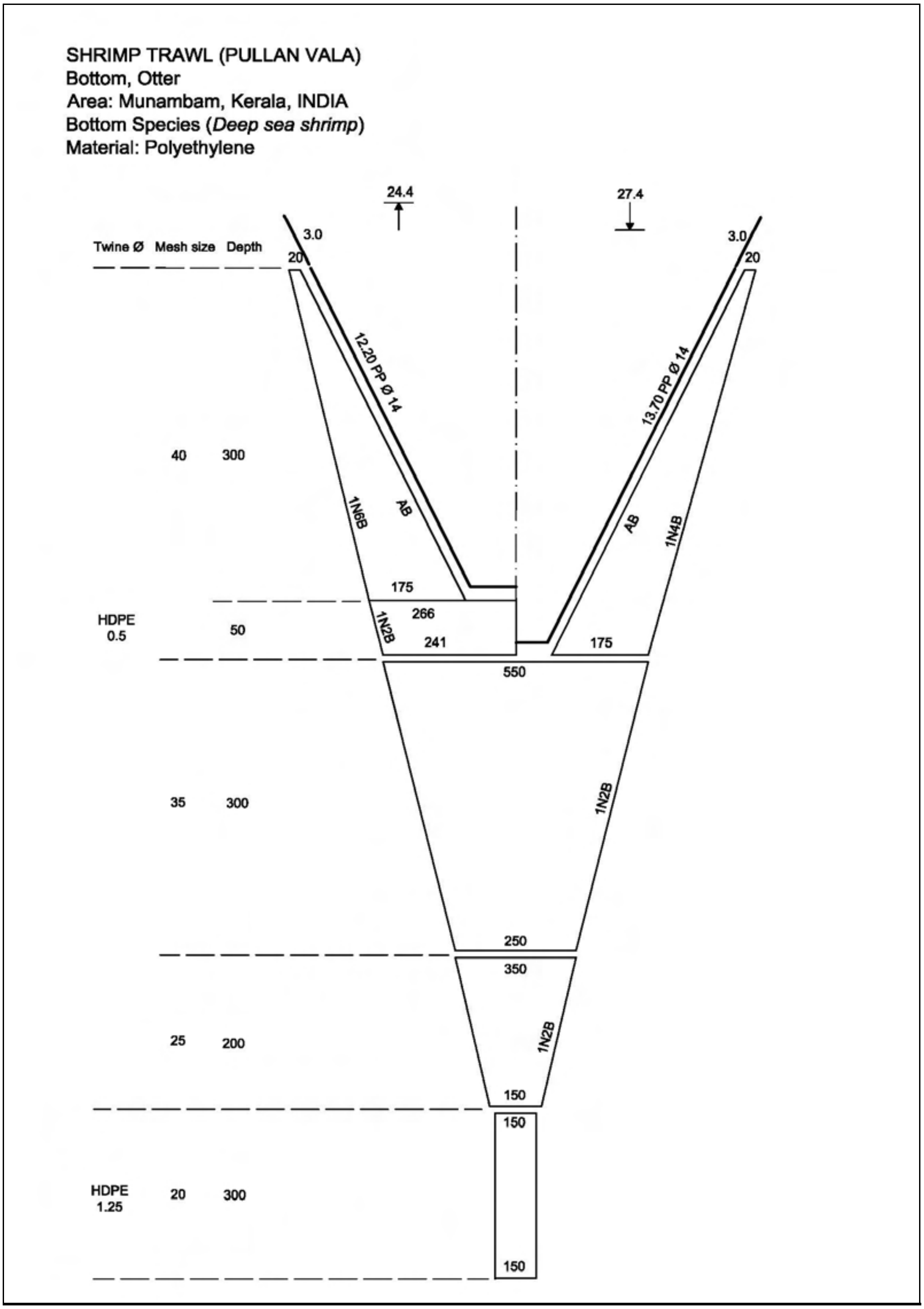


Fig. 4.4 Design of 24.4 m deep sea shrimp trawl (Munambam centre)

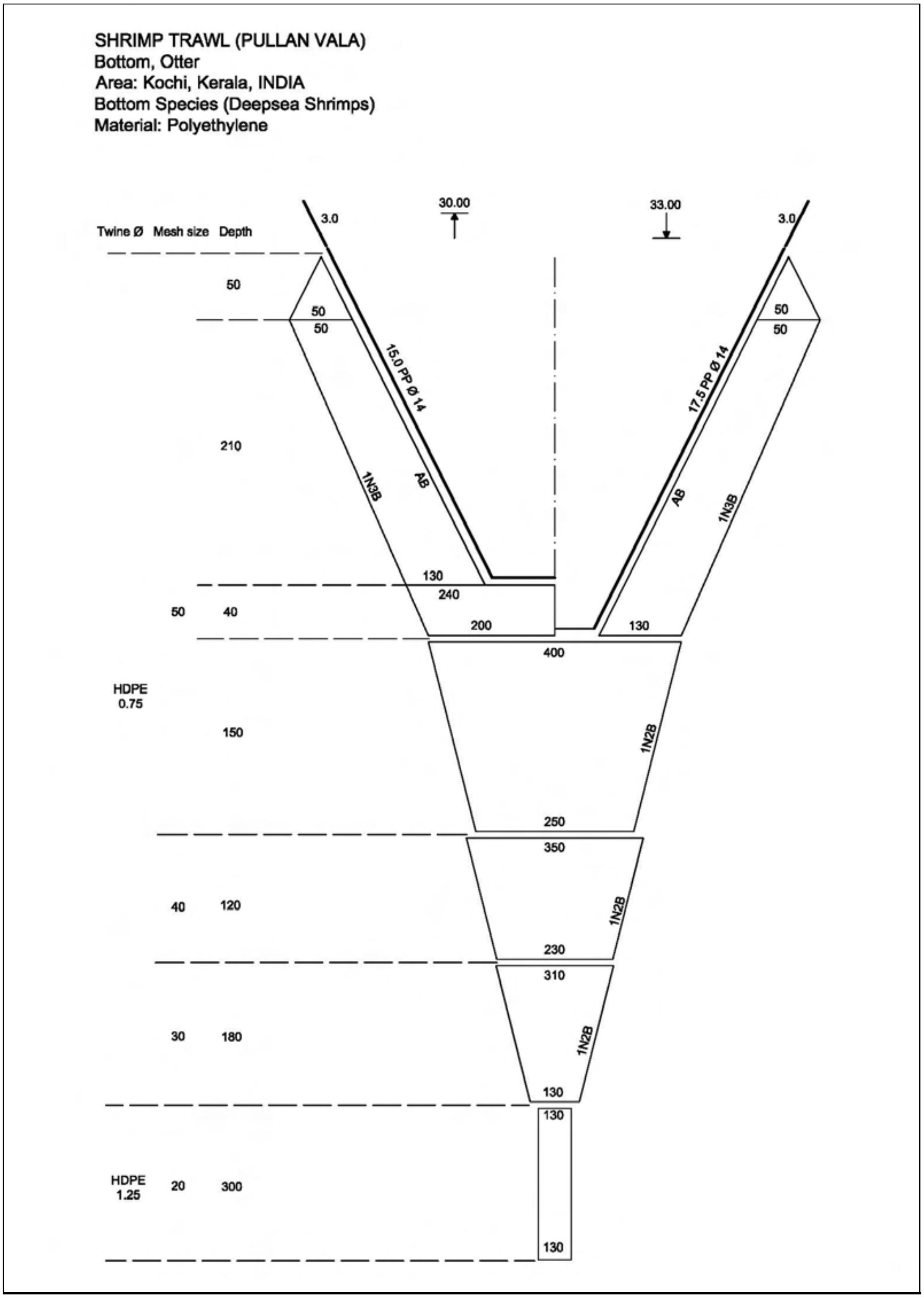


Fig. 4.5 Design of 30.0 m deep sea shrimp trawl (Cochin centre)

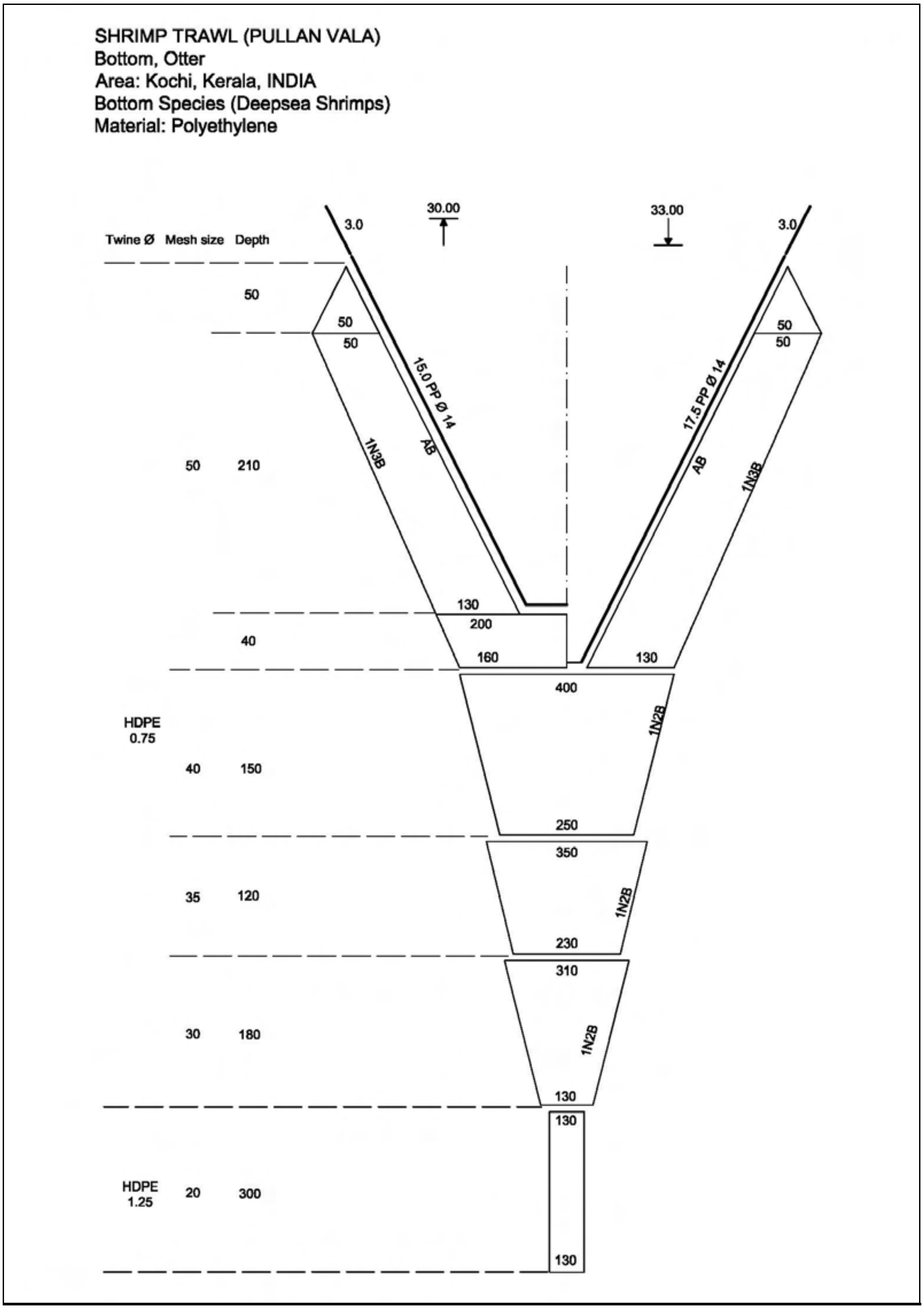


Fig. 4.6 Design of 30.0 m deep sea shrimp trawl (Cochin centre)

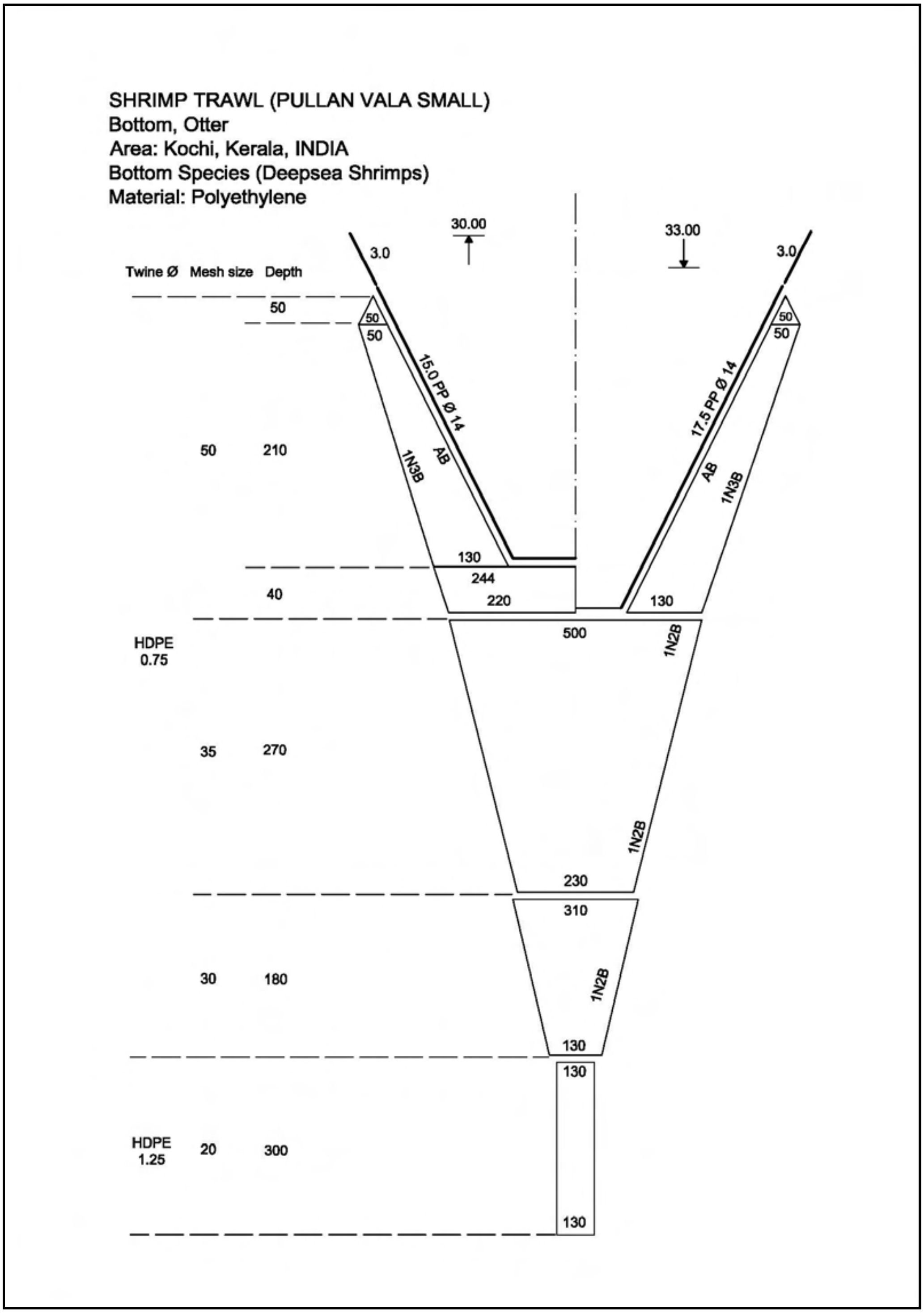


Fig. 4.7 Design of 30.0 m deep sea shrimp trawl (Cochin centre)

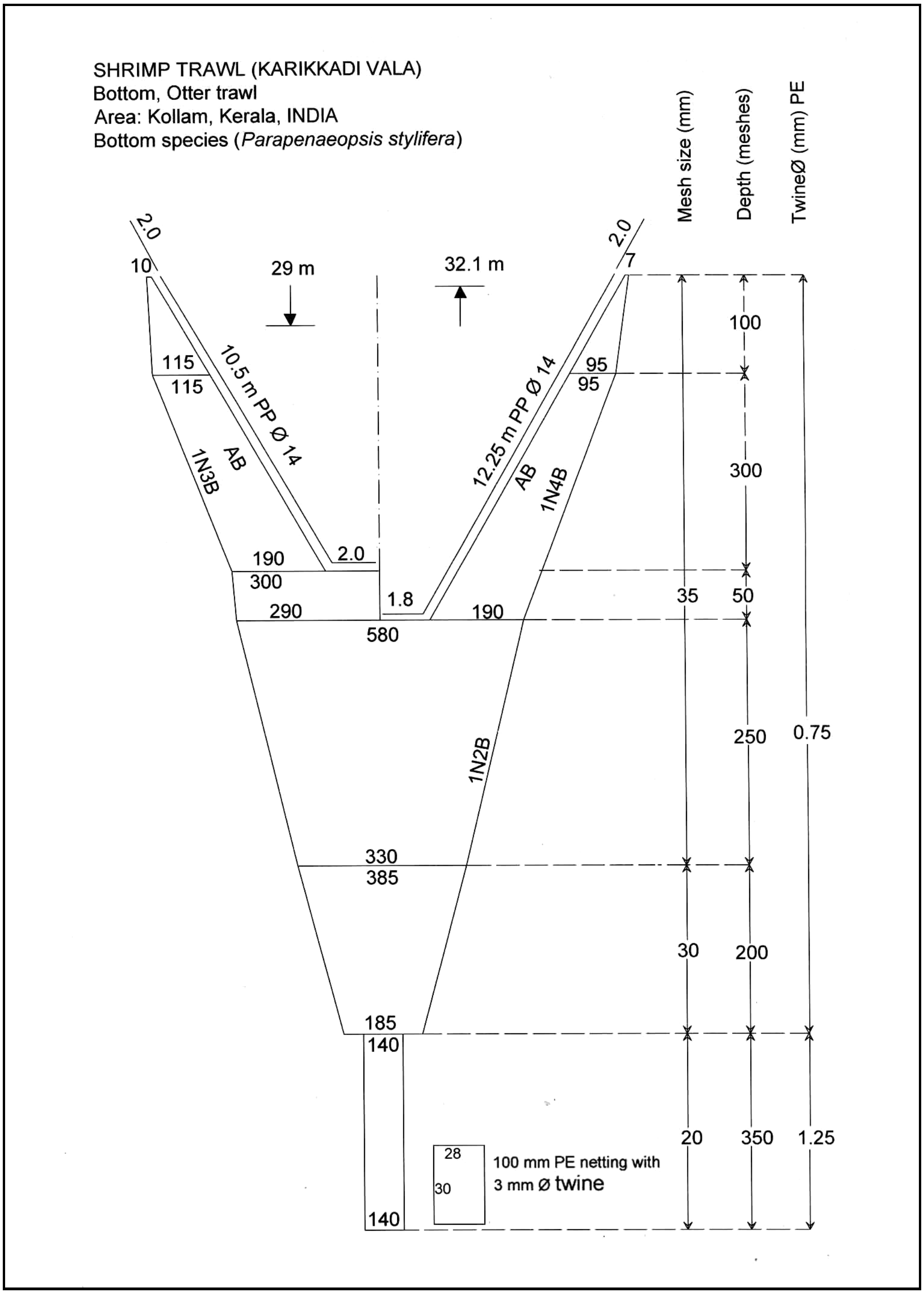


Fig. 4.8 Design of 29.0 m shrimp trawl (Kollam centre)

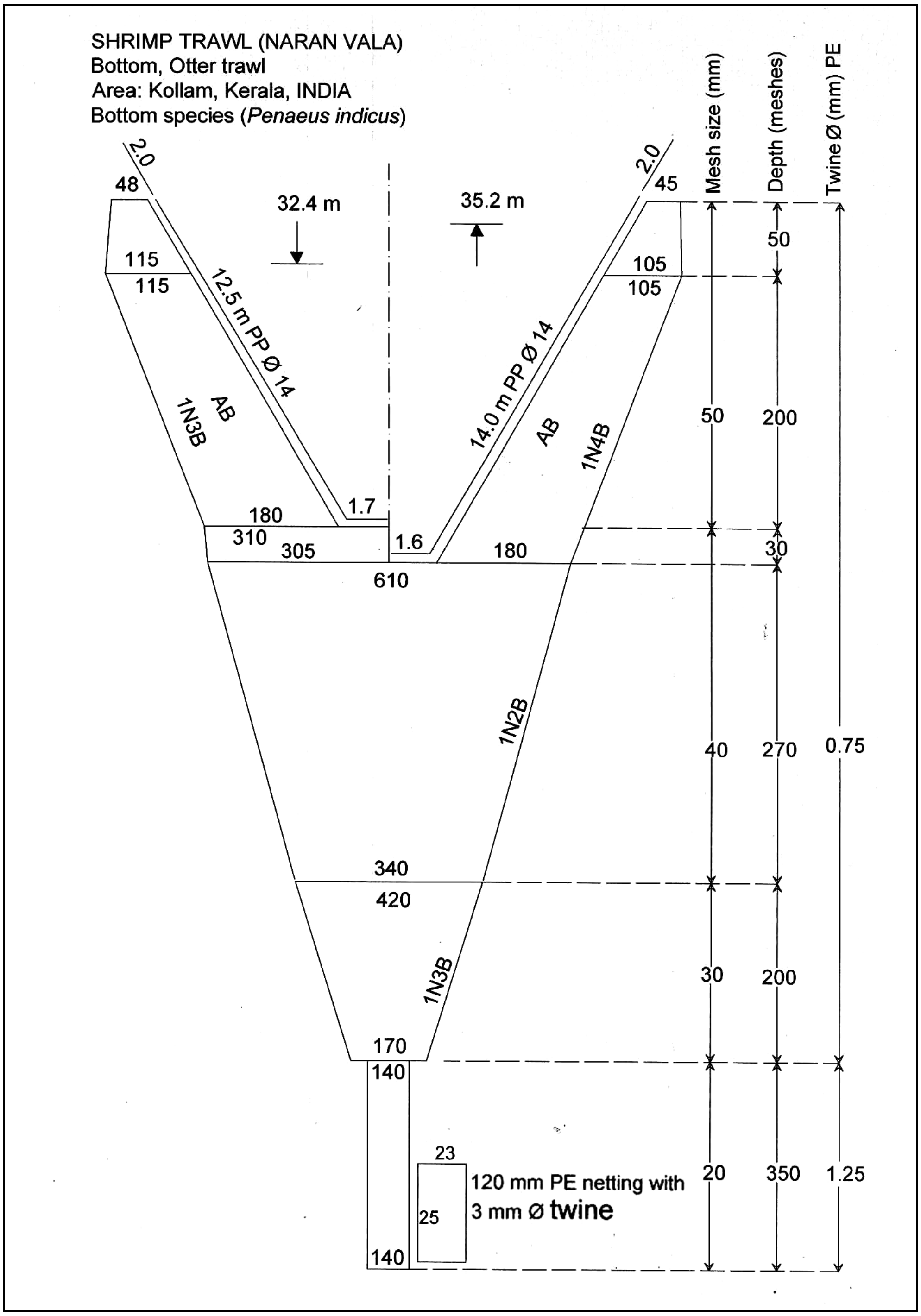


Fig. 4.9 Design of 32.4 m shrimp trawl (Kollam centre)

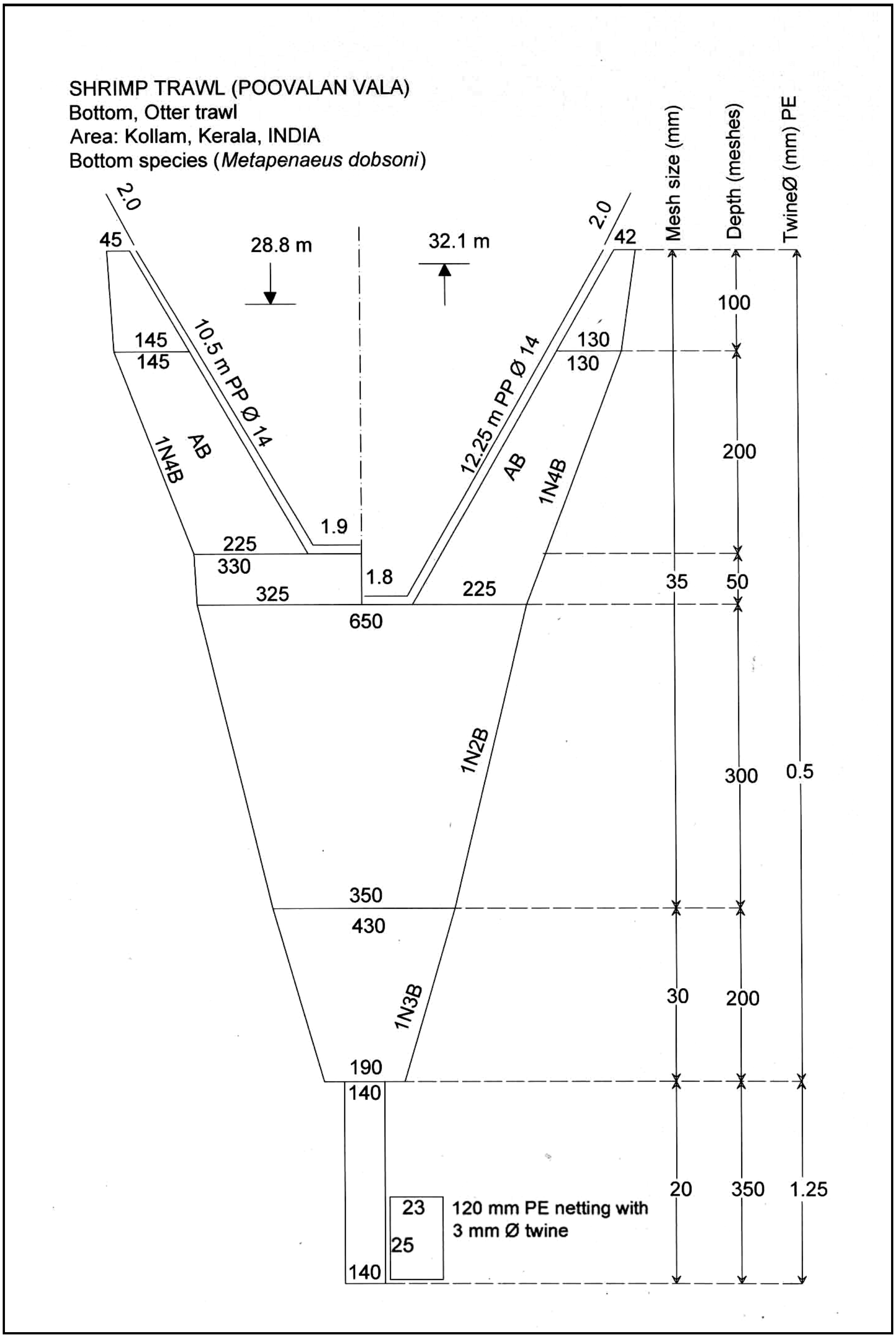


Fig. 4.10 Design of 28.8 m shrimp trawl (Kollam centre)

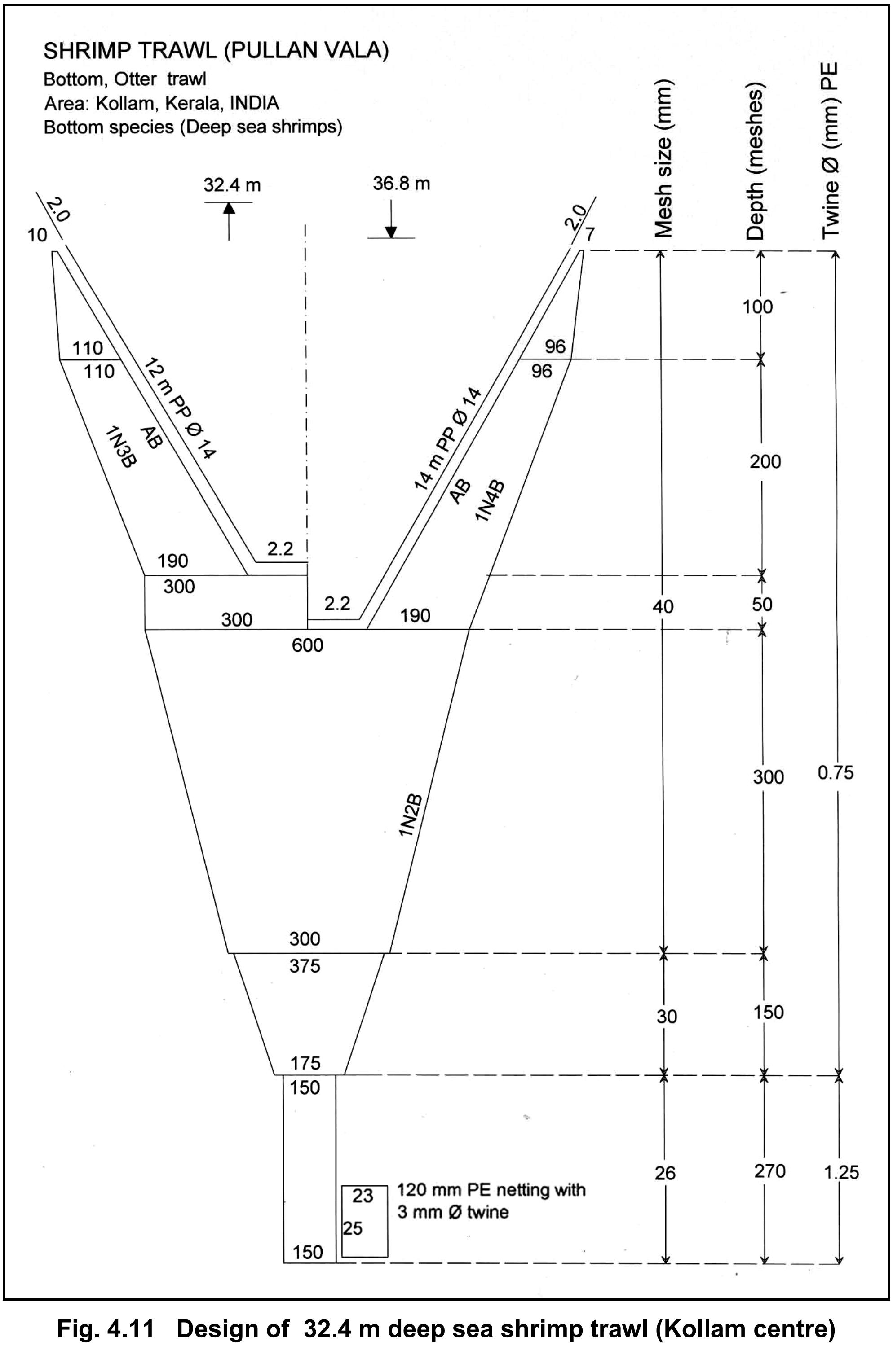


Fig. 4.11 Design of 32.4 m deep sea shrimp trawl (Kollam centre)

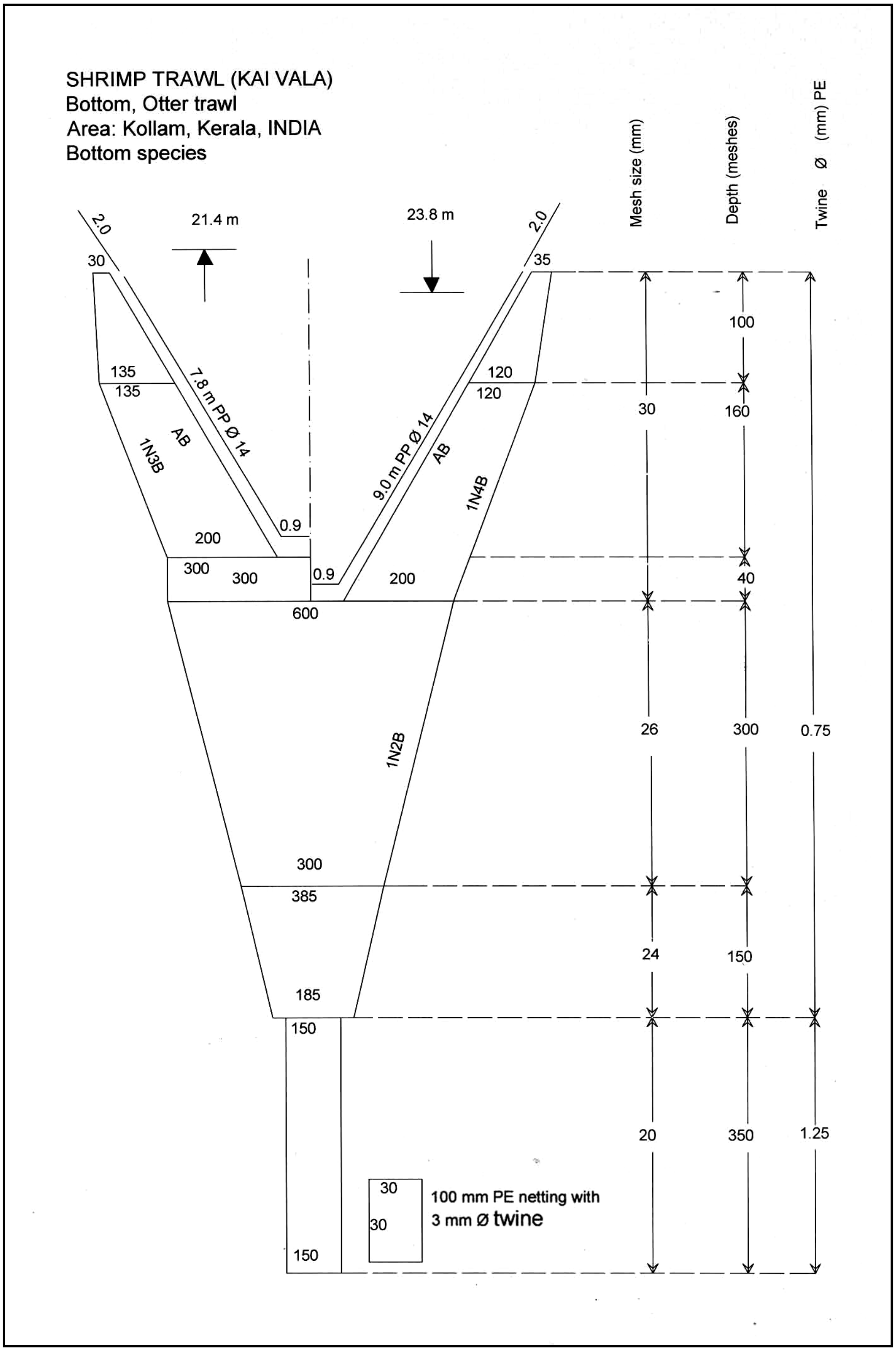


Fig. 4.12 Design of 21.4 m shrimp trawl (Kollam centre)

Otter boards

About 95 % of trawlers above 10.6 m L_{OA} use V-type otter boards (Fig. 4.13) as sheer device for operation of trawls. Use of flat rectangular otter boards of wood and steel construction (Fig. 4.14) is seen to have considerably declined. The weight of otter board ranges from 50 to 88 kg each. Table 4.2 gives the details of dimensions of otter boards commonly used in trawlers. Small trawlers below 10.6 m L_{OA} use flat rectangular otter boards made of wood reinforced by steel plates.

Table 4.2 Otter board dimensions and weight

Engine	Length (cm)	Breadth (cm)	Weight (kg)
V-type steel otter boards			
ALM 370	132.08	76.2	50 - 60
ALM 400	132.08	76.2	60 -70
ALM 402	132.08	76.2	75
ALM 412	137.16	81.28	75 -78
ALM 680	137.16	81.28 - 83.82	80 -88
Wooden otter boards			
ALM 370	137.16	68.58	60
ALM 400	147.32	71.12	65
ALM 402	152.40	76.2	75 -80
ALM 412	152.40	76.2	75 -80
ALM 680	152.40	76.2	75 -80

Fig. 4.13 V-type otter board of all steel construction (80 kg)

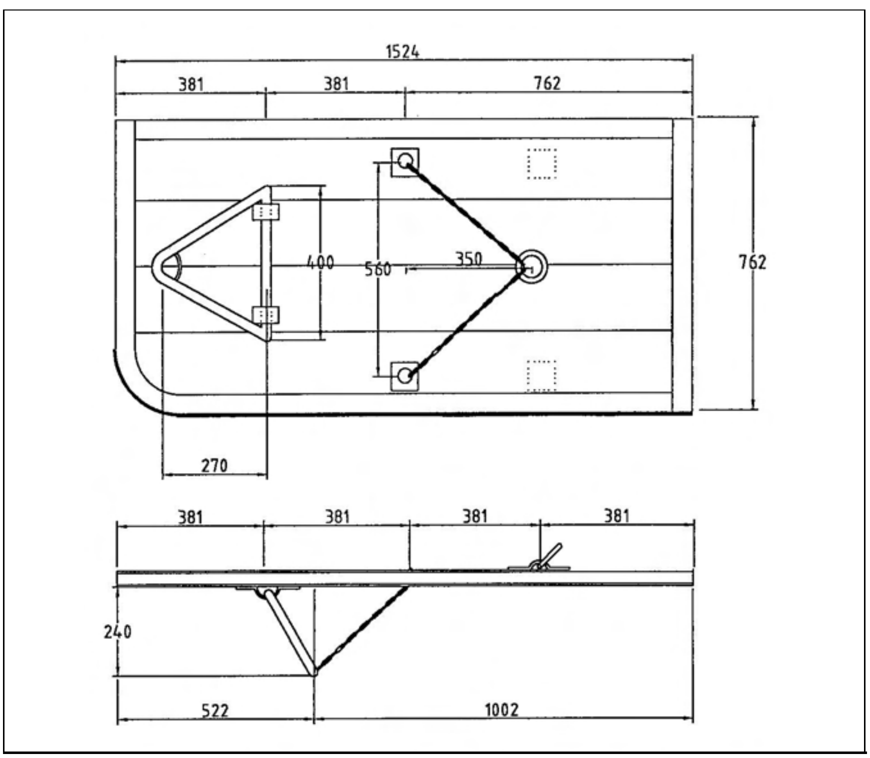


Fig. 4.14 Design details of flat rectangular otter board of wood and steel construction (1524x762 mm; 75 kg)

4.3.3 Trawl accessories

Polypropylene ropes are commonly used for bridles, hauling rope, centre rope, head rope and foot-ropes. Towing warps used in the winch are steel wire rope (SWR) of 8-10 mm dia Aluminium floats earlier preferred by the trawlers are now replaced almost entirely by HDPE floats. Single eyed floats were replaced by 2-eyed floats having various diameters (15 cm, 20 cm, 25 cm and 30 cm) are used in trawl nets. Sinkers are usually made of lead and are available in 25 g, 30 g, 50 g, 100 g and 200 g. Cast iron is also used in some cases. Chain is not preferred by most of the net makers since it corrodes rapidly. For deep-sea trawling tickler chain is widely used. Rubber sinkers or bushes (650 g) are commonly used in bottom trawls.

4.3.4 Duration of fishing

Duration of fishing ranges from 9 h to 10 days depending on the size and capacities of the fishing boat, facilities onboard and also species targeted. Small vessels up to 10.6 m L_{OA} undertake daily fishing from 3 am to 12 pm in peak season only. Three or four hauls with a tow duration of 1.5 to 2.5 h are undertaken, mainly targeting shrimps and anchovies in coastal waters. Medium vessels up to 15.2 m L_{OA} undertake fishing trips of 2-5 days, targeting shrimps, squids and finfishes. They generally make 4-5 hauls/day with tow duration of 1.5 - 3 h. Large vessels more than 15.2 m undertake multi-day fishing ranging from 5 to 10 days. These trawlers undertake 4-5 hauls during day time operation and up to 4 hauls if there is night fishing with tow duration ranging between 1.5 and 3 h. All the vessels prefer day fishing and night fishing is undertaken very rarely and is according to the availability of shrimps and cephalopods. Now-a-days line fishing is undertaken by trawler fishermen during night. Main target species groups are barracudas, seerfishes, reef cods, snappers and large carangids. Jigging is also conducted in reef areas to catch cuttle fish and squids.

4.4 Conclusions

The trawl fishery of south-west coast of India has developed tremendously in recent years. Significant changes in design features of trawls were noted, when compared with earlier reports (Mukundan and Hameed, 1993; Boopendranath, 2000). Due to reducing catch volumes per unit effort and impacts of economic overfishing, the boat owners are compelled to construct larger trawlers capable of undertaking multi-day fishing and are expanding fishing activities to deeper waters targeting a diverse group of finfishes and shellfishes. A significant shift from traditional wood to steel as the preferred boat building materials is noticeable, with the hulls of almost all new constructions being built exclusively using steel. The use of electronic navigation equipment such as GPS and acoustic fish detection devices such as echosounder has significantly contributed to precision fishing and use of communication equipment (VHF radiotelephone) has improved the safety in operations.

There have been significant changes in the number of trawl nets carried on board and in the diversity of trawl designs used for targeting an increasingly wider range of finfish and shellfish species. The dimensions of the trawls have been increasing commensurate with the increase in size of the vessel and installed engine power. Use of large mesh trawls in the front trawl sections which reduce the drag and facilitate construction of trawl with significant larger mouth area has become widespread in the case of fish trawls, due to direct and indirect of impact of R&D efforts of CIFT in this area.

There has been no evidence of the use of any bycatch reduction technologies in the trawl fisheries, during the period of observations.

5.0 Performance Evaluation of Fisheye BRDs

5.1 Introduction

Fisheye is an important bycatch reduction device facilitating the escapement of actively swimming finfishes which has entered the codend (Pillai, 1998; Pillai et al., 2004). It consists of an oval shaped rigid structure of 80-150 mm in height and 300-400 mm in width with supporting frames made of stainless steel or aluminium rods. This opening facilitates the escape of the fish, which try to swim backward from the codend. Device is suitable for excluding actively swimming juveniles and young fishes while retaining the big ones (Pillai, 1998; Brewer et al., 1998; Gregor and Wang, 2003). Fisheye can be used either singly or in combination with other BRDs such as Nordmore grid, Super shooter, Square mesh window and Radial escapement device.

5.2. Materials and Methods

The method of installation of Fisheye BRD in the shrimp trawl is shown in Fig. 5.1. Three different designs of Fisheye BRDs with different exit configuration and orientation as listed below were used for performance evaluation:

i. Fisheye BRD with 300x200 mm oval exit of horizontal orientation (Fig. 5.2 and 5.5)
ii. Fisheye BRD with 300x200 mm oval exit of vertical orientation (Fig. 5.3 and 5.6)
iii. Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation (Fig. 5.4 and 5.7)

The Fisheye BRDs were fabricated using stainless steel rods of 6 mm dia. The Fisheye BRDs were fitted on the top side of the trawl codend at a distance of and 1.5 m (75 meshes) from the distal end of the codend (Fig. 5.1).

Field trials were conducted using a 29.0 m shrimp trawl with a diamond mesh codend of 20 mm mesh size, off Cochin, south-west coast of India. Covered codend method was adopted to study the selectivity and exclusion characteristics of the BRD (Sparre et al.,1989; Wileman et al., 1996). Catch from the codend and the cover were separately sorted and identified up to species level. Length statistics and weight of each species contributing to the catch was taken. Sub-sampling was done, in the case of large catches. In the case of fishes and shrimps total length is taken and for cephalopods the mantle length was measured.

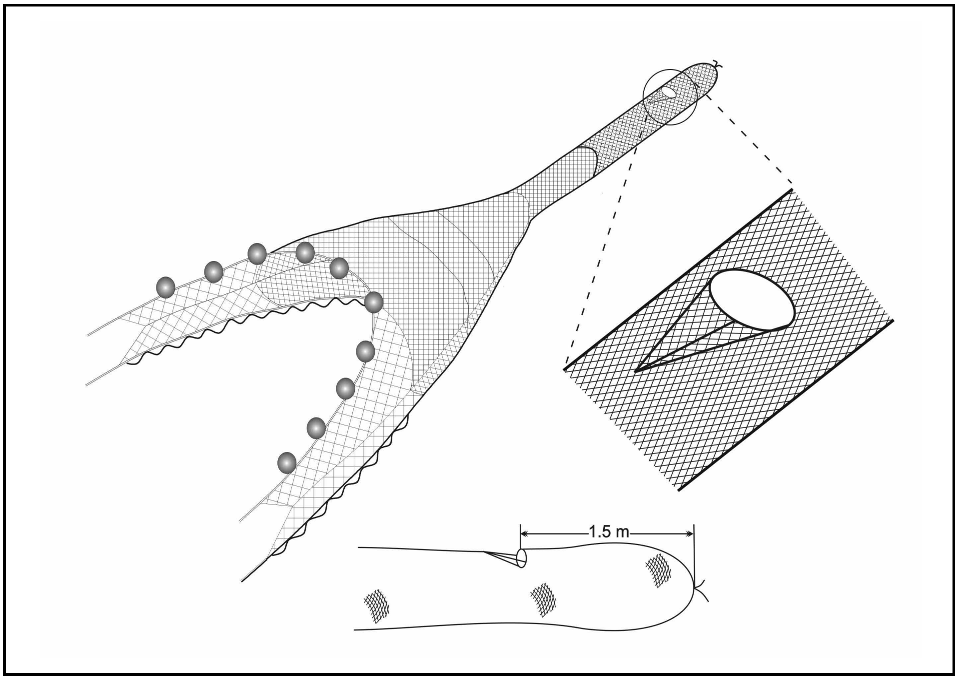


Fig. 5.1 Installation of Fisheye BRD

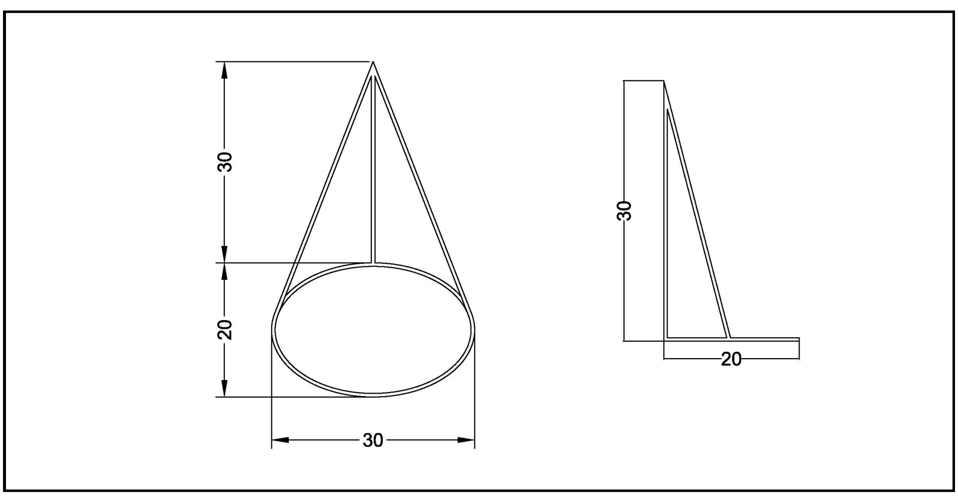


Fig. 5.2 Fisheye BRD design with 200x300 mm oval exit of horizontal orientation

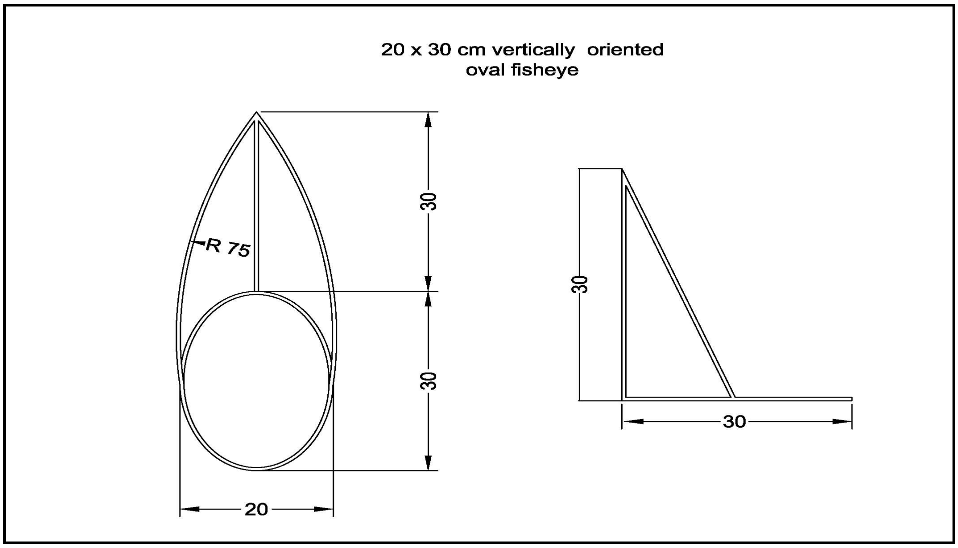


Fig. 5.3 Fisheye BRD with 300x200 mm oval exit of vertical orientation

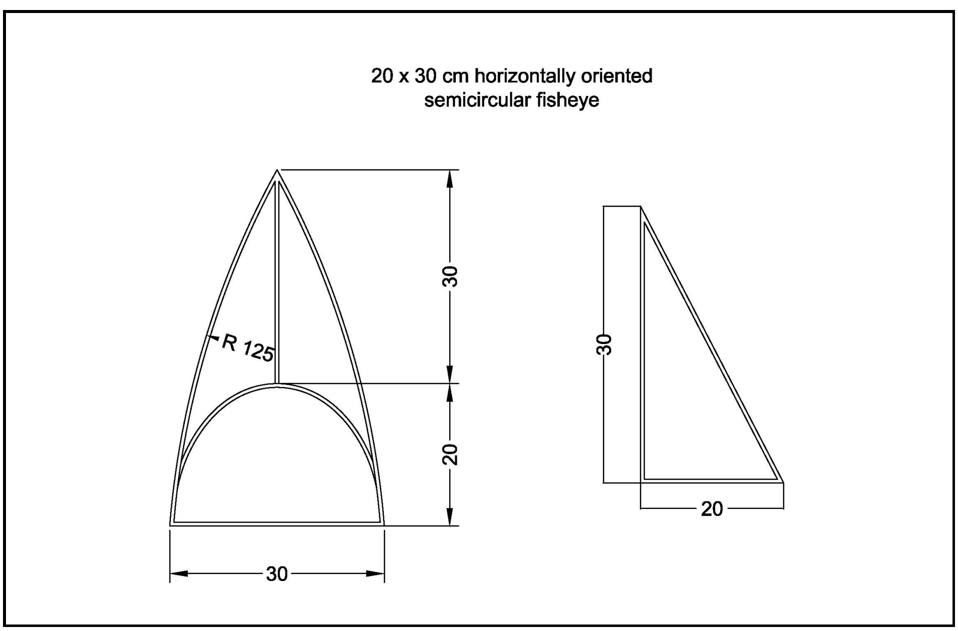


Fig. 5.4 Fisheye BRD with 300 x 200 mm semicircular exit of horizontal orientation

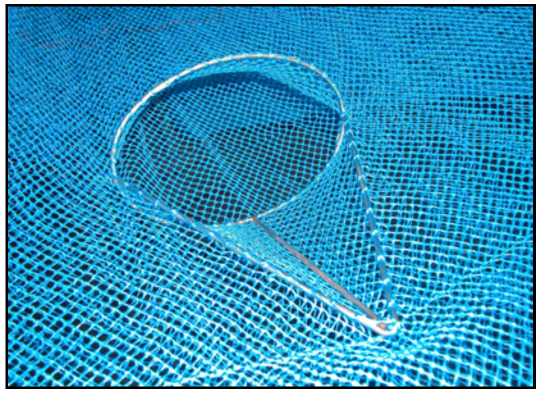


Fig. 5.5 A view of Fisheye BRD design with 200x300 mm oval exit of horizontal orientation fitted to the codend

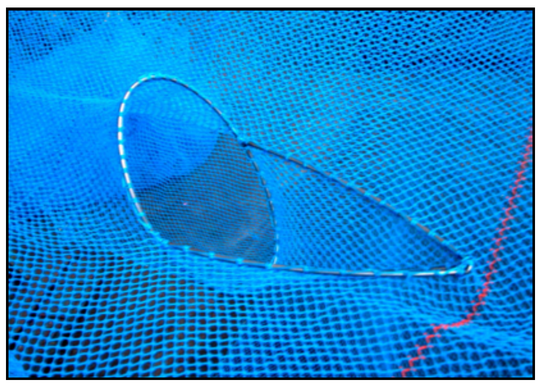


Fig. 5.6 A view of Fisheye BRD with 300x200 mm oval exit of vertical orientation fitted to the codend

Fig. 5.7 Fisheye BRD design with 200x300 mm semicircular exit of horizontal orientation being fitted to the trawl codend

5.3 Results and Discussion

5.3.1 Performance evaluation of Semicircular, Oval horizontal and Oval vertical Fisheye BRDs

Results of experiments using Fisheye BRD with 300x200 mm oval exit of horizontal orientation, Fisheye BRD with 300x200 mm oval exit of vertical orientation and Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation are summarized in Table 5.1.

Table 5.1 Results of experiments with Fisheye BRDs

	Fisheye BRD with 300x200 mm oval exit of horizontal orientation	Fisheye BRD with 300x200 mm oval exit of vertical orientation	Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation
No. of hauls	22	14	17
Total catch (kg)	140.02	343.89	277.71
CPUE (kg/h)	6.36	24.56	16.34
Retained catch (%)	73.21	57.19	52.02
Excluded catch (%)	26.79	42.81	47.98
Total shrimp catch (kg)	65.014	37.89	14.513
Retained shrimp catch (%)	95.13	73.83	99.17
Excluded shrimp catch (%)	4.87	26.17	0.83
Total bycatch (catch other than shrimps) (kg)	75.00	305.99	263.20
Retained bycatch (%)	54.21	55.12	49.42
Excluded bycatch (%)	45.79	44.88	50.58
Species encountered (No.)	80	110	75
Fish species (No.)	62	83	59
Shrimp species (No.)	7	6	5
Other species	11	21	11
100% exclusion (No.)	13	13	2
>50% exclusion (No.)	10	25	8
Up to 50% exclusion (No.)	33	53	34
0% exclusion ((No.)	24	19	31

5.3.1.1 Fisheye BRD design with 200x300 mm oval exit of horizontal orientation

Field trials with Fisheye BRD design with 200x300 mm oval exit of horizontal orientation were carried out during the months of March-May 2006. Overall catch during 22 hauls were 140.02 kg of which 73.21% was retained in the codend and 26.79% was excluded through the Fisheye BRD. Catch included 80 species consisting of 62 species of finfishes, 7 species of shrimps, 6 species of crabs, 2 species of cephalopods, 1 species of molluscan shell, 1 species of stomatopod and 1 species of jellyfish. Overall bycatch reduction was 45.79% and the shrimp loss was 4.87% (Table 5.1).

Finfishes consisted 37.45% of the retained catch and *Megalaspis cordyla* was found to be the most dominant species contributing 13.34% of the total catch during the period of observations, followed by *Pampus argenteus* 7.56%, *Encrasicholina devisi* 6.17%, and *Ambassis ambassis 2.79*%. Shrimps consisted 46.43% of the total catch. *Metapenaeus dobsoni* contributed 93.47% of total shrimp catch. Cephalopods contributed 2.98% of the total catch. *Uroteuthis (photololigo) duvauceli* contributed 98.25% and *Sepiella inermis* contributed 1.75% of the total cephalopod catch. Crabs formed 1.04% of total catch, of which *Portunus sanguinolentus* formed 70%. Stomatopods comprised 1.33% and molluscan shells contributed 0.04% of the total catch.

Among the species, which were excluded through the Fisheye, 13 species *viz., Nemipterus japonicus, Scomberomorus guttatus, Valamugil speigleri, Johnius carutta, Carangoides armatus, Gerres filamentosus, Sardinella albella, Leiognathus dussumieri, Gnathodon speciosus, Liza parsia, Siganus canaliculatus Sphyraena obtusata* and *Penaeus semisulcatus,* showed 100% escapement, 10 species showed escapement above 50%, 33 species showed exclusion upto 50% and 24 species of finfishes showed no exclusion (Table 5.1). In terms of shrimp retention, performance of 200x300 mm oval exit of horizontal orientation stands next to Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation.

5.3.1.2 Fisheye BRD with 300x200 mm oval exit of vertical orientation

Field trials using Fisheye BRD with 300x200 mm oval exit of vertical orientation was carried out during March 2006. Overall catch during this period was 343.89 kg, of which 57.19% was retained in the codend and 42.81% was excluded through the Fisheye BRD. Catch was contributed by 110 species consisting of 82 species of teleosts, 1 species of elasmobranch, 6 species of shrimps, 1 species of lobster, 7 species of crabs, 4 species of cephalopods, 8 species of molluscan shells, 1 species of stomatopod and occasional catches of sea-snakes. Shrimp loss was

26.17% of the total shrimp catch. The overall bycatch reduction was found to be about 45%.

Finfishes consisted of 73.7% of the total catch and among finfishes *Sardinella longiceps* was found to be the most dominant species contributing 11.44% of the total catch, followed by *Sphyraena obtusata* 9.87%, *Encrasicholina devisi* 6.17%, *Rastrelliger kanagurta* 5.54%, *Secutor insidiator* 5.45%. Shrimps was the next dominant group consisted 11.02% of total catch and *Metapenaeus affinis and Metapenaeus dobsoni* were the dominant species forming 41.64% and 33.54% respectively of total shrimp catch. Cephalopods contributed 8.95% of the total catch. *Uroteuthis (photololigo) duvauceli* contributed 84.45% and *Sepiella inermis* contributed 11.23% of the total catch cephalopods. Crabs formed 3.6% of total landings, of which *Charybdis natator* formed 31.65%. Stomatopods comprised 1.62% and molluscan shells contributed 1.4% of total catch. Among the molluscan shells *Turritella attenuata* contributed 36.3%.

Among the species caught, 12 species of finfishes *viz*., *Epinepheleus diacanthus, Johnius carouna, Congresox talabonoides, Sardinella fimbriatus, Stolephorus waitei, Gerres oyena, Kathala axillaries, Mugil cephalus, Samaris cristatus, Scomberoides tala, Caranx sexfasciatus* and *Scomberoides tol* and one lobster species (*Thenus orientalis*) showed 100% escapement, 37 species showed exclusion above 50% and 12 species showed no exclusion (Table 5.1).

In terms of shrimp retention, performance of 200x300 mm oval exit of vertical orientation, was poor compared other two Fisheye BRDs. The high loss of shrimp is attributed to the vertical orientation of the exit opening, which may facilitate eddy currents promoting exclusion of passively drifting shrimp species.

5.3.1.3 Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation

The field trials Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation was carried out during January-February 2006. During the 17 hauls undertaken, overall catch obtained was 277.71 kg, of which 52.02% retained in the codend and 47.98% excluded through the Fisheye BRD. Catch consisted of 75 species contributed by 59 species of teleosts, 5 species of shrimps, 1 species of lobster, 6 species of crabs, 1 species of cephalopods, 2 species of molluscs, 1 species of stomatopod and occasional catches of sea-snakes. The shrimp loss was found to be very low at 0.83% of total shrimp catch. The overall bycatch reduction was found to be about 50%.

Sardinella longiceps dominated among finfishes contributing 62.19% of the total catch, followed by *Encrassicholina devisi* 5.53%. Among cephalopods *Uroteuthis (photololigo) duvauceli* contributed 3.31% of the total catch. Crabs contributed 0.45% and molluscan shells contributed 0.02% of total catch. Shrimps contributed 5.23% of total catch and *Metapenaeus dobsonii* was the dominant species contributing 94.2% of total shrimp catch. *Oratosqilla nepa* contributed 2.29% of the total catch.

Among the species which escaped through the Fisheye BRD, 2 species of finfishes *viz*., *Caranx sexfasciatus and Secutor ruconius* showed 100% escapement, 8 species including *Liza parsia, Sardinella longiceps*, *Lactarius lactarius, Ambassis ambassis, Megalaspis cordyla, Rastrelliger kanagurta* and *Mugil cephalus* showed exclusion rates of more than 50%, 34 species showed exclusion rates up to 50% and 31 species consisted 19 species of teleosts, 4 species of shrimps, 2 species cephalopods, 5 species of crabs, 1 species of elasmobranch and 7 species of molluscan shells showed no exclusion.

It is significant to note that the target catch loss was very low (0.83% of total shrimp catch). In terms of shrimp retention, the performance Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation was better than the other two Fisheye BRDs.

5.3.2 Comparative performance evaluation of semicircular and oval horizontal Fisheye BRDs

After conducting individual field testing of the three different Fisheye BRDs, two promising designs of Fisheye BRDs *viz.*, semicircular and oval horizontal designs were subjected to further comparative field trials, using alternate haul method. Twelve pairs of alternate hauls were taken using 29.0 m shrimp trawl with the respective Fisheye BRDs positioned on the top of the codends. Codend covers were used to retain the excluded catch in order to study the exclusion and selectivity properties. Results of experiments using semicircular and oval horizontal designs are summarized in Table 5.2.

5.3.2.1 Operational performance

A total of 280.29 kg of catch and an average CPUE of 9.12 $kg.h^{-1}$ were obtained during the field trials. Semicircular Fisheye retained 71.6% and Oval horizontal Fisheye retained 68.2% of the catch encountered by the gear excluding 28.4% and 31.8% respectively. 100% exclusion was shown by 9 species each among 77 species in Semicircular Fisheye and among 70 species in Oval horizontal Fisheye. More than 50% escapement was shown by another 26 species semicircular Fisheye and 14 species in oval horizontal Fisheye. In terms of target catch retention, semicircular Fisheye performed much better than oval horizontal fisheye retaining 97.76% of the shrimp catch, compared to oval horizontal Fisheye (86.8%). Overall bycatch reduction due to installation of the Fisheye BRDs was 35-36%.

Table 5.2 Results of experiments with Oval and Semicircular Fisheye BRDs

	Fisheye BRD with 300x200 mm oval exit	Fisheye BRD with 300x200 mm semicircular exit
No. of hauls	12	12
Total catch (kg)	94.89	185.40
CPUE (kg/h)	7.30	14.26
Retained catch (kg)	64.70	132.67
Retained catch (%)	68.19	71.56
Excluded catch (%)	31.81	28.44
Total shrimp catch (kg)	18.08	36.67
Retained shrimp catch (%)	86.80	97.76
Excluded shrimp catch (%)	13.20	2.24
Total bycatch (catch other than shrimps) (kg)	76.81	148.73
Retained bycatch (%)	63.81	65.10
Excluded bycatch (%)	36.19	34.90
Species encountered (No.)	70	77
Fish species (No.)	57	61
Shrimp species (No.)	5	5
Other species (No.)	8	11
100% exclusion (No.)	9	9
>50% exclusion (No.)	13	24
Up to 50% exclusion (No.)	37	28
0% exclusion ((No.)	11	16

Statistical analysis using Student *t*-test has shown significant difference in the exclusion rate in respect of five species between the Fisheye BRDs tested. *Secutor ruconius* and *Thryssa mystax* showed higher exclusion rates from semicircular Fisheye BRD, which was statistically significant ($p<0.05$). *Secutor insidiator* , *Metapenaeus dobsoni* and *Parapenaeopsis stylifera* showed higher exclusion rates from oval horizontal Fisheye BRD, which was statistically significant ($p<0.05$). Shrimp loss from oval horizontal Fisheye BRD was statistically significant compared to semicircular Fisheye BRD. Though statistically insignificant, 28 species showed higher exclusion rates from semicircular Fisheye BRD while from oval horizontal Fisheye BRD 15 species showed better exclusion rates.

5.3.2.2 Selectivity studies

Selectivity curves and selectivity parameters of dominant species such as *Ambassis ambassis, Alepes djedaba, Dussumieria acuta, Encrasicholina devisi, Lepturacanthus savala, Megalaspis cordyla, Rastrelliger kanagurta, Sardinella longiceps, Stolephorus commersonnii* and *Thryssa mystax* are given in Fig. 5.8 to 5.17 and Table 5.3, respectively.

Juveniles of all species showed good exclusion through both Fisheye BRDs. L_{50} values in respect of *Ambassis ambassis, Alepes djedaba, Megalaspis cordyla, Sardinella longiceps* and *Thryssa mystax* were higher in Semicircular Fisheye BRD compared to Oval horizontal BRD. L_{50} values in respect of *Dussumieria acuta, Encrasicholina devisi, Lepturacanthus savala, Rastrelliger kanagurta* and *Stolephorus commersonnii* was comparatively higher in Oval horizontal BRD. L_{50} values were higher than the length at first maturity (L_m) in respect of four species *viz*., *Ambassis ambassis, Encrasicholina devisi, Stolephorus commersonnii* and *Thryssa mystax* in the Semicircular Fisheye BRD and in respect of three species *viz*., *Dussumieria acuta*, *Encrasicholina devisi* and *Stolephorus commersonnii* in the case of Oval horizontal Fisheye BRD. Wherever L_{50} values were higher than L_m values, it indicated better exclusion opportunities for immature fishes, as the mid-length classes were plotted against excluded fractions in the selectivity estimates.

Table 5.3 Selectivity parameters for Semicircular Fisheye and Oval horizontal Fisheye

Species	Fisheye	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection range, mm	Length at first maturity, mm
Ambassis ambassis	Semicircular	77.74	89.93	77.74	102.13	55-75
	Oval horizontal	69.24	77.69	86.14	16.90	
Alepes djedaba	Semicircular	133.79	156.09	178.40	44.62	180-189
	Oval horizontal	57.21	109.52	161.84	104.63	
Dussumieria acuta	Semicircular	112.01	116.40	120.79	8.79	140-150
	Oval horizontal	131.02	166.46	201.90	70.88	
Encrasicholina devisi	Semicircular	70.53	75.77	81.01	10.48	64.5
	Oval horizontal	75.90	85.36	94.82	18.93	
Lepturacanthus savala	Semicircular	335.40	403.09	470.78	135.38	418-750
	Oval horizontal	420.46	786.67	1152.8	732.41	
Megalaspis cordyla	Semicircular	76.09	137.12	198.16	122.07	250
	Oval horizontal	11.09	87.38	163.67	152.59	
Rastrelliger kanagurta	Semicircular	29.13	39.53	108.19	137.33	190-220
	Oval horizontal	22.00	62.69	103.38	81.38	
Sardinella longiceps	Semicircular	59.84	85.27	110.70	50.86	150-162
	Oval horizontal	62.86	80.00	97.14	34.28	
Stolephorus commersonnii	Semicircular	90.47	101.22	111.97	21.50	74
	Oval horizontal	97.19	112.34	127.50	30.31	
Thryssa mystax	Semicircular	104.25	161.76	219.28	115.04	130
	Oval horizontal	93.56	103.55	113.53	19.97	

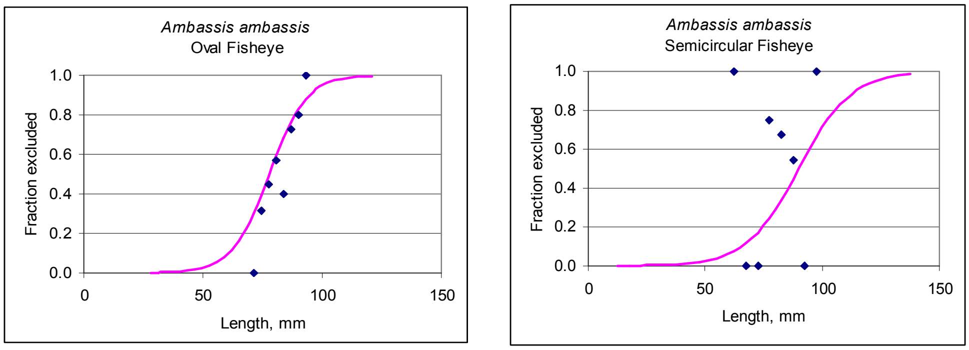


Fig. 5.8 Selectivity curves for Ambassis ambassis

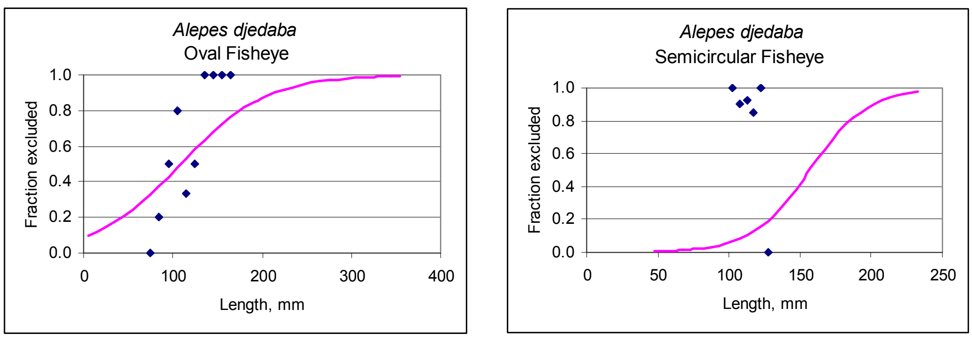


Fig. 5.9 Selectivity curves for *Alepes djedaba*

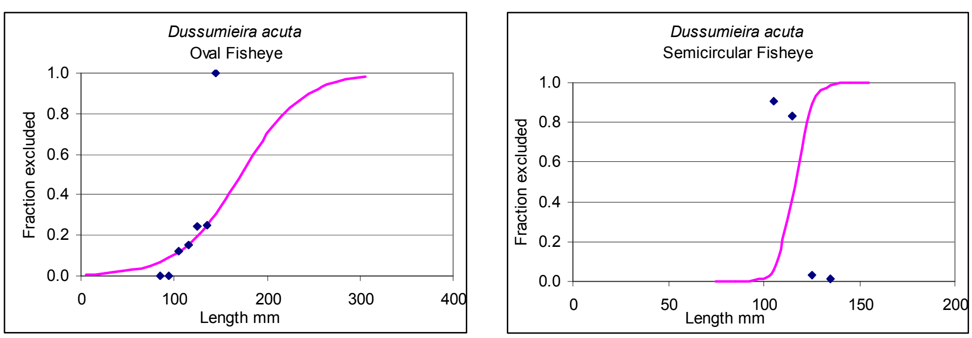


Fig. 5.10 Selectivity curves for *Dussumieria acuta*

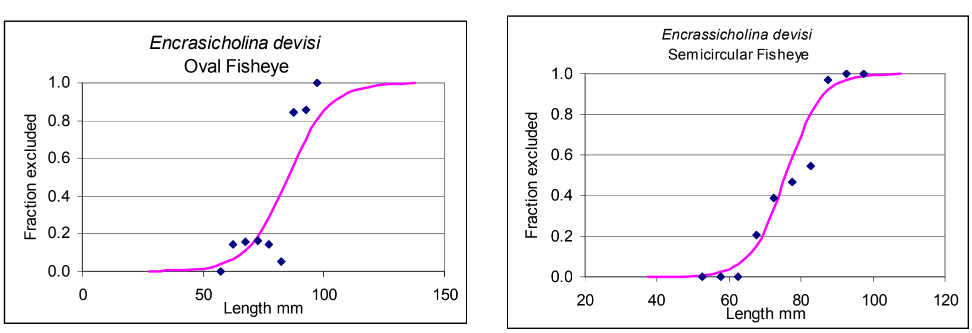


Fig. 5.11 Selectivity curves for *Encrasicholina devisi*

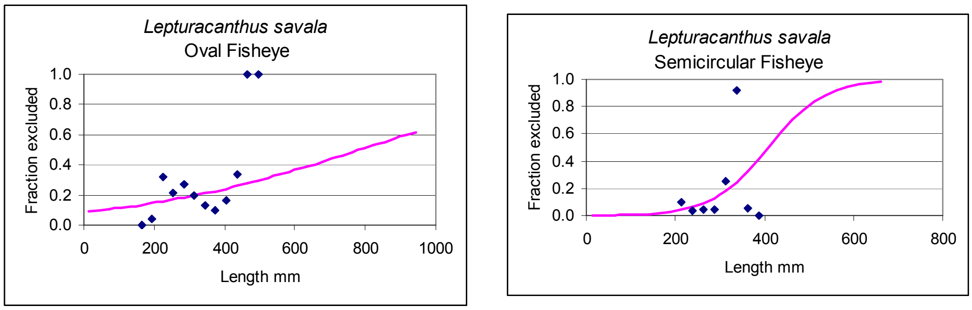


Fig. 5.12 Selectivity curves for *Lepturacanthus savala*

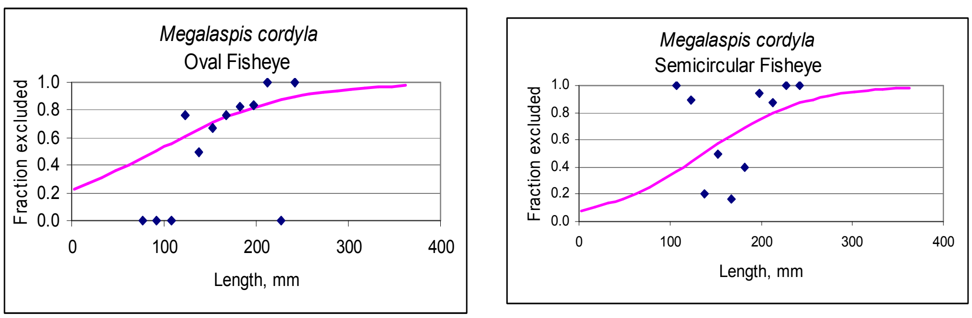


Fig. 5.13 Selectivity curves for *Megalaspis cordyla*

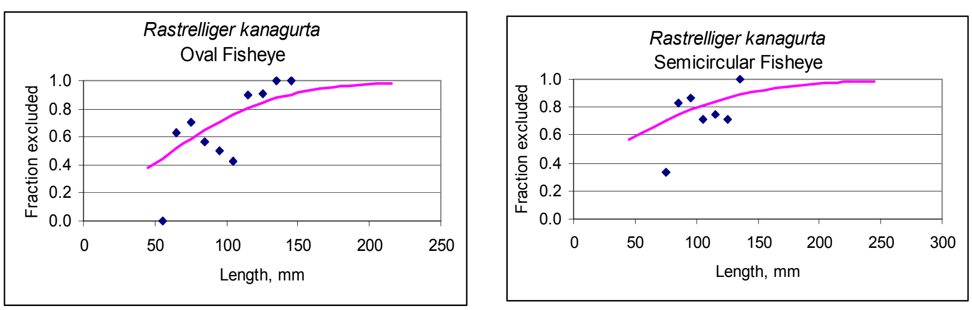


Fig. 5.14 Selectivity curves for *Rastrelliger kanagurta*

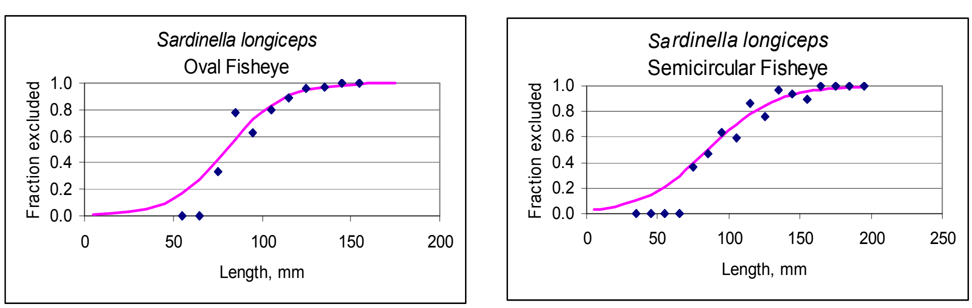


Fig. 5.15 Selectivity curves for *Sardinella longiceps*

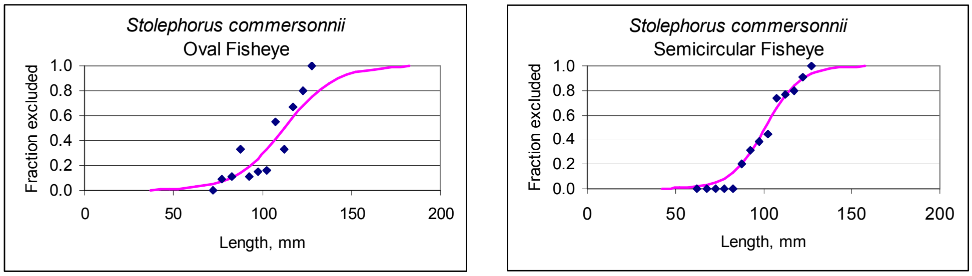


Fig. 5.16 Selectivity curves for *Stolephorus commersonnii*

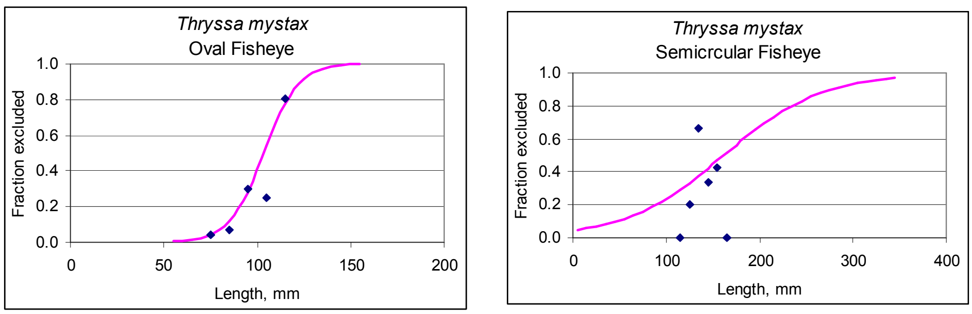


Fig. 5.17 Selectivity curves for *Thryssa mystax*

5.4 Conclusions

Of the three Fisheye BRD designs evaluated, Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation performed better in terms bycatch exclusion efficiency and target catch retention properties, compared to Fisheye BRD with 300x200 mm oval exit of horizontal orientation and Fisheye BRD with 300x200 mm oval exit of vertical orientation.

Juveniles of several species such as *Ambassis ambassis, Alepes djedaba, Dussumieria acuta, Encrasicholina devisi, Lepturacanthus savala, Megalaspis cordyla, Rastrelliger kanagurta, Sardinella longiceps, Stolephorus commersonnii* and *Thryssa mystax* showed good exclusion through the semi-circular Fisheye BRDs. L_{50} values were higher than the length at first maturity (L_m) in respect of four species studied *viz.*, *Ambassis ambassis, Encrasicholina devisi, Stolephorus commersonnii* and *Thryssa mystax* in the Semicircular Fisheye BRD. Out of 70 non-shrimp species encountered during the field trials, about 56% showed varying levels of exclusion.

Comparatively better performance of semicircular Fisheye BRD in reducing the target catch loss is attributed to the low turbulence due to its streamlined design. The higher bycatch exclusion of semicircular Fisheye BRD is attributed to the higher area of the exit opening which has about 9.6% more than other two designs. Based on its performance, Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation is recommended for adoption and use in shrimp trawling in Indian waters, in order to reduce bycatch of finfish species without compromising on shrimp catches.

6.0 Performance Evaluation of Flat Grid BRDs

6.1 Introduction

The main disadvantage of soft bycatch reduction devices which make use of nettings and rope frames for their construction is the difficulty in maintaining shape under water during fishing operations, which resulted in improper sorting and inadequate bycatch exclusion. This disadvantage can be minimized by using rigid structures. Bycatch reduction devices in the form of rigid separation grid were developed in Norway in 1980s. The rigid design was developed by the fishermen primarily to minimise the bycatch of jellyfish in shrimp trawling and is now popularly known as the Nordmore grid (Isaksen et al., 1992).

The ideal configuration for a sorting grid system includes a funnel that accelerates the catch in conjunction with a sorting grate that causes minimum disturbance to the water flow and separate small animals from large and result in little or no loss of target species in trawls. The Nordmore grid system consists of a rectangular or oval grid made of steel or aluminium provided with longitudinal bars with appropriate bar-spacing. One or two horizontal bars may be attached to provide additional strength to the grid, which also reduces the flexibility of bars thereby maintaining constant bar-spacing. Bar-spacing of Nordmore grid varies from 10 to 100 mm. The grids are usually installed in the extension piece between throat and codend of a trawl net. The angle of attack is usually between 45° to 60° from the horizontal. There will be a fish outlet either at the top or at the bottom in front of the grid. An accelerator funnel or guiding panels or flapper constructions will be mounted in front of the grid in order to guide the catch in to the grid (Isaksen et al., 1992).

The bycatch reduction and sorting effect of the Nordmore system is effected by taking advantage mainly of the difference in size and to some extend the behaviour of shrimp and other animals caught in the trawl. Large animals and active swimmers are released out through the exit opening while the organisms that can pass through the grid is caught and retained in the codend. Even though the bycatch exclusion characteristics of a BRD is promising, fishers will have more concern regarding the short-term loss of target catches. Shrimp loss can happen due to incorrect grid angle, grid blockage or poor performance of the accelerator funnels and guiding panels.

6.2 Materials and Methods

Two different designs of Flat grid BRDs with different shapes *viz*., rectangular and oval were used for performance evaluation.

6.2.1 Rectangular grid BRD

The Rectangular grid BRD (Fig 6.1) is an inclined rectangular grid design of 1000 mm in height, 800 mm in width and bar-spacing of 22 mm. It is fabricated out of stainless steel rods 8 mm dia for outer frame and 4 mm dia for grid bars. The grid is kept at an angle 45° from horizontal. Two floats are provided on the top of the grid on either side, to compensate for the weight of the grid and also to keep the grid stable in the upright position. A triangular exit opening of 600 mm at base and 450 mm at sides is provided at the top of the trawl extension in front of the grid. The triangular opening is made by cutting all bars from the corners of the grid. Edge of the trigngular opening is reinforced by a 4 mm dia PP rope. An accelerator or guiding funnel is provided in front of the grid at a distance of 0.5 m from the bottom of the grid. The funnel is inclined towards the bottom so that the water flow will be directed towards the bottom of the grid. The method of installation of Rectangular grid BRD in the shrimp trawl is shown in Fig. 6.2.

6.2.2 Oval grid BRD

The Oval grid BRD (Fig 6.1) is an inclined oval grid design of 1000 mm in height, 800 mm in width and bar-spacing of 22 mm. It is fabricated out of stainless steel rods 8 mm dia for outer frame and 4 mm dia for grid bars. The grid is kept at an angle 45° from horizontal. Two floats are provided on the top of the grid on either side, to compensate for the weight of the grid and also to keep the grid stable in the upright position. A triangular exit opening of 600 mm at base and 450 mm is provided at the top of the trawl extension in front of the grid and an accelerator funnel is provided exactly as in the case of Rectangular grid BRD. The method of installation of Oval grid BRDs in the shrimp trawl is shown in Fig. 6.3.

Field trials were conducted using a 29.6 m shrimp trawl with a diamond mesh codend of 20 mm mesh size, off Cochin, south-west coast of India (Fig. 6.4). Covered codend method was adopted to study the selectivity and exclusion characteristics of the BRD (Sparre et al., 1989; Wileman et al., 1996). Catch from the codend and the cover were separately sorted and identified up to species level. Length statistics and weight of each species contributing to the catch was taken. Sub-sampling was done, in the case of large catches. In the case of fishes and shrimps total length is taken and for cephalopods the mantle length was measured.

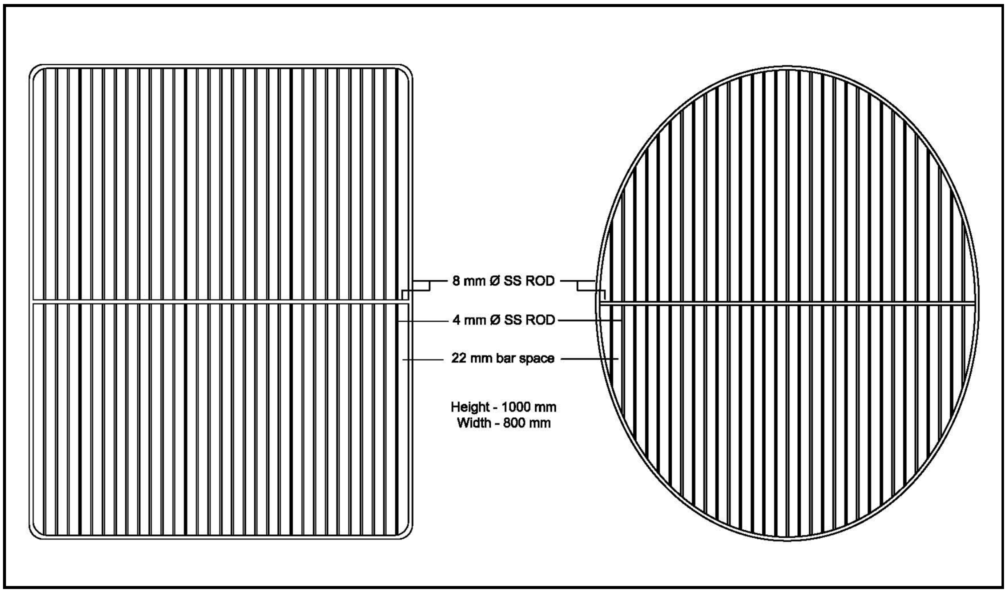


Fig. 6.1 Design of Rectangular Grid (left) and Oval grid (right) BRDs

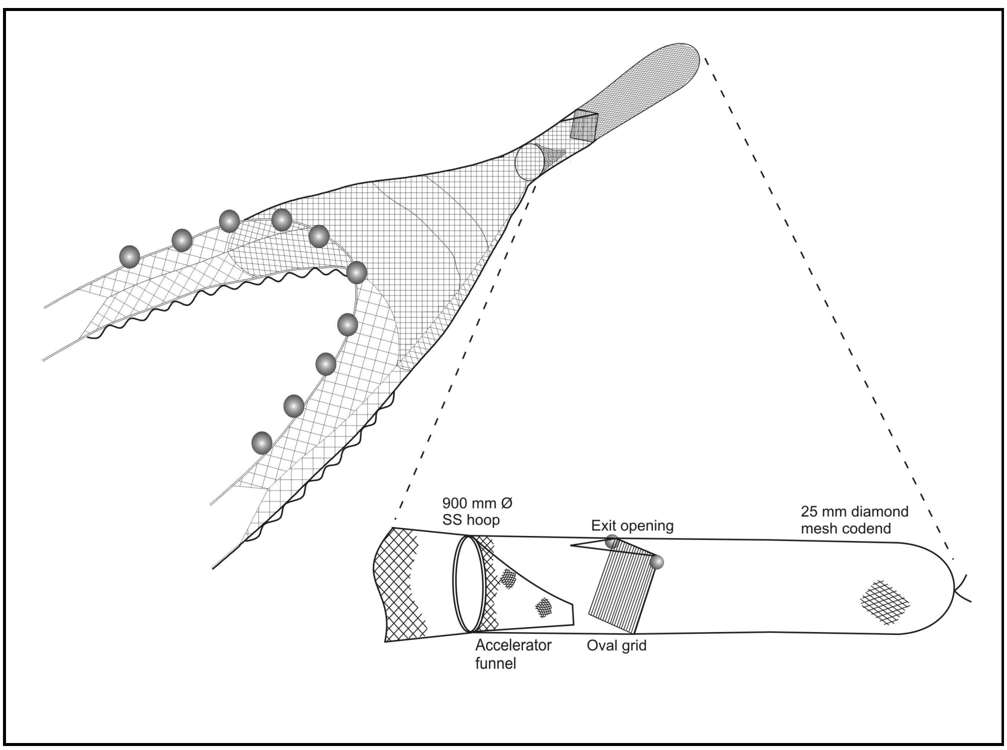


Fig. 6.2 Perspective view of Rectangular Grid BRD and the method of its installation in shrimp trawl

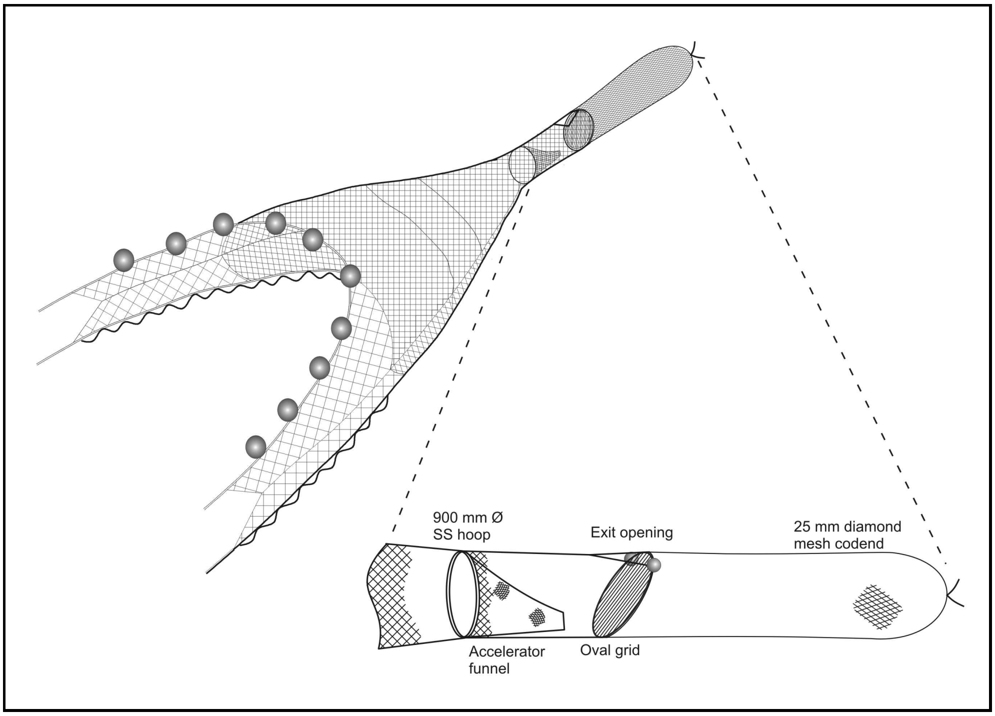


Fig. 6.3 Perspective view of Oval Grid BRD and the method of its installation in shrimp trawl

Fig. 6.4 Field trial of Oval Grid BRD, off Cochin

6.3 Results and Discussion

A total catch of 305.1 kg was obtained during comparative field trials using sorting grid installed trawl operations, in the traditional shrimp trawling grounds, off Cochin, south-west coast of India. Results are presented in Table 6.1. Rectangular grid installed trawl operations caught 168.50 kg (CPUE: 12.79 $kg.h^{-1}$) of which about 52 % was retained in the codend and 48 % was excluded. Oval grid installed trawl operations caught 136.66 kg (CPUE: 10.79 $kg.h^{-1}$) of which 44% was retained and 56% was excluded.

Out of a total 63 species which entered the oval grid trawl system, 100% exclusion was shown by 16 species, >50% exclusion by 27 species, up to 50% exclusion by 14 species and no exclusion by 6 species. In the case of rectangular grid, out of 54 species encountered, 5 species showed 100% exclusion, 26 species showed more than 50% exclusion, 16 species showed up to 50% exclusion and 7 species showed no exclusion.

Table 6.1 Results of experiments with Oval and Rectangular grid BRDs

	Oval grid BRD	Rectangular grid BRD
No. of hauls	13	13
Total catch (kg)	136.66	168.50
CPUE ($kg.h^{-1}$)	10.79	12.79
Retained catch (%)	43.92	51.54
Excluded catch (%)	56.08	48.44
Total shrimp catch (kg)	20.37	22.65
Retained shrimp catch (%)	89.69	86.75
Excluded shrimp catch (%)	10.31	13.25
Total bycatch (catch other than shrimps) (kg)	116.29	145.76
Retained bycatch (%)	35.91	46.10
Excluded bycatch (%)	64.09	53.90
Species encountered (No.)	63	54
Fish species (No.)	54	46
Shrimp species (No.)	6	6
Other species (No.	3	2
100% exclusion (No.)	16	5
>50% exclusion (No.)	27	26
Up to 50% exclusion (No.)	14	16
0% exclusion (No.)	6	7

Bycatch reduction was about 64% and 54%, respectively due installation of rectangular grid and oval grid in the shrimp trawl. Shrimp loss was 10.31 and 13.25%, respectively for rectangular grid and oval grid installed operations. Oval grid showed a relatively higher bycatch reduction and slightly lower shrimp loss, compared to the rectangular grid.

Statistical analysis using Student's *t*-test has shown significant difference between exclusion performance of oval and rectangular grids. *Ambassis ambassis* and *Epinephelus diacanthus* ($p<0.05$) showed significantly higher levels of exclusion from the Oval grid BRD. Oval grid performed signicantly better than rectangular grid in terms of shrimp (*Parapenaeopsis stylifera*) retention ($p<0.05$). Loss of *Metapenaeus dobsoni* was 62% higher in the rectangular grid system, however, the difference was not statistically significant. Among other species encountered in the trawl system, 23 species showed comparatively higher exclusion from Oval grid while 15 species showed comparatively higher exclusion from Rectangular grid BRD; however, the differences were not statistically significant.

6.3.1 Selectivity studies

The selectivity of grid devices is determined by the grid bar-spacing, the shape, dimensions and orientation of the grid and operational factors. As in the case of net devices the physical separation based on size is taking place at the grids. The main difference between grid selectivity and trawl codend mesh selectivity is that in the case of nets the physical sorting will retain the larger individuals while releasing the smaller individuals. In the case of grids, which are usually positioned in front of the codend with an opening either at top or bottom for the exit of organisms or objects which are larger than the inter-bar spacing, so that smaller individuals pass through the grid and get accumulated in the codend while larger ones are separated and excluded. In mesh selectivity studies, the selectivity ogive is generally plotted by taking mid-length class against fraction retained in codend. The grid selectivity ogives presented here are constructed by plotting mid-length class of the species against the fraction which are separated and excluded.

Grid selectivity parameters and selectivity curves in respect of nine species *viz*., *Alepes kleini, Cynoglossus macrostomus, Lactarius lactarius, Leiognathus splendens, Lepturacanthus savala, Sardinella longiceps, Metapenaeus dobsoni, Parapenaeopsis stylifera* and *Fenneropenaeus indicus* caught in the grid installed trawl system are given in Table 6.2 and Fig. 6.5 to 6.13, respectively. L_{50} values in respect of *Cynoglossus macrostomus, Lactarius lactarius, Leiognathus splendens, Fenneropenaeus indicus* were higher the length at first maturity (L_m) in both the grids. In the case of *Metapenaeus dobsoni,* L_{50} value was higher than L_m in the case of Rectangular grid BRD. L_{50} values in respect of *Alepes klieni*, *Lactarius lactarius, Leiognathus splendens, Sardinella* *longiceps, Metapenaeus dobsoni,* and *Parapenaeopsis stylifera* were found to be lower than L_m in the Oval grid BRD. L_{50} values in respect of *Alepes klieni*, *Lactarius lactarius, Leiognathus splendens* and *Sardinella longiceps* were found to be lower than L_m in the Rectangular grid BRD. Wherever L_{50} values were higher than L_m values, it indicated better exclusion opportunities for immature fishes below L_m, as the mid-length classes were plotted against excluded fractions in the selectivity estimates.

Table 6.2 Selectivity parameters for Oval and Rectangular grids

Species	Grid type	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection Range, mm	Length at first maturity, mm
Alepes kleini	Oval	75.74	88.52	101.30	25.56	129
	Rectangular	71.53	86.73	101.92	30.39	
Cynoglossus macrostomus	Oval	124.04	137.64	151.24	17.19	100-120
	Rectangular	128.18	140.95	153.73	25.55	
Lactarius lactarius	Oval	69.46	84.31	99.15	29.69	135
	Rectangular	78.24	102.83	127.42	49.18	
Leiognathus splendens	Oval	29.63	77.71	125.79	96.16	60-94
	Rectangular	82.13	90.32	98.50	16.37	
Lepturacanthus savala	Oval	332.52	410.99	489.46	156.94	418-750
	Rectangular	234.71	351.83	468.96	234.25	
Sardinella longiceps	Oval	79.46	122.04	164.63	85.16	150-162
	Rectangular	136.60	154.91	173.22	36.62	
Metapenaeus dobsoni	Oval	33.33	82.87	199.06	232.39	88.6
	Rectangular	94.17	113.45	132.72	38.55	
Parapenaeopsis stylifera	Oval	35.98	53.42	70.86	34.88	63.2
Fenneropenaeus indicus	Oval	122.90	150.37	177.83	54.93	130.2
	Rectangular	145.48	170.91	196.34	50.86	

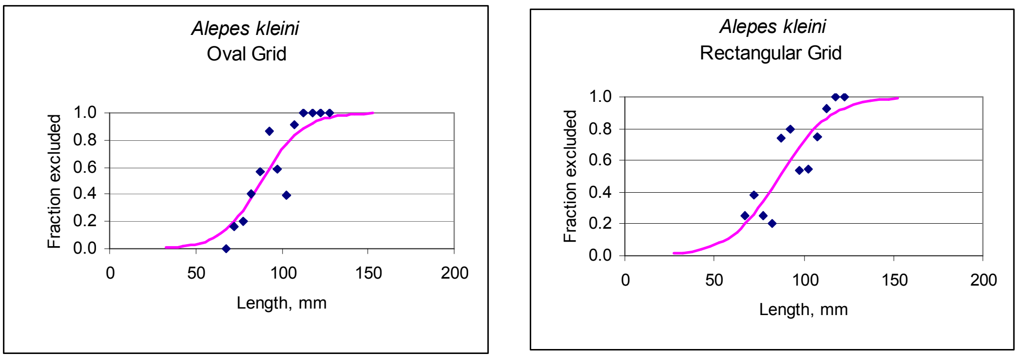


Fig. 6.5 Selectivity curves for *Alepes kleini*

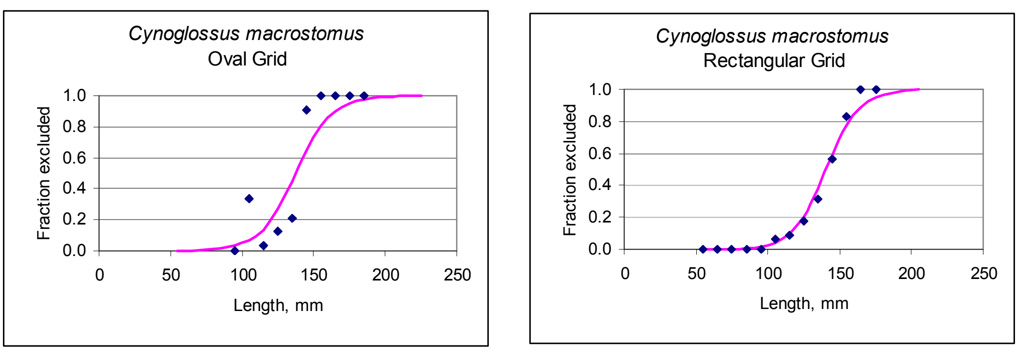


Fig. 6.6 Selectivity curves for *Cynoglossus macrostomus*

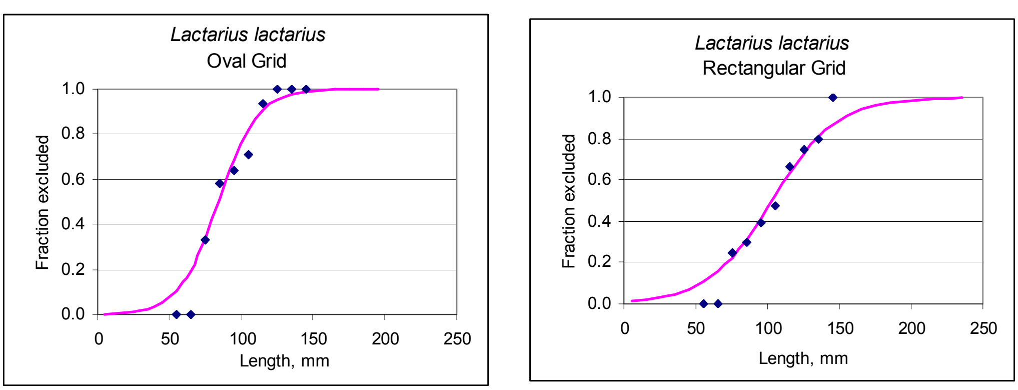


Fig. 6.7 Selectivity curves for *Lactarius lactarius*

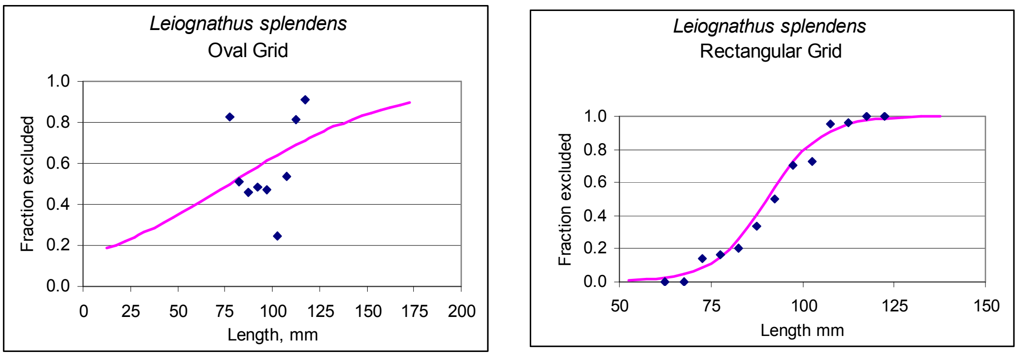


Fig. 6.8 Selectivity curves for *Leiognathus splendens*

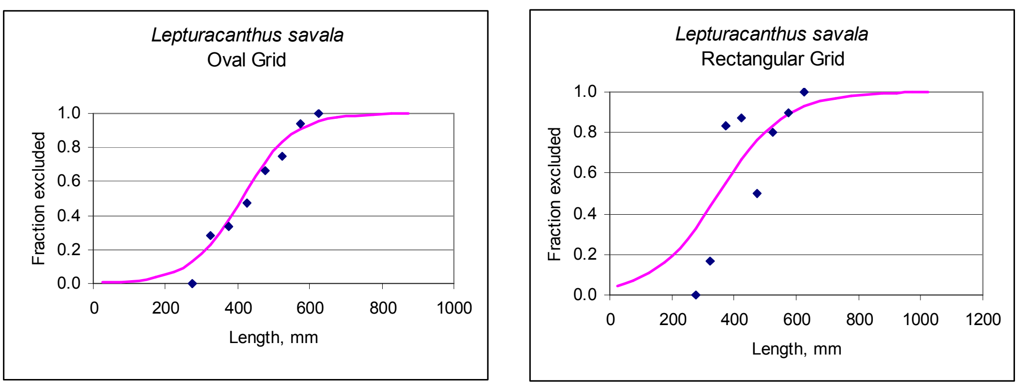


Fig. 6.9 Selectivity curves for *Lepturacanthus savala*

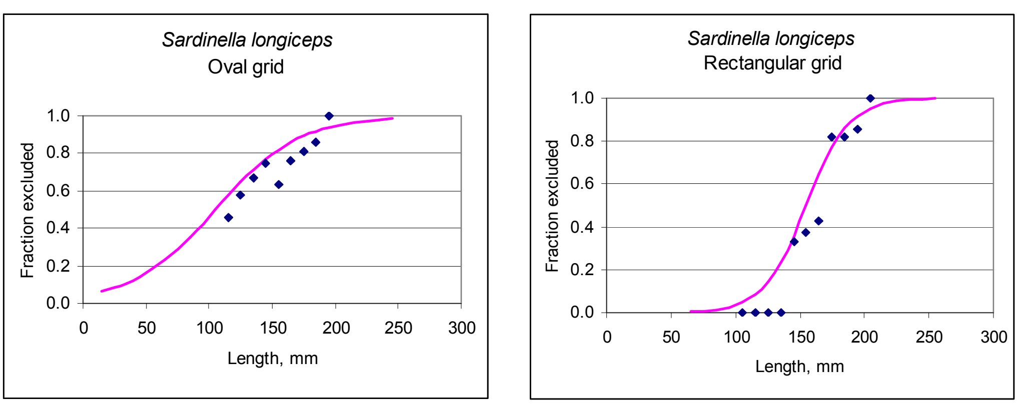


Fig. 6.10 Selectivity curves for *Sardinella longiceps*

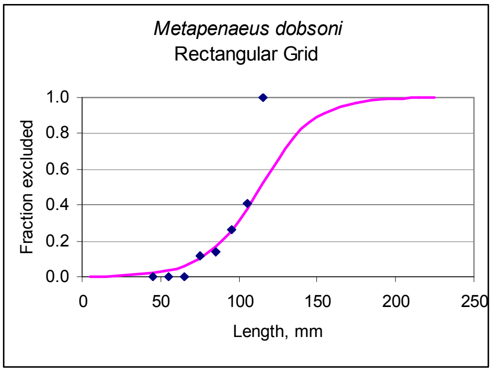


Fig. 6.11 Selectivity curve for *Metapenaeus dobsoni*

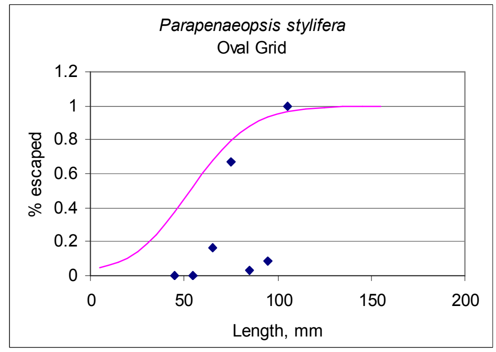


Fig. 6.12 Selectivity curve for *Parapenaeopsis stylifera*

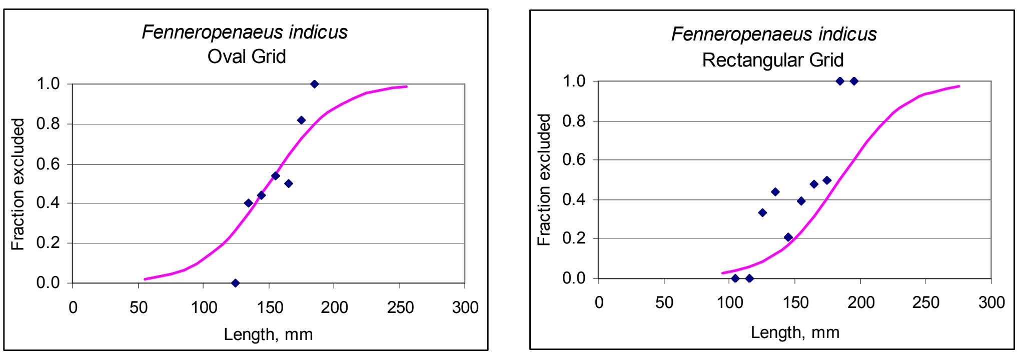


Fig. 6.13 Selectivity curves for *Fenneropenaeus indicus*

6.4 Conclusions

Experiments with flat and oval sorting grids have shown promising results. The use of sorting grids has been emerging as an effective tool for improving size and species selection in many trawl fisheries. In spite of the multi-species nature of bottom trawling, the grids offer reasonably higher bycatch exclusion rates with good shrimp separation and retention properties. Analysis of the results of field trials of flat grids has shown that Oval grid provides higher bycatch exclusion compared to rectangular grid. Exclusion of higher number of bycatch species at levels exceeding 50%, in the oval grid has indicated its better performance, compared to rectangular grid design. In terms of target catch retention also oval grid performed better than rectangular grid. Better performance of oval grid is attributed to the lower turbulence during the tow as it fits into the net cylinder assuming a streamlined shape without causing protuberances by virtue of its oval shape unlike rectangular grid.

Trawl caught species such as *Ambassis ambassis* and *Epinephelus diacanthus* showed significantly higher ($p<0.05$) exclusion from the oval grid and significantly higher ($p<0.05$) shrimp (*Parapenaeopsis stylifera*) retention, compared to rectangular grid. The higher exclusion rate of 10-13% in the case of shrimps in grid BRDs is attributed to the clogging of the grids by debris and due to inadequate bar-spacing. As bar-spacing is a critical parameter influencing the selectivity of grid BRD, further studies were undertaken on this aspect and results are presented in Chapter 7.

7.0 Comparative Evaluation of Oval Grid BRDs and Semicircular Fisheye BRD

7.1 Introduction

Flat grids and Fisheye BRDs are important bycatch reduction devices that can be easily incorporated to a trawl system. In the case of Fisheye, the active swimming fishes are given a provision for escaping from the codend by way of exit openings provided at specific locations in the codend and in the case of Flat grids the non-targeted catch is excluded using grids of appropriate bar-spacing placed in front of the codend by means of size sorting.

Earlier experiments with various designs of Fisheye BRD have shown that the Semicircular Fisheye BRD with 300x200 mm exit opening performed better compared to two other Fisheye BRD designs with oval exit openings (see Chapter 5). Experiments with rectangular flat grid BRDs have shown that 1000x800 mm Oval grid BRD preformed better than Rectangular grid BRD (1000x800 mm), in terms of target catch retention and bycatch exclusion. Through Oval grid BRD has shown satisfactory exclusion rate for bycatch, shrimp loss was about 10% of total shrimp catch. In this Chapter, results of experiments conducted to evaluate (i) the effect of grid bar-spacing of Oval grid BRDs on bycatch exclusion and target catch retention and (ii) comparative performance of optimized Oval grid BRD and Semicircular Fisheye BRD are discussed.

7.2 Materials and Methods

7.2.1 Oval Grid BRDs with different bar spacing

Two oval shaped grid designs having dimensions of 1000 mm in height, 800 mm in width with different bar-spacing of 26 mm and 20 mm respectively were used for the first of experiments to evaluate the effect of bar-spacing on bycatch exclusion and target catch retention characteristics. Design details of oval grid BRDs are given in Fig. 7.1. The grid was fixed at an angle of 45° from the horizontal inside the netting cylinder. Two floats were provided on the top of the grid on either side, to compensate for the weight of the grid and also to stabilize the grid in the upright position during towing operations. An exit opening of 600 mm at the base and 450 mm at sides was provided in the top panel, in front of the grid. An accelerator or guiding funnel is provided in front of the grid at a distance of 0.5 m from the bottom of the grid. The method of installation of Oval grid BRD in the shrimp trawl is shown in Fig. 6.3.

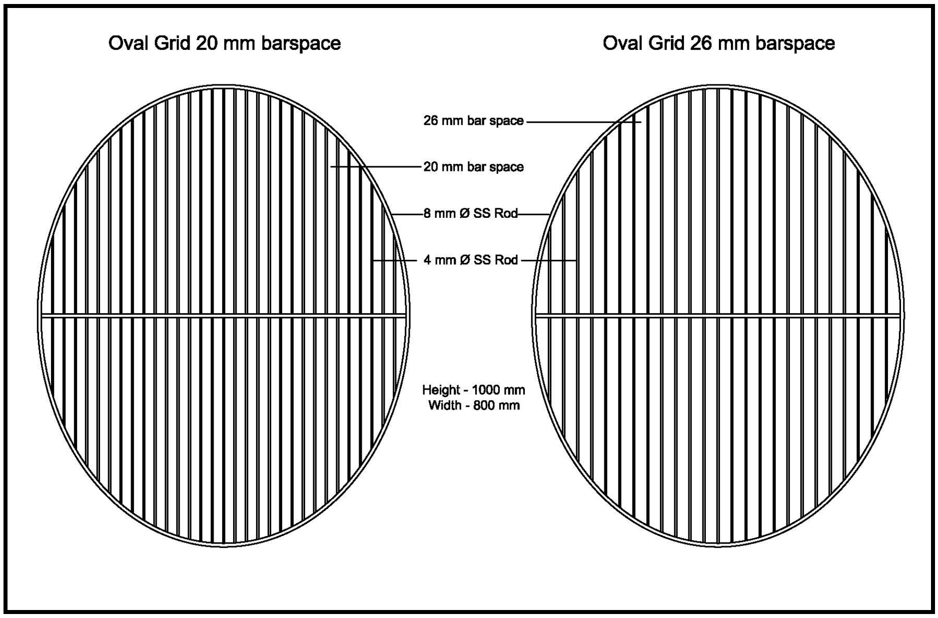


Fig. 7.1 Designs of Oval grid BRDs

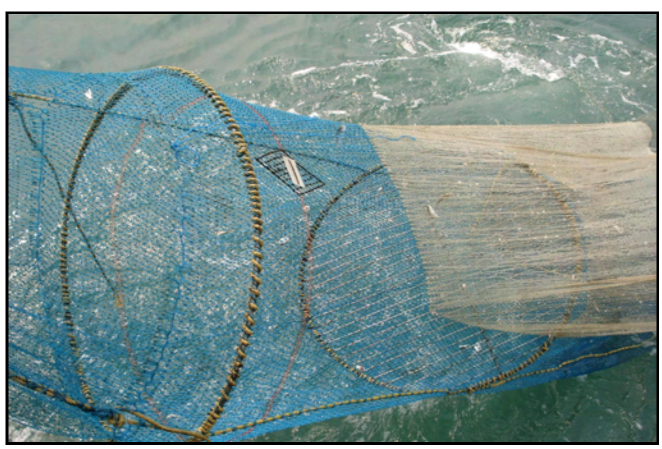


Fig. 7.2 Oval grid BRD in operation

7.2.2 Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation

The design details of the Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation are given in Fig. 5.4. The Fisheye BRDs were fitted on the top side of the trawl codend at a distance of 1.5 m (75 meshes) from the distal end of the codend (Fig. 5.1).

7.2.3 Field trials, data collection and analysis

Comparative field trials (alternate hauls) were conducted using a 29.0 m shrimp trawl fitted with a diamond mesh codend of 20 mm mesh size, off Cochin, south-west coast of India. The excluded catch was collected in a separate small meshed cover codend. Procedure for covered codend method was used to study the selectivity and exclusion characteristics of the BRD (adapted from Sparre et al., 1989 and Wileman et al., 1996). Catch from the codend and the cover were separately sorted and identified up to species level. Length statistics and weight of each species contributing to the catch was taken. Sub-sampling was done, in the case of large catches. In the case of fishes and shrimps total length was taken and for cephalopods the mantle length was measured. Student's *t*-test was applied for assessing if there is any significant difference in exclusion rate of different species.

7.3. Results and Discussion

7.3.1 Comparative evaluation of grids with different bar spacing

7.3.1.1 Operational performance

In order to evaluate the influence of different bar-spacing in the selectivity and exclusion characteristics of oval grids, comparative fishing trials were conducted with flat oval grids with different bar-spacing *viz.*, 20 mm (20 mm grid) and 26 mm (26 mm grid). A total of 11 sets of paired hauls were taken landing a total catch of 99.67 kg at an average CPUE of 4.33 $kg.h^{-1}$. Grid with 20 mm bar-spacing retained 63.63% of the catch encountered and excluded 36.37% while the grid with 26 mm bar-spacing retained 52.14% of the catch encountered and excluded 47.86%. Among 87 species encountered in the 20 mm grid incorporated trawl, 10 species showed 100% exclusion, 17 species showed more than 50% exclusion, 31 species up to 50% exclusion and 29 species showed no exclusion. During operations with 26 mm grid incorporated trawl among a total of 90 species encountered, 12 species showed 100% exclusion, 24 species showed more than 50% exclusion, 26 species up to 50% exclusion and 26 species showed no exclusion. Bycatch exclusion was 45.35% for 20 mm grid and

58.68% in the case of 26 mm grid. Shrimp loss was 13.8% for 20 mm grid and 6.12% for 26 mm grid.

Statistically significant differences were observed in the exclusion characteristics of two oval flat grid BRDs with respect to some species. *Alepes kleini*, *Gazza minuta*, *Leiognathus bindus*, *Leiognathus brevirostris* and *Opisthopterus tardoore* showed significantly higher ($p<0.05$) exclusion rate from 26 mm grid compared to 20 mm grid. An additional 22 species showed better exclusion rate from 26 mm grid, through the differences were not statistically significant. Target catch retention (*Metapenaeus dobsoni*) was significantly higher ($p<0.05$) in the 26 mm grid, compared to 20 mm grid. In the 20 mm grid installed trawl operations, 20 species showed comparatively higher exclusion compared to 26 mm grid, though the differences in exclusion rates were not statistically significant.

Table 7.1 Results of experiments with Oval grid BRDs with 20 and 26 mm bar-spacing

	Oval grid BRD with 20 mm bar-spacing	Oval grid BRD with 26 mm bar-spacing
No. of hauls	11	11
Total catch (kg)	46.73	52.94
CPUE ($kg.h^{-1}$)	4.06	4.60
Retained catch (%)	63.73	52.59
Excluded catch (%)	36.27	47.41
Total shrimp catch (kg)	13.45	11.36
Retained shrimp catch (%)	86.21	93.88
Excluded shrimp catch (%)	13.79	6.12
Bycatch (catch other than shrimps) (kg)	33.29	41.59
Retained bycatch (%)	54.65	41.32
Excluded bycatch (%)	45.35	58.68
Species encountered (No.)	87	88
Fish species (No.)	64	63
Shrimp species (No.)	7	7
Other species (No.)	16	18
100% exclusion (No.)	10	12
>50% exclusion (No.)	17	24
Up to 50% exclusion (No.)	31	26
0% exclusion ((No.)	29	26

7.3.1.2 Selectivity studies

The selectivity analyses of oval grids with 20 mm and 26 mm bar-spacing were performed in respect of eleven species *viz., Alepes djedaba, Ambassis ambassis, Lagocephalus spadiceus, Leiognathus brevirostris, Lepturacanthus savala, Megalaspis cordyla, Opisthopterus tardoore, Sardinella longiceps, Stolephorus commersonnii, Stolephorus waitei* and *Thryssa mystax*. Selectivity curves and selectivity parameters of these species were given in Fig. 7.2 to 7.12 and in Table 7.2, respectively.

Table. 7.2 Selectivity parameters in respect of Oval grids with 20 mm and 26 mm bar-spacing

Species	Grid type	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection Range, mm	Length at first maturity, mm
Alepes djedaba	20 mm	109.42	114.78	120.14	10.78	180-189
	26 mm	124.55	135.88	147.20	22.62	
Ambassis ambassis	20 mm	56.94	78.31	99.67	42.74	55-75
	26 mm	53.71	64.96	76.22	22.51	
Lagocephalus spadiceus	26 mm	66.15	82.81	99.46	33.32	
Leiognathus brevirostris	26 mm	63.85	76.06	88.26	24.41	181
Lepturacanthus savala	20 mm	284.69	328.63	372.58	87.89	418-750
	26 mm	258.14	330.08	402.03	143.89	
Megalaspis cordyla	20 mm	87.04	109.88	132.72	45.68	250
	26 mm	80.00	99.71	119.42	39.43	
Opisthopterus tardoore	20 mm	53.82	79.98	106.13	52.31	-
	26 mm	87.49	127.76	168.03	80.54	
Sardinella longiceps	20 mm	76.37	108.88	141.38	65.01	150-162
	26 mm	50.08	84.95	119.83	69.75	
Stolephorus commersonnii	26 mm	99.06	108.53	118.01	18.94	74
Stolephorus waitei	26 mm	70.02	83.75	97.48	27.47	81-84
Thryssa mystax	20 mm	24.73	106.72	188.70	163.97	130
	26 mm	74.86	118.80	162.74	87.89	

L_{50} values were higher in 20 mm oval grid in respect of *Ambassis ambassis, Leiognathus brevirostris, Megalaspis cordyla, Sardinella longiceps, Stolephorus commersonnii* and *Stolephorus waitei* while in 26 mm oval grid L_{50} were higher in respect of *Alepes djedaba, Lagocephalus spadiceus, Lepturacanthus savala, Opisthopterus tardore* and *Thryssa mystax*. L_{50} values were higher than the length at first maturity (L_m) in respect of *Ambassis ambassis, Stolephorus commersonnii* and *Stolephorus waitei* in both the oval grid designs (Table 7.2), indicating better escapement opportunity for individuals less than L_m.

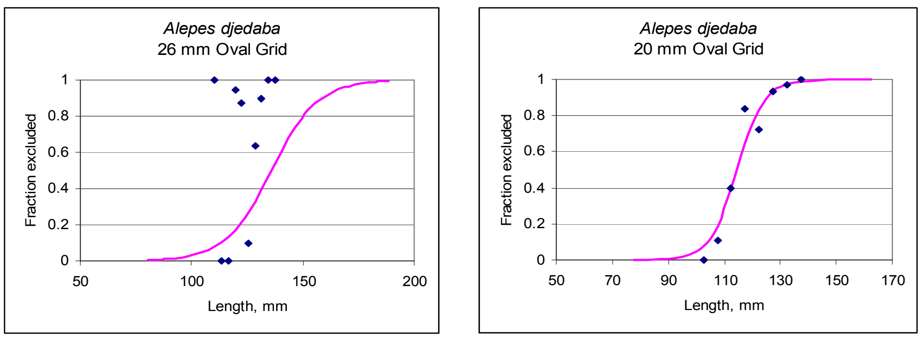


Fig. 7.2 Selectivity curves for *Alepes djedaba*

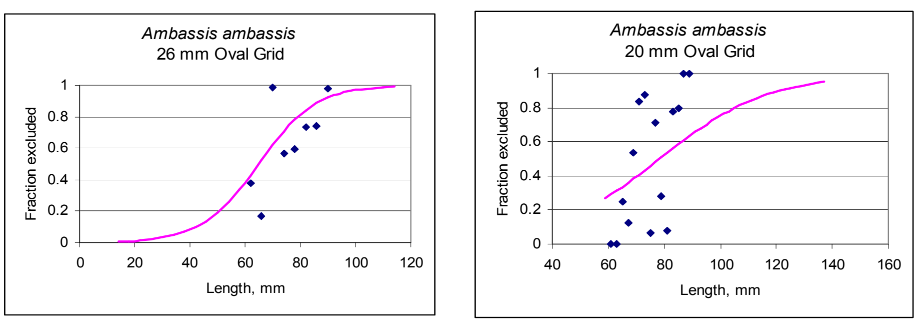


Fig. 7.3 Selectivity curves for *Ambassis ambassis*

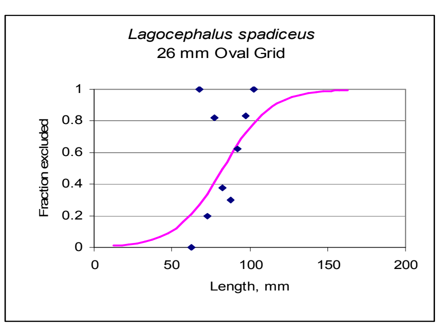


Fig. 7.4 Selectivity curve for *Lagocephalus spadiceus*

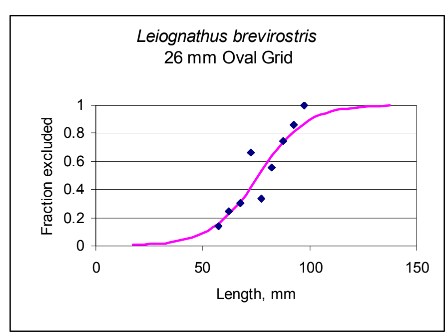


Fig. 7.5 Selectivity curve for *Leiognathus brevirostris*

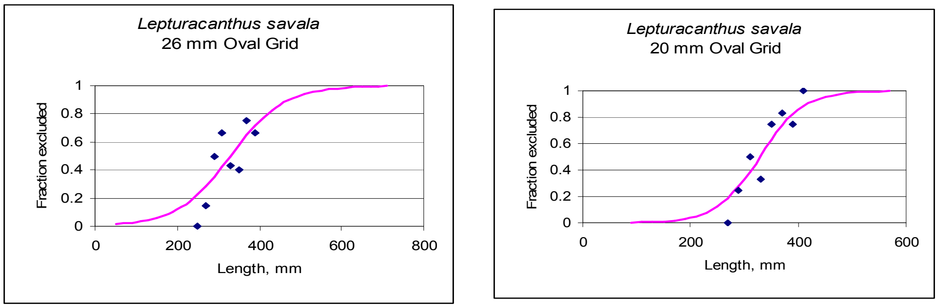


Fig. 7.6 Selectivity curves for *Lepturacanthus savala*

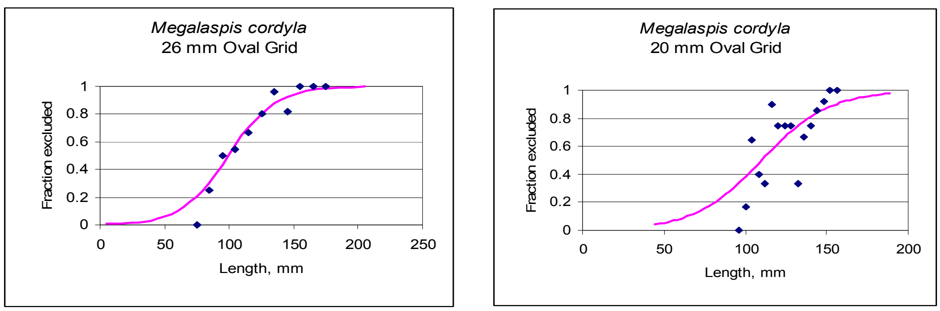


Fig. 7.7 Selectivity curves for *Megalaspis cordyla*

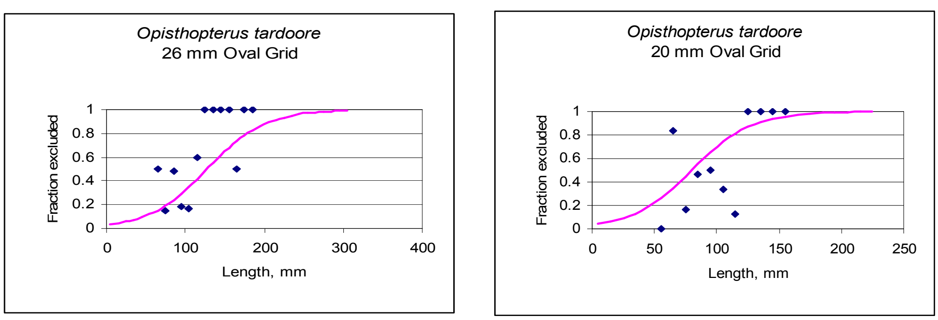


Fig. 7.8 Selectivity curves for *Opisthopterus tardoore*

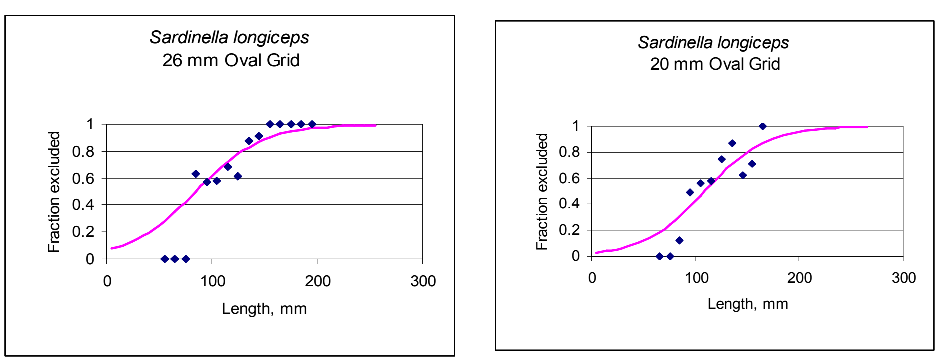


Fig. 7.9 Selectivity curves for *Sardinella longiceps*

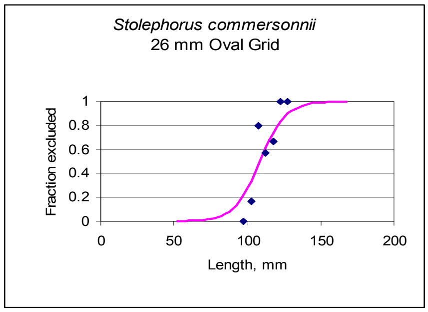


Fig. 7.10 Selectivity curve for *Stolephorus commersonnii*

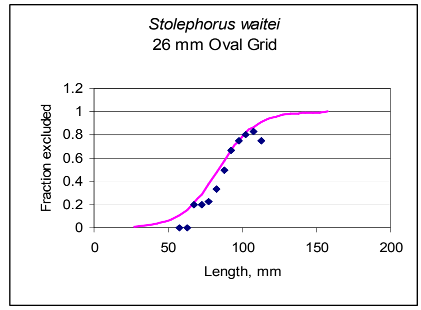


Fig. 7.11 Selectivity curves for *Stolephorus waitei*

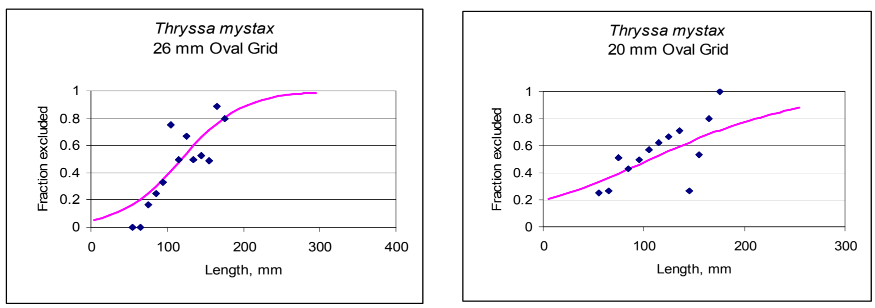


Fig. 7.12 Selectivity curves for *Thryssa mystax*

7.3.2 Comparative evaluation of Oval grid BRD with 26 mm bar-spacing and Semicircular Fisheye BRD

7.3.2.1 Operational performance

A total of 11 pairs of alternate hauls were undertaken to evaluate comparative performance of Oval grid BRD with 26 mm bar-spacing and Semicircular fisheye BRD using a 29.6 m shrimp trawl for operations landing a total catch of 91.41 kg catch was obtained with an average CPUE of 3.83 kg.h^{-1}. The trawl net fitted with flat oval grid caught 35.17 kg of which 49.65% was retained and 50.35% was excluded. Semicircular Fisheye installed operations obtained a total catch of 56.24 kg of which 57.63% was retained and 42.37% was excluded. Bycatch exclusion was to the tune of 47% in the Semicircular Fisheye BRD and about 58% in the Oval grid BRD. In respect of shrimp retention during operations, Semicircular Fisheye BRD performed better retaining 98.4% of the shrimps than Oval grid BRD with 26 mm bar spacing which retained only 92.0% of the shrimp encountered (Table 7.3). Number of species encountered during operations of Oval grid BRD was 80, of which 16 species showed 100% exclusion, 22 species showed more than 50% exclusion, 24 species up to 50% and 27 species were not excluded. In the case of Fisheye BRD, 89 species were encountered, of which 6 species showed 100% exclusion, 9 species showed exclusion rates exceeding 50%, 26 species up to 50% exclusion while 39 species showed no exclusion.

Table 7.3 Results of experiments with Flat grid BRD with 26 mm bar- spacing and Semicircular Fisheye BRD

	Semicircular fisheye BRD	26 mm Oval grid BRD
No. of hauls	11	11
Total catch (kg)	56.24	35.17
CPUE (kg.h^{-1})	4.72	2.95
Retained catch (%)	57.63	49.65
Excluded catch (%)	42.37	50.35
Total shrimp catch (kg)	5.33	5.25
Retained shrimp catch (%)	98.41	92.00
Excluded shrimp catch (%)	1.59	8.00
Bycatch (catch other than shrimps) (kg)	50.91	29.92
Retained bycatch (%)	53.36	42.21
Excluded bycatch (%)	46.64	57.79
Species encountered (No.)	80	89
Fish species (No.)	66	66
Shrimp species (No.)	4	5
Other species (No.)	10	18
100% exclusion (No.)	6	16
>50% exclusion (No.)	9	22
Up to 50% exclusion (No.)	26	24
0% exclusion ((No.)	39	27

In Oval grid BRD, exclusion rate was higher in respect of 11 species and the difference was highly significant ($p<0.01$) in the case of 2 species *viz*., *Thryssa mystax* and *Stolephorus commersonnii* and significant ($p<0.05$) in the case of 9 species *viz*., *Lepturacanthus savala*, *Opisthopterus tardore*, *Otolithes cuvieri*, *Otolithes ruber*, *Pampus argenteus*, *Portunus sanguinolntus*, *Thryssa malabarica*, *Thryssa purava and Loligo(Uroteuthis) duvaceli.* 15 species have shown higher rates of exclusion from the Oval grid BRD and 12 species have shown higher exclusion from the fisheye, however, the differences were not statistically significant. The loss of shrimp species *Metapenaeus dobsoni* was higher in Oval grid BRD compared to Semicircular Fisheye BRD and the difference was statistically highly significant ($p<0.01$). *Parapenaeopsis stylifera* also showed higher loss from the Oval grid BRD, compared to Fisheye BRD, though the difference was not statistically significant. As the commercial trawler fishermen are very concerned with the loss of target catch, the preference is likely to be towards the Semicircular Fisheye BRD which retained over 98% of the shrimp catch.

7.3.2.2 Selectivity studies

The results of selectivity analyses of 26 mm oval grid and semicircular fisheye in respect of nine species *viz., Alepes djedaba, Ambassis ambassis, Lagocephalus spadiceus, Lepturacanthus savala, Megalaspis cordyla, Sardinella longiceps, Stolephorus commersonnii, Stolephorus waitei* and *Thryssa mystax* are given in Table 7.4. L_{50} values obtained in the Semicircular Fisheye BRD were higher, in respect of Alepes *djedaba, Ambassis ambassis, Lepturacanthus savala, Megalaspis cordyla, Sardinella longiceps, Stolephorus waitei* and *Thryssa mystax* compared to Oval grid BRD and in the case *Thryssa mystax* L_{50} value was higher than L_m for the species. Higher L_{50} values were obtained in respect of two *viz*., *Lagocephalus spadiceus, Stolephorus commersonnii,* in the case of Oval grid BRD. In the case of three species *viz*., *Ambassis ambassis, Stolephorus commersonnii* and *Stolephorus waitei* L_{50} values were found to be greater than L_m values for the respective species in both the BRDs, indicating better escapement opportunity for immature fish.

Table. 7.4 Selectivity parameters for Oval grid and Semicircular Fisheye BRD

Species	BRD type	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection Range, mm	Length at first maturity, mm
Alepes djedaba	Semicircular	133.79	156.09	178.40	44.62	180-189
	26 mm	124.55	135.88	147.20	22.62	
Ambassis ambassis	Semicircular	77.74	89.93	77.74	102.13	55-75
	26 mm	53.71	64.96	76.22	22.51	
Lagocephalus spadiceus	Semicircular	83.57	75.72	91.42	15.69	-
	26 mm	66.15	82.81	99.46	33.32	
Lepturacanthus savala	Semicircular	335.40	403.09	470.78	135.38	418-750
	26 mm	258.14	330.08	402.03	143.89	
Megalaspis cordyla	Semicircular	76.09	137.12	198.16	122.07	250
	26 mm	80.00	99.71	119.42	39.43	
Sardinella longiceps	Semicircular	59.84	85.27	110.70	50.86	150-162
	26 mm	50.08	84.95	119.83	69.75	
Stolephorus commersonnii	Semicircular	90.47	101.22	111.97	21.50	74
	26 mm	99.06	108.53	118.01	18.94	
Stolephorus waitei	Semicircular	90.82	109.54	128.25	37.43	81-84
	26 mm	70.02	83.75	97.48	27.47	
Thryssa mystax	Semicircular	104.25	161.76	219.28	115.04	130
	26 mm	74.86	118.80	162.74	87.89	

7.4 Conclusions

Performance of Oval grid with 26 mm bar-spacing was better compared to grid with 20 mm bar spacing. There was a 55.6% reduction in the shrimp loss when bar spacing was increased from 20 to 26 mm. Oval grid BRD with 26 mm bar spacing excluded on an average 59% of the bycatch and 36 species have shown exclusion at rates exceeding 50%. In the case of 20 mm oval grid BRD, bycatch exclusion obtained was 45% and only 27 species showed exclusion at rates exceeding 50%. Statistical analysis has shown that the difference in performance was significant in respect of five fish species and in terms of shrimp retention in the case of oval grid BRD with 26 mm bar-spacing compared to the Oval grid BRD with 20 mm bar spacing.

During comparative performance evaluation, bycatch exclusion shown by the Oval grid BRD with 26 mm bar-spacing was about 58% and that by Semicircular Fisheye BRD was about 47%. More than 50% exclusion in respect of 38 species was observed in the Oval grid BRD compared to 14 species in Semicircular Fisheye. Statistical analysis has shown significantly higher exclusion rates in the Oval grid BRD, in respect of several bycatch species. However, shrimp loss was significantly low ($p<0.01$) in Semicircular fisheye BRD (1.59%) compared Oval grid BRD with 26 mm bar-spacing (8%). Oval grid BRD with 26 mm bar-spacing has given excellent results in terms of exclusion of bycatch species during the two sets of experiments (about 58%). Semicircular Fisheye BRD showed promising results in terms of target catch retention (98.41%) which in Oval grid BRD with 26 mm bar-spacing was in the range of 92-94%.

The Gulf Council has recently recommended a minimum reduction in total finfish (by weight) of 30%, as performance standard for certification of BRDs for shrimp trawls in the Gulf of Mexico west of Cape San Blas, Florida under the Fishery Management Plan for the shrimp fishery of the Gulf of Mexico (Gulf of Mexico FMC, 2006). Both the BRDs evaluated performed better than this criteria, in terms of bycatch exclusion.

8.0 Performance Evaluation of Radial Escapement Devices

8.1 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. The function of this BRD is based on the difference in the swimming power 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).

8.2 Materials and Methods

Two design variations of Radial Escapement Device (RED) were evaluated. First design had 100 mm large square mesh escapement section (30 meshes in depth and 56 meshes in circumference; 2 mm dia twine) attached to 900 dia stainless steel hoop (8 mm dia rod) at both ends (overall length: 1.5 m) with a 20 mm small mesh funnel inside to guide the catch to the codend. The device is attached to a codend of 4.0 m in length (200 meshes depth and 280 meshes circumference) (20 mm mesh size; 1.5 mm dia twine size). The second RED design was constructed of 150 mm large square mesh escapement section (20 mesh depth and 38 mesh circumference; 3 mm dia twine) with similar features as above.

The RED was positioned between the hind belly and codend of a 28.8 m shrimp trawl. Small meshed cover codends were used for retaining the excluded species. In these experiments, a stainless steel hoop was used in order to reduce the masking effect of small meshed cover on the square mesh escapement section. Eleven paired field trials were undertaken using REDs having 100 and 150 mm escapement sections. The evaluation of the REDs was carried out, off Cochin, during January-March 2006.

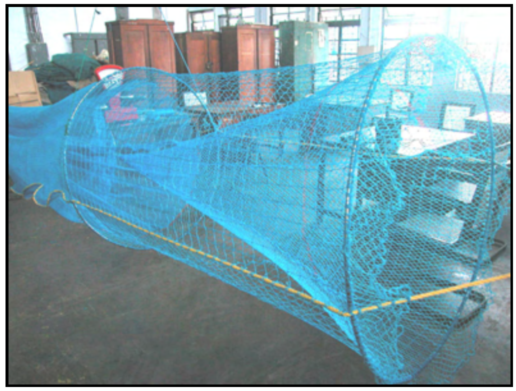


Fig. 8.1 Radial Escapement Device

Fig. 8.2 Scenes from field trials of Radial Escapement Device, off Cochin

Fig. 8.3 A view of the excluded catch from RED

8.3 Results and Discussion

The results of comparative performance evaluation of REDs with 100 and 150 mm escapement sections are represented in Tables 8.1 and 8.2. A RED ready for installation and scenes from field trials off Cochin are shown in Fig. 8.1-8.3.

8.3.1 RED with 100 mm square mesh escapement section

The total catch during the period of operations was 86.65 kg of which 79.32% was retained in the codend and 20.68% was excluded through 100 mm square mesh escapement section. The 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, 1 species of stomatopod. Among the 67 species encountered during the operations, 10 species *viz*., *Valamugil cunnesious, Otolithus ruber, Uroconger lepturus, Selar crumenophthalmus, Cynoglossus bilineatus, Terapon theraps, Leiognathus brevirostris*, *Lagocephalus spadicious*, *Scylla serrata* and *Portunus sanguinolentus* showed 100% escapement, 14 species showed exclusion above 50% and 28 species showed exclusion at leels up to 50%. Fifteen species consisting of 10 species of finfishes, 2 species of crabs, 2 species of cephalopods and 1 species of molluscan shell did not show any exclusion. Bycatch exclusion was 20.09% and shrimp loss was 24.29%.

8.3.2 RED with 150 mm square mesh escapement section

Total catch obtained during the experiments was 87.69 kg of which 84.40% was retained in the codend and 15.60% excluded through the large square mesh section. The catch during this period of observations included 54 species of fin fishes 5 species of shrimps, 3 species of crabs, 2 species of cephalopods, 1 species of molluscan shell, 1 species of stomatopod. Among the 67 species encountered, 9 species of finfishes *viz*., *Valamugil cunnesious, Dasciana albida, Scatophagus argus, Terapon jarbua, Anadontostoma chaucunda, Valamugil spiegleri, Alectis indicus, Liza subviridis* and *Terapon theraps* showed 100% escapement, 10 species showed escapement above 50%and 29 species showed exclusion up to 50%. Nineteen species consisting of 15 species of finfishes, 2 species of crabs, 1 species of cephalopod and 1 species of molluscan shell did not show any exclusion. Bycatch exclusion was 14.60% and shrimp loss was 20.33% of the total shrimp catch.

Table 8.1 Results of experiments with Radial Escapement Devices

	100 mm RED	150 mm RED
No. of hauls	11	11
Total catch (kg)	86.65	87.69
CPUE ($kg.h^{-1}$)	7.25	7.34
Retained catch (%)	79.32	84.40
Excluded catch (%)	20.67	15.61
Total shrimp catch (kg)	11.98	15.45
Retained shrimp catch (%)	75.71	79.67
Excluded shrimp catch (%)	24.29	20.33
Bycatch (catch other than shrimps) (kg)	74.67	72.24
Retained bycatch (%)	79.91	85.40
Excluded bycatch (%)	20.09	14.60
Species encountered (No.)	67	67
Fish species (No.)	51	54
Shrimp species (No.)	5	5
Other species (No.)	11	8
100% exclusion (No.)	9	9
>50% exclusion (No.)	14	10
Up to 50% exclusion (No.)	28	29
0% exclusion (No.)	16	19

Table 8.2 Shrimp retention characteristics of RED

	Total catch (kg)	Retention (%)	Exclusion (%)
RED-100 mm			
Metapeneaeus dobsonii	7.55	68.54	31.46
Parapenaeopsis stylifera	2.82	94.67	5.33
Metapenaeus affinis	0.99	68.53	31.47
Metapenaeus monoceros	0.56	89.29	10.71
Fenneropenaeus indicus	0.07	78.57	21.43
All shrimps	11.98	75.71	24.29
RED-150 mm			
Metapeneaeus dobsonii	12.63	76.56	23.44
Parapenaeopsis stylifera	1.75	92.86	7.14
Metapenaeus affinis	0.15	95.39	4.61
Metapenaeus monoceros	0.73	94.48	5.52
Fenneropenaeus indicus	0.20	94.87	5.13
All shrimps	15.45	79.67	20.33

Statistical analysis of the performance between REDs with 100 and 150 mm square mesh escape sections, showed that the difference in exclusion rates was not significant ($p>0.05$).

Selectivity studies

Selectivity parameters and selectivity curves in respect of nine species *viz*., *Ambassis ambassis*, *Johnius dussumieri*, *Kathala axillaries, Pellona ditchella, Lepturacanthus savala*, *Secutor insidiator*, *Parapenaeopsis stylifera* and *Metapenaeus dobsoni* are given in Table 8.3 and Fig. 8.3 to 8.10, respectively.

L_{50} values in respect of *Ambassis ambassis* and *Kathala axillaries* were higher in 100 mm RED compared to 150 mm RED, while L_{50} value in respect of *Metapenaeus dobsoni* was higher in 150 m RED. L_{50} values higher 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} vlaues in respect of *Ambassis ambassis*, *Pellona ditchella, Parapenaeopsis stylifera* and *Metapenaeus dobsoni* were higher than L_m values reported.

Table 8.3 Selectivity parameters for Radial Escapement Device

Species	RED type	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection Range, mm	Length at first maturity, mm
Ambassis ambassis	100 mm	78.66	86.66	94.66	16.00	55-75
	150 mm	64.54	80.97	97.40	32.86	
Johnius dussumieri	150 mm	99.08	103.47	107.8	8.77	115
Kathala axillaris	100 mm	100.18	131.06	161.94	61.75	-
	150 mm	99.19	118.57	137.94	38.7	
Pellona ditchella	150 mm	134.65	160.20	185.75	51.10	130-140
Lepturacanthus savala	100 mm	373.98	404.13	434.29	60.31	-
Secutor insidiator	100 mm	98.25	102.34	106.4	8.18	-
Parapenaeopsis stylifera	150 mm	113.23	141.53	169.82	56.59	63.2
Metapenaeus dobsoni	100 mm	52.28	94.91	137.54	85.26	88.6
	150 mm	79.90	107.62	135.33	55.43	

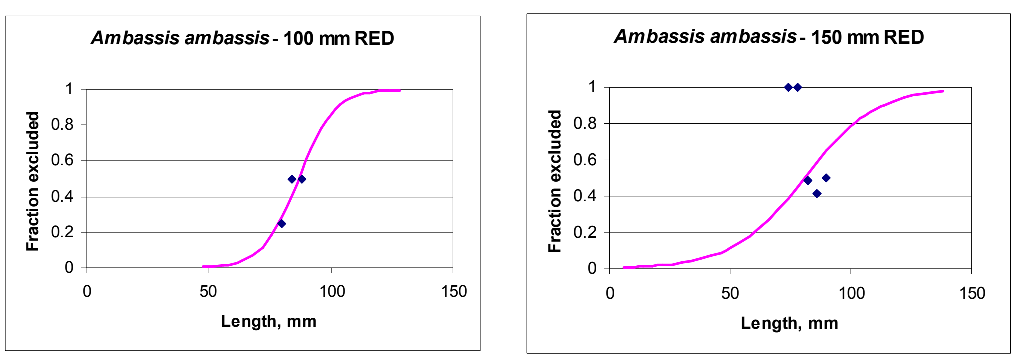


Fig. 8.3 Selectivity curves for *Ambassis ambassis*

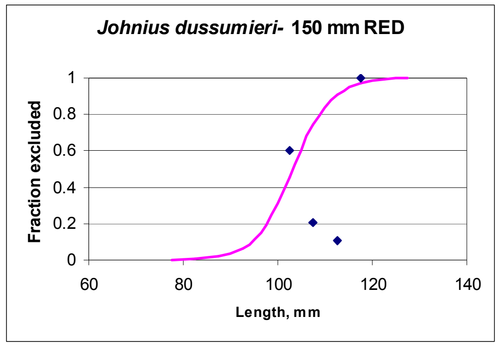
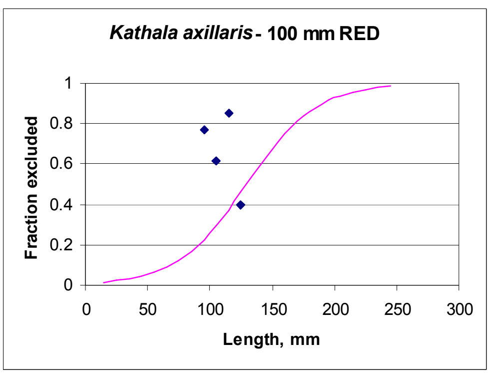


Fig. 8.4 Selectivity curve for *Johnius dussumieri*



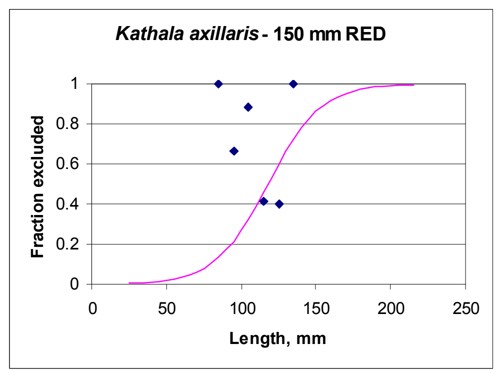


Fig. 8.5 Selectivity curves for *Kathala axillaries*

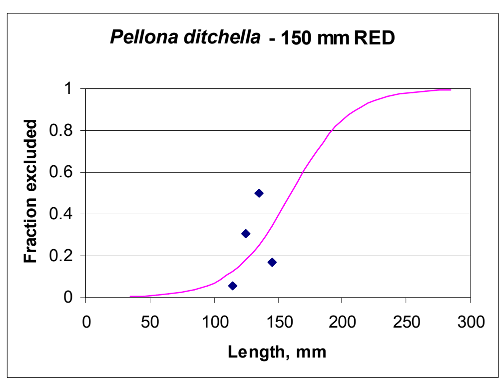


Fig. 8.6 Selectivity curve for *Pellona ditchella*

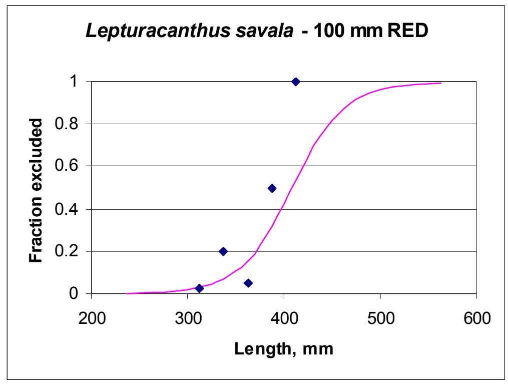


Fig. 8.7 Selectivity curve for *Lepturacanthus savala*

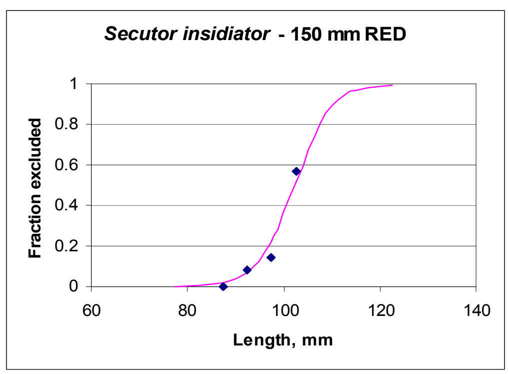


Fig. 8.8 Selectivity curve for *Secutor insidiator*

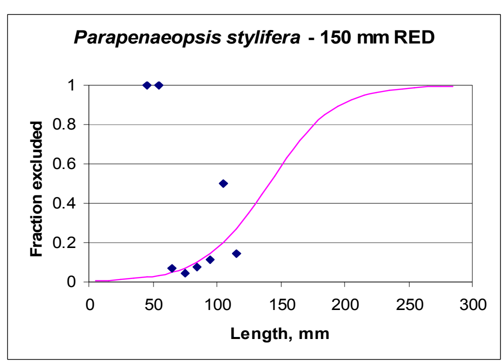
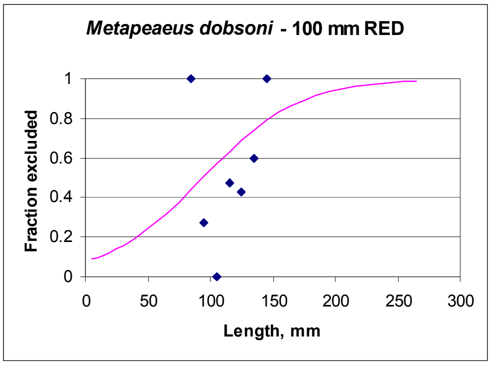


Fig. 8.9 Selectivity curve for *Parapenaeopsis stylifera*



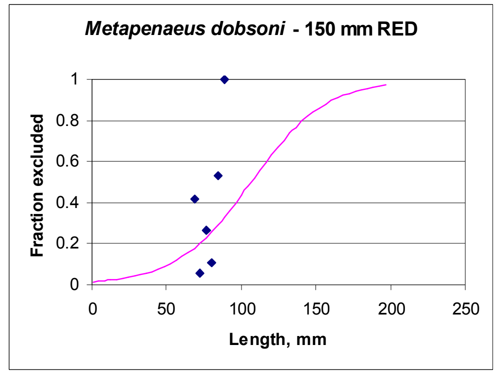


Fig. 8.10 Selectivity curves for *Metapenaeus dobsoni*

8.4 Conclusions

During the performance evaluation, exclusion of bycatch in RED with 100 mm square mesh escape section was on an average 20% and the shrimp loss was about 24%. Bycatch exclusion from RED with 150 mm square mesh escape section was about 15% and shrimp loss was 20%. Bycatch exclusion rates and shrimp loss rates indicate that Radial Escapement Device may not be an appropriate BRD for Indian fisheries conditions.

9.0 Performance Evaluation of Bigeye BRDs

9.1 Introduction

Bigeye BRD is a simple device constructed by making a horizontal slit in the upper part of codend or hind belly, where the opening is maintained by means of float and sinker arrangement 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 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. The Big eye 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).

9.2 Materials and Methods

Bigeye BRDs positioned at (i) 1.5 m from the distal end of codend (Bigeye-1.5) and (ii) 0.5 m from the leading edge of the codend (Bigeye-0.5) were used for performance evaluation.

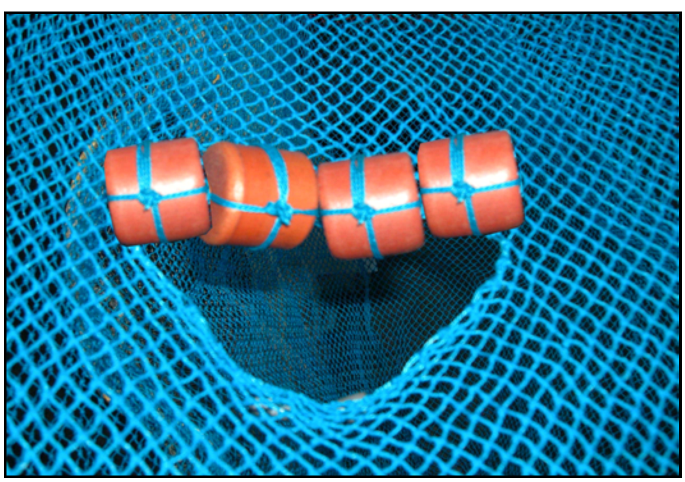


Fig. 9.1 Bigeye BRD in the trawl codend, kept open by means of floats and sinkers

The Bigeye was constructed by making a slit on the top of the shrimp trawl codend (5 m long; 20 mm mesh size) by cutting 15 meshes across the codend on the top panel at the appropriate location. The slit is kept open by means of sinkers (30g x2; 125g x2) and 2-4 floats of sufficient extra-buoyancy. A small meshed cover codend was provided around the slit to retain the excluded catch.

Comparative performance evaluation of Bigeye BRDs fixed at two different positions on shrimp trawl codend was conducted off Cochin, during May-July 2006 and April 2007 and fourteen paired hauls were used for analysis.

9.3 Results and Discussion

9.3.1 Bigeye BRD positioned at 0.5 m from the leading edge of codend

The total catch during the period of experiments was 71.79 kg of which 93.87% was retained in the codend and 6.13% was excluded. The catch during the period of observations consisted of 61 species including 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 jellyfish (Table 9.1).

Among the 61 species encountered, 20 species showed exclusion through the BRD. Excluded species included 16 species of finfishes, 2 species of crabs, 2 species of shrimp. Forty-one species consisting of 32 species of finfishes, 4 species of shrimps, 1 species of cephalopod, 1 species of crab, 1 species of stomatopod, 1 species of jellyfish and 1 species of echinoderm did not show any exclusion through the BRD, during the experiments. Among the shrimps, *Metapenaeus dobsonii* showed 98.35% retention and other shrimps *viz*., *Parapenaeopsis stylifera, Fenneropenaeus indicus, Meapenaeus monoceros* and *Metapenaeus affinis* showed 100% retention. Bycatch exclusion was 7.83% and shrimp loss was 0.81%.

9.3.2 Bigeye BRD positioned in 1.5 m from the distal end of codend

The total catch during the period of experiments was 81.49 kg of which 90.83% was retained in the codend and 9.17% was excluded. The catch during the period of observations consisted of 70 species including 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 9.1).

Among the 70 species encountered, 6 species of finfishes consisting of *Ambassis ambassis, Gerrus limbatus, Mene maculata, Pelates quadrilineatus, Secutor ruconius* and *Valamugil cunnesius* were fully excluded and another 6 species showed exclusion rates above 50%, during the experiments. Thirty-five species consisting of 26 species of finfishes, 3 species of crabs, 1 species of elasmobranch, 2 species of molluscan shells, 1 species of stomatopod, 1 species of echinoderm and 1 species of coelenterate did not show any exclusion through the BRD. Among the shrimps, *Parapenaeopsis stylifera, Fenneropenaeus indicus, Metapenaeus affinis* and *Metapenaeus dobsonii* showed more than 97% retention in the codend.

Bycatch exclusion was on an average 11.42% and shrimp loss was 2.27%. Statistical anaysis did not show any significant difference in the exclusion rates between the BRDs. However, overall performance in terms of bycatch exclusion and shrimp retention was better in the case of Bigeye BRD positioned at 1.5 m from the distal end of codend compared to the one positoned at 0.5 m from the leading edge of codend

Table 9.1 Results of experiments with Bigeye BRDs

	Bigeye-0.5	Bigeye-1.5
No. of hauls	14	14
Total catch (kg)	71.79	81.49
CPUE ($kg.h^{-1}$)	5.6	6.15
Retained catch (%)	93.87	90.83
Excluded catch (%)	6.13	9.17
Total shrimp catch (kg)	17.35	20.02
Retained shrimp catch (%)	99.19	97.73
Excluded shrimp catch (%)	0.81	2.27
Bycatch (catch other than shrimps) (kg)	54.44	61.47
Retained bycatch (%)	92.17	88.58
Excluded bycatch (%)	7.83	11.42
Species encountered (No.)	61	70
Fish species (No.)	48	55
Shrimp species (No.)	6	5
Other species (No.)	7	10
100% exclusion (No.)	0	6
>50% exclusion (No.)	0	5
Up to 50% exclusion (No.)	20	25
0% exclusion (No.)	41	34

Selectivity studies

Selectivity parameters and selectivity curves in respect of six species *viz*., *Alepes djedaba*, *Megalaspis cordyla*, *Rastrelliger kanagurta*, *Stolephorus indicus*, *Thryssa mystax* and *Sardinella longiceps* are given in Table 9.2 and Fig. 9.2 to 9.7, respectively. L_{50} values in respect of *Sardinella longiceps* was higher in Bigeye-0.5 positioned close to the leading edge of the codend compared to Bigeye-1.5. L_{50} values were higher than the length at first maturity (Lm) for *Thryssa mystax* and close to Lm in the case of *Sardinella longiceps.* L_{50} values higher 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.

Table 9.2 Selectivity parameters for Radial Escapement Device

Species	Bigeye	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection Range, mm	Length at first maturity, mm (TL)
Alepes djedaba	Bigeye-1.5	130.00	136.13	142.26	12.26	180-189
Megalaspis cordyla	Bigeye-1.5	86.62	104.31	121.99	35.37	250
Rastrelliger kanagurta	Bigeye-1.5	111.31	122.22	133.12	21.81	190-220
Stolephorus indicus	Bigeye-1.5	104.42	110.59	116.76	12.35	-
Trhyssa mystax	Bigeye-1.5	122.41	155.76	189.11	66.70	130
Sardinella longiceps	Bigeye-1.5	48.69	109.78	170.87	122.18	150-162
	Bigeye-0.5	127.72	159.74	191.77	64.04	

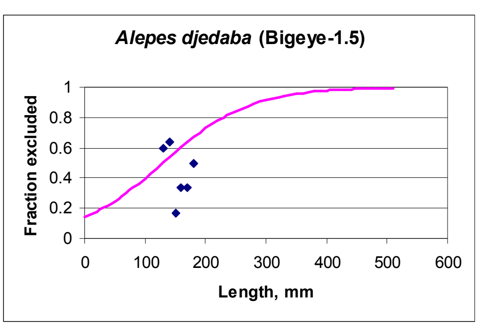


Fig. 9.2 Selectivity curve for *Alepes djedaba*

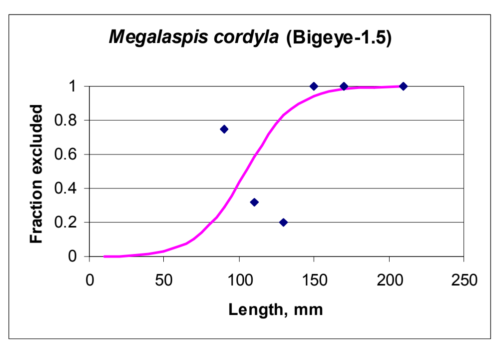


Fig. 9.3 Selectivity curves for *Megalaspis cordyla*

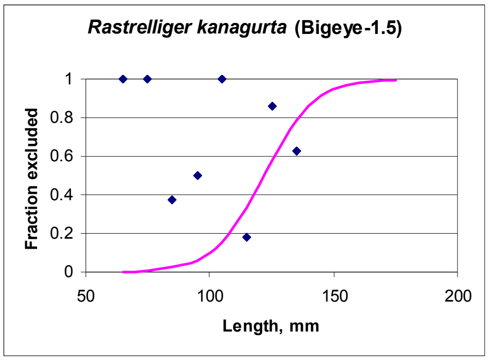


Fig. 9.4 Selectivity curve for *Rastrelliger kanagurta*

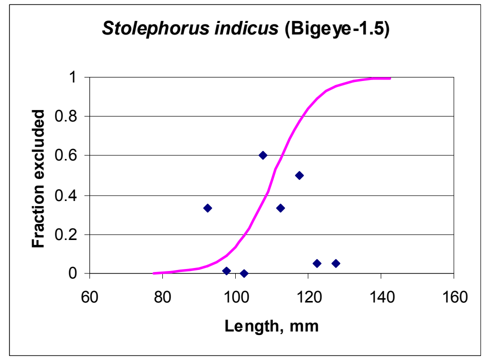


Fig. 9.5 Selectivity curve for *Stolephorus indicus*

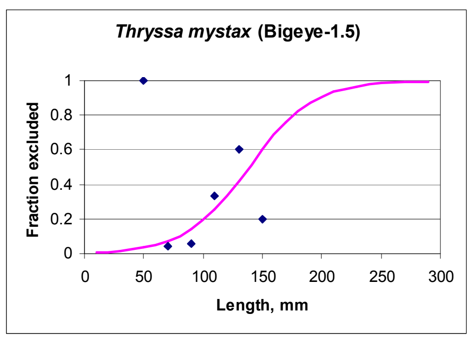
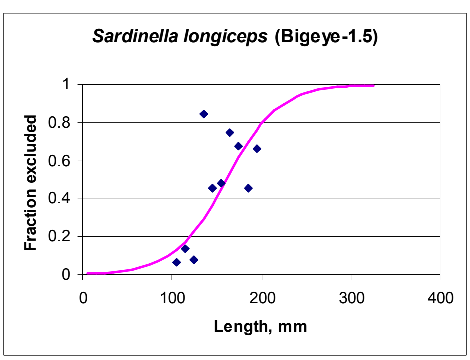


Fig. 9.6 Selectivity curve for *Thryssa mystax*



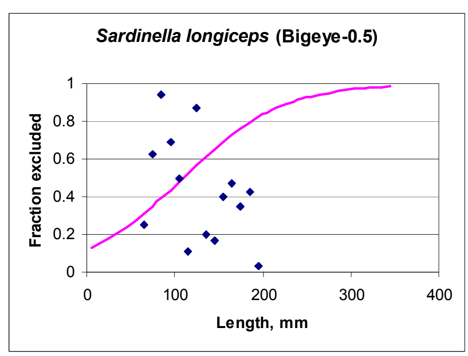


Fig. 9.7 Selectivity curve for *Sardinella longiceps*

9.4 Conclusions

During the field trials, bycatch exclusion from Bigeye BRDs ranged from 8 to 11% and shrimp loss was less than 2.3%. Bycatch exclusion rates were observed to be low in the Bigeye BRDs, compared to some other BRD designs evaluated. However, performance in terms of shrimp retention was favourable as it was more than 97%. One of the major advantages of the Bigeye BRD is that it is very simple in design and can be easily fabricated and installed.

10.0 Comparative Evaluation of Fisheye BRD and Bigeye BRD

10.1 Introduction

Fisheye is an important bycatch reduction device facilitating the escapement of fish especially those which are undersized, from the codend. Bigeye BRD consists of a simple horizontal slit in the upper panel of the codend or hind belly, which is kept open 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 these two categories of BRDs. Fishes that have entered the codend are given opportunity to swim back and escape through exit openings in the BRD, 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). In this Chapter, performance evaluation of the Fisheye BRD and Bigeye BRD is attempted, based on comparative field trials.

10.1 Materials and Methods

Bigeye BRD and Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation and positioned at 1.5 m from the distal end of codend were used for comparative performance evaluation. Design and construction details of Fisheye BRD and Bigeye BRD are described in Chapter 5 and 9, respectively. BRDs were positioned at 1.5 m from the distal end of codend. Ten paired hauls were undertaken, during November 2006, off Cochin, using a 28.8 m shrimp trawl. A small meshed cover codend was provided around the exit opening of BRDs, in order to retain the excluded catch for analysis.

10.2 Results and Discussion

Results of comparative field trials using Fisheye and Bigeye BRDs are presented in Table 10.1. A total of 458 kg of fish and shellfish was landed during the experiments, of which shrimps contributed 7%.

10.2.1 Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation

The catch during the field trials was 223.23 kg, of which 41.97% was retained in the codend and 58.03% was excluded. Out of a total of 73 species encountered during the field trials, 11 species *viz*., *Decapterus russeli, Dasciana albida, Anadontostoma chacunda, Pampus chinenesis, Megalaspis cordyla, Thryssa puruva, Johnius amblycephalus, Sepiella inermis, Parastromateus niger, Sillago sihama, Caranx sexfasciatus* showed 100% exclusion through the BRD and 16 finfishes and 1 cephalopod showed more than 50% exclusion. Twenty-four species consisting of 13 finfishes, 3 shrimps, 5 crabs, 2 molluscan shells and 1 stomatopod species showed no exclusion though the BRD.

Metapenaeus dobsoni dominated the shrimp landings which contributed 95.45% of total shrimp catch followed by *Parapenaeopsis stylifera*. *Metapenaeus affinis, Metapenaeus monoceros,* and *Penaeus semisulcatus* showed 100% retention in the codend. Shrimp loss form the Fisheye BRD was 3.80% of total shrimp catch.

Table 10.1 Results of experiments with Bigeye BRD and Semicircular Fisheye BRD

	Bigeye	Fisheye
No. of hauls	10	10
Total catch (kg)	234.76	223.23
CPUE (kg.h^{-1})	22.90	21.78
Retained catch (%)	69.44	41.97
Excluded catch (%)	30.56	58.03
Total shrimp catch (kg)	14.55	17.61
Retained shrimp catch (%)	95.88	96.20
Excluded shrimp catch (%)	4.12	3.80
Bycatch (catch other than shrimps) (kg)	220.21	205.62
Retained bycatch (%)	67.46	37.33
Excluded bycatch (%)	32.54	62.67
Species encountered (No.)	70	73
Fish species (No.)	56	56
Shrimp species (No.)	6	6
Other species (No.)	8	11
100% exclusion (No.)	10	11
>50% exclusion (No.)	5	17
Up to 50% exclusion (No.)	36	20
0% exclusion (No.)	19	25

10.2.2 Bigeye BRD

The catch during the field trials was 234.76 kg, of which 69.44% was retained in the codend and about 30.56% was excluded through the BRD. Out of a total of 69 speceis encountered, ten species *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 through the BRD and 7 species of finfishes showed more than 50% exclusion. Eighteen species showed no exclusion through the BRD. Five species *viz*., *Alepes kleinii*, *Johnius carouna*, *Lepturocanthus savala*, *Otolithes ruber* and *Selar crumenophthalmus* have shown significantly higher ($p<0.05$) exclusion rate from Semicircular Fisheye, compared to Bigeye BRD.

Metapenaeus dobsonii dominated the shrimp landing which contributed 93.22% of total shrimp catch, followed by *Parapenaeopsis stylifera*. *Metapenaeus monoceros,* and *Fenneopenaeus indicus* showed 100% retention in the codend. Shrimp loss form the Bigeye BRD was 4.12%, during the period of field trials.

10.4 Conclusions

During comparative field trials, the mean excluded catch was about 37% in the Bigeye BRD and 63% in the Fisheye BRD. Shrimp loss during the operations was about 4.2% n the Bigeye BRD and 3.8% in the Fisheye BRD. Performance of Fisheye BRD was better compared to the Bigeye BRD, in terms of bycatch exclusion and shrimp retention. However, Bigeye BRD has the comparative advantage of being extremely simple in construction and installation.

11.0 Performance Evaluation of Sieve Net BRDs

11.1 Introduction

Sieve nets (also known as veil nets) are cone shaped nets inserted into standard trawls which direct unwanted bycatch to an escape hole cut into the body of the trawl leading to a second codend. The large mesh funnel inside the net 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 are used in commercial shrimp fleets of The Netherlands, Denmark, UK, France, Germany and Belgium (Van Marlen et al., 1998; Polet et al., 2004; Revill and Holst, 2004). Experiments using Sieve net in Belgium fishery has given bycatch exclusion rates of 29-50% in different seasons, with less than 15% loss of shrimps (Polet et al., 2004; Catchpole, 2008). Sieve net reduced 29% by weight of small shrimp (*Crangon crangon*) and was recommended for mandatory use in beam trawls in UK (Revill, 1999). Sieve nets have significantly reduced environmental impact in the brown shrimp fisheries by releasing large quantities of juvenile fish and invertebrates from the trawls during the towing process. The technology has potential for use in other fisheries, but has not been taken up yet. (CEFAS, 2003).

11.2 Materials and Methods

Fishing experiments with two designs of Sieve nets were conducted using 29.0 m shrimp trawl, during 2007, off Cochin (Fig. 11.1 and 11.2). Codend covers were used to retain the excluded catch in order to study the exclusion and selectivity characteristics.

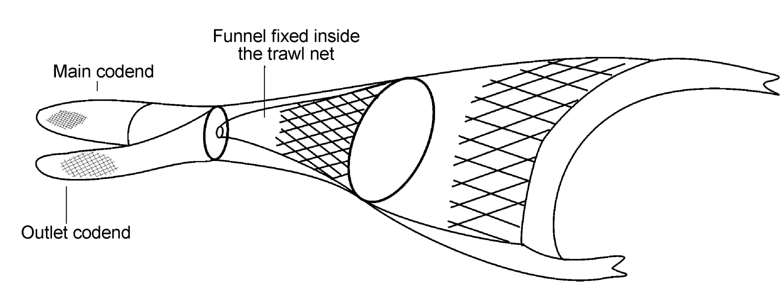


Fig. 11.1 Perspective view of Sieve net BRD installed in the trawl net

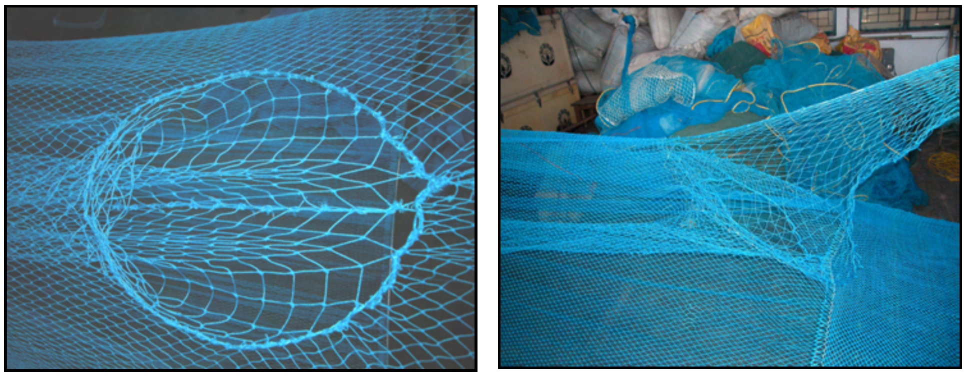


Fig 11.2 Construction of Sieve net BRD: (i) a view of the funnel exit opening (left) (ii) a view after fixing the outlet codend (right)

Fig. 11.3 Scenes from Sieve net BRD installed trawl operations, off Cochin

11.2.1 Sieve net with 60 mm diamond mesh funnel (Sieve net-60D)

The design (Sieve net-60D) consisted of a 60 mm diamond mesh funnel (135 meshes in circumference in the leading edge and 19 meshes in circumference in the tapering edge; 70 meshes in depth). The hind end of the funnel led to an outlet codend of 80 mm mesh size (60 meshes in circumference, 53 meshes in depth) with a length of 4 m. The outlet cover codend is surrounded by small mesh cover of PA netting (12 mm mesh size; 14.5 m in circumference and 7 m in length) in order to retain the catch excluded through 80 mm mesh codend. The throat section with sieve net is attached to the small meshed codend of 5 m length (20 mm mesh size; 250 meshes in circumference and 250 meshes in length). Netting of 1.25 mm dia twine was used for fabrication of sieve net and codend. Eighteen experimental hauls were taken using Sieve net-60D installed shrimp trawl.

11.2.2 Sieve net with 50 mm diamond mesh funnel (Sieve net-50D)

In the second design (Sieve net-50D), a 50 mm diamond mesh funnel (162 meshes in circumference in the leading edge and 22 meshes in circumference in the tapering edge; 84 meshes in depth). The hind end of the funnel opened to an outlet codend of 60 mm mesh (70 meshes in circumference and 64 meshes in depth) with an overall length of 4 m. Other arrangements remained the same as in Sieve net-50D. Sixteen experimental hauls were taken with Sieve net-50D

11.3 Results and Discussion

11.3.1 Sieve net-60D

Results of Sieve net-60D installed trawl operations are presented in Table 11.1. A total catch of 244 kg (CPUE: 13.3 $kg.h^{-1}$) was landed during the operations of which 56.6% was contributed by jellyfish. In addition to jellyfish, the catch consisted of 60 species consisting of 46 species of finfishes, 5 species of shrimps and 8 other species including cephalopods, elasmobranches, molluscan shells and snakes. Out of the total catch of 244.4 kg, 28.52% was retained in the main codend, 57.25% in the outlet codend connected to the sieve net funnel and 14.23% was excluded though larges meshes of the outlet codend. Jellyfish formed a dominant component of the trawl catch during the period of experimental operations. Out of a total catch of 138.3 kg of jelly fish, 98.19% was diverted and accumulated in the upper codend leading from the sieve net funnel and only 1.8% reached lower codend. Analysis excluding jellyfish component in the catch, has shown that out of the total catch of 106.1 kg, 63.33% 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.

Among the species which were excluded through the Sieve net-60D, 2 species of finfishes *viz*., *Mene maculata and Cynoglossus arel* showed 100% exclusion. Twelve species *viz*., *Sepiella inermis, Johnius carouna, Secutor insidiator, Pellona ditchella, Anadontostoma chaucunda, Johnius dussumieri, Therapon theraps, Megalaspis cordyla, Otolithus ruber, Decapterus ruselli, Encrasicholina devisi* and *jellyfish (Rhopilema* sp.) were excluded through Sieve net-60D at levels exceeding 50%. Twenty-nine species showed escapement between 0 to 50 % and 18 species *viz*., *Pampus argenteus*, *Narcine* sp., *Caranx ignobilis*, *Scylla serrata, Charybdis feriatus*, *Congresox talabonoides*, *Cynoglossus dubius, Dussumieria acuta, Liza parsia, Scoliodon laticaudus, Sphyraena forsteri, Sphyraena obtusata, Stolephorus indicus, Terapon jarbua, Thryssa malabarica, Turritella attenuata, Upeneus sulphurus, Valamugil speigleri* did not show any exclusion.

Among the 53 species retained in the main codend, 14 species *viz*., *Cynoglossus dubius, Scoliodon laticaudus, Valamugil spiegleri, Upeneus sulphureus, Liza parsia, Sphyraena fosteri, Congressox talabanoides, Sphyraena obtustata, Therapon jarbua, Thryssa malabarica, Dussumieria acuta, Stolephorus indicus, Turetella attuneata,* and *Charybdis feriatus,* showed 100 % retention, another 18 species of finfishes showed greater than 50% retention and 17 species showed retention between 0 to 50 %. Shrimp catch was constituted by *Parapenaeopsis stylifera* (53.80%), *Metapenaeus dobsoni* (36.95%), *Fenneropenaeus indicus* (4.68%) and *Metapenaeus affinis* (1.56%). On an average 95% of the shrimps were retained in the main codend which included *Parapenaeopsis stylifera* (99.1%), *Metapenaeus affinis* (92.11%), *Metapenaeus dobsoni* (95.84%) and *Fenneropenaeus indicus* (38.6%) (Table 11.2). Among the shrimps *Fenneropenaeus indicus* has shown a tendency to be led to the outlet codend; however, contribution of this species to the total shrimp catch was low. Shrimp loss due to the installation of Sieve net-60D was estimated to be 4.47%. Overall bycatch reduction obtained was 14.74% of the total catch encountered including jellyfish and 36.45% when jellyfish was exclude from analysis.

In the 80 mm outlet codend 14 species were retained which included 11 species of finfishes (*Pampus argenteus, Leiognathus splendens, Lepturacanthus savala, Ambassis ambassis, Secutor insidiator, Caranx ignobilis, Sardinella longiceps, Johnius carutta, Ilisha filigera, Encrasicholina devisi* and *Alepes djedaba*), 1 species of elasmobranch (*Narcine* sp.), 1 species of cephalopod (*Sepiella inermis*) and 1 species of crab (*Scylla serrata*) and 1 species of shrimp (*Fenneropenaeus indicus*). *Pampus argenteus, Caranx ignobilis, Charybdis feriatus* and *Narcine* sp. showed 100% retention in the oulet codend.

Table 11.1 Results of Sieve net-60D 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 11.2 Retention and exclusion of shrimps in Sieve net-60D installed trawl operations

	Total, kg	Retained, %	Excluded, %
Metapeanaeus affinis	0.19	92.11	7.89
Fenneropenaeus indicus	0.57	50.88	49.12
Metapeanaeus dobsonii	4.497	95.84	4.16
Parapenaeopsis stylifera	6.912	99.10	0.90
All shrimps	12.169	95.53	4.47

Statistical analysis using Student *t*-test has shown that in respect of *Ambassis ambassis*, *Cynoglossus macrostomus*, *Johnius carouna*, *Lactarius lactarius*, *Lepturocanthus savala* and *Otolithes ruber* exclusion rates were highly significant ($p<0.01$) and in respect of *Alepes djedaba Johnius carutta*, *Leiognathus splendens Megalaspis cordyla Otolithes ruber Sardinella longiceps* exclusion rates significant ($p<0.05$). Among target species, retention rate of *Metapenaeus dobsonii* was found to be highly significant ($p<0.01$).

Selectivity studies

Selectivity parameters and selectivity curves in respect of five species caught in Sieve net-60D *viz*., *Alepes djedaba, Ambassis ambassis, Encrasicholina devisi, Johnius carouna* and *Lactarius lactarius* are given in Table 11.3 and Fig. 11.4 to 11.8, respectively. L_{50} values obtained by plotting mid-length classes against retained fractions were found to be lower than the length at first maturity values (L_m) for *Alepes djedaba, Ambassis ambassis* and *Encrasicholina devisi* and *Lactarius lactarius*, indicating that immature fishes are able to escape through the Sieve net BRD.

Table. 11.3 Selectivity parameters of Sieve net-60D

Species	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	Selection Range, mm	Length at first maturity (TL), mm
Alepes djedaba	86.98	103.52	120.06	33.08	180-189
Ambassis ambassis	75.67	99.41	123.15	47.48	55-75
Encrasicholina devisi	66.89	70.22	73.55	6.66	64.5
Johnius carouna	91.75	110.49	129.23	37.48	-
Lactarius lactarius	42.46	113.49	184.52	142.06	135

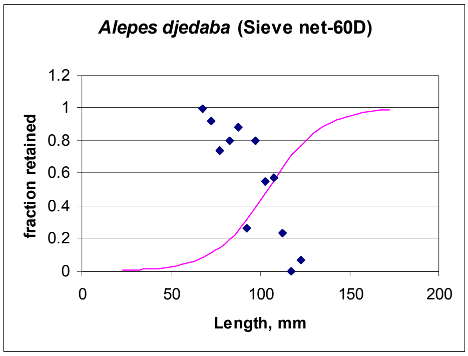


Fig 11.4 Selectivity curve for *Alepes djedaba*

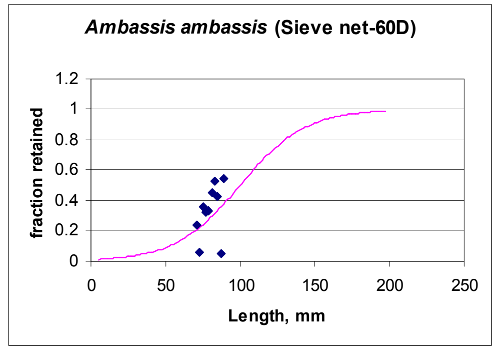


Fig 11.5 Selectivity curves for *Ambassis ambassis*

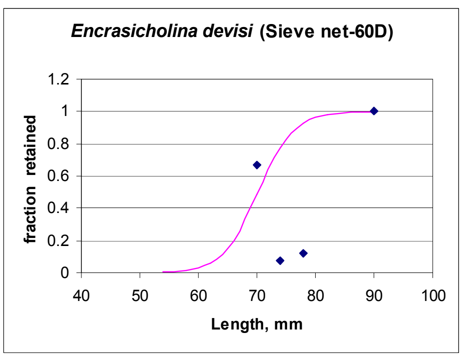


Fig. 11.6 Selectivity curves for *Encrasicholina devisi*

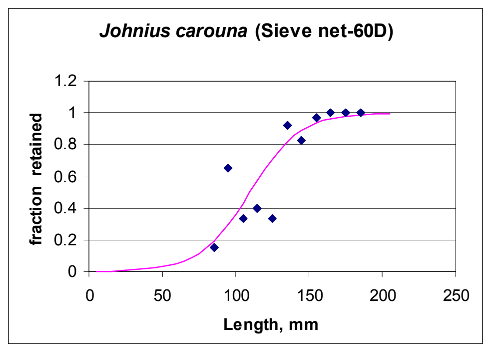


Fig. 11.7 Selectivity curves for *Johnius carouna*

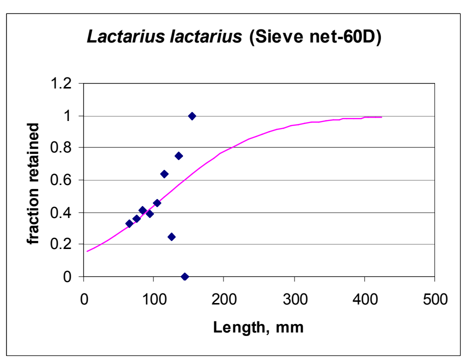


Fig. 11.8 Selectivity curves for *Lactarius lactarius*

11.3.2 Sieve net- 50D

Results of Sieve net-50D installed operations are presented in Tables 11.4 and 11.5. Total catch obtained during 16 experimental hauls using Sieve net-50D was 290 kg of which 60.65% retained in the main codend, 9.80% of total catch retained in the outlet codend and 29.55% predominantly consisting of juveniles were excluded through the 60 mm meshes of the outlet codend. The catch during the period of observations was constituted by 81 species including 62 species of finfishes, 6 species of shrimps, 6 species of crabs, 2 species of cephalopods, 4 species of molluscan shells, 1 species of stomatopod.

Table 11.4 Results of Sieve net-50D installed trawl operations

	Sieve net- 50D
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 (%)	80.46
Excluded shrimp catch (%)	19.54
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 11.5 Retention and exclusion of shrimps in Sieve net-60D installed trawl operations

	Total, kg	Retained, %	Excluded, %
Metapenaeus dobsoni	68.35	83.08	16.92
Parapenaeopsis stylifera	4.66	57.83	42.17
Metapenaeus monoceros	1.30	64.47	35.53
Metapenaeus affinis	1.33	40.93	59.07
All shrimps	75.64	80.46	19.54

Among the species which were excluded through the large meshes of the outlet codend of the Sieve net-50D, 14 species showed 100% exclusion which includes 9 finfishes (*Scomberoides lysan*, *Scomberomorus commerson*, *Scomberomorus guttatus*, *Epinepheleus diacanthus*, *Alectis indicus*, *Leiognathus dussumieri, Drepene punctata*, *Alectis ciliaris, Arius jella*), 2 species of molluscan shells (*Bufonaria echinata Turritella acutangula*) and 1 species of crab (*Charybdis natator*); 19 species including 14 species of finfishes, 2 species of shells, 1 species of shrimp, 1 species of cephalopod and 1 species of stomatopod showed exclusion rates above 50%; 24 species consisting of 19 species of finfishes, 4 species of shrimps, and 1 species of molluscan shell showed exclusion between 0 and 50 %. Seventeen species including fishes such as *Carangoides armatus*, *Upeneus sulphurus, Fenneropenaeus indicus, Trypauchen vagina, Scatophagus argus, Gazza minuta, Gerres erythrourus, Nemipterus mesoprion, Secutor ruconius, Sillago sihama, Thryssa setirostris, Congresox talabonoides, Pisodonophis cancrivorus, Upeneus vittatus and crabs* (*Charybdis feriatus* and *Charybdis lucifera*) did not show any exclusion through Sieve net-50D.

Among the 69 species retained in the trawl, 50 species was observed in the outlet codend and 19 species in the main codend. Species such as *Mene maculata*, *Caranx ignobilis, Portunus pelagicus*, *Johnius dussumieri*, *Saurida undosquamis*, *Cynoglossus dubius*, *Upeneus sulphurus*, *Carangoides armatus*, *Charybdis feriatus*, *Charybdis lucifera*, *Portunus sanguinolentus*, *Babylonia spirata* and *Turritella attenuata* were fully retained in the outlet codend. Species such as *Nemipterus japonicus, Terapon jarbua, Leiognathus brevirostris, Sphyraena jello, Rastrelliger kanagurta, Pampus argenteus, Terapon theraps, Pomadasis maculates,* and *Secutor insidiator* accumulated in the outlet at levels exceeding 50%. Nineteen species including *Dussumieria acuta*, *Alepes djedaba*, *Siganus* *canaliculatus*, *Scomberoides tala*, *Oxiurichthys paulae, Lactarius lactarius, Cynoglossus macrostomus, Lagocephalus spadiceus, Johnius amblycephalus, Congresox talabonoides, Gazza minuta, Gerres erythrourus, Nemipterus mesoprion, Penaeus semisulcatus, Pisodonophis cancrivorus, Secutor ruconius, Sillago sihama, Thryssa setirostris* and *Upeneus vittatus* were fully retained in the main codend.

Shrimp loss during using Sieve net-50D installed trawl operations was 19.53 %. High loss was observed for all shrimp species caught *viz*., *Metapenaeus dobsoni* (16.92%), *Parapenaeopsis stylifera* (42.17%), *Metapenaeus monoceros* (35.53%) and *Metapenaeus affinis* (59.07%), indicating that 50 mm mesh size in the sieve net funnel is inadequate for the shrimps to pass through to the main codend. Bycatch reduction obtained due to installation of Sieve net-50D was about 33%.

Statistical analysis using Student *t*-test has shown that exclusion rates were significant ($p<0.05$) in respect of species such as *Cynoglossus macrostomus*, *Gazza minuta*, *Lactarius lactarius*, *Leiognathus bindus*, *Megalaspis cordyla*, *Otolithes ruber* and *Pampus argenteus* and exclusion rates were highly significant ($p<0.01$) in respect of *Lagocephalus spadicious* and *Lepturocanthus savala.* Retention rates was significant ($p<0.05$) for shrimp species such as *Metapenaeus affinis* and *Metapenaeus monoceros*.

11.4 Conclusions

Sieve net is a funnel of netting with appropriate mesh size placed in side of trawl net to guide unwanted species to outside. Sieve nets were recently made mandatory under EU legislation in all European brown shrimp fisheries, and are preferred by the fishers to grids, which may be used as an alternative to sieve nets under the legislation. Sieve nets do not have the same handling problems as grids and are less prone to blockage, because they have a larger sorting area (CEFAS, 2003).

Sieve net is effectively used by many fisheries around the world to reduce fish, jelly fish and other bycatch species from shrimp trawling and could be easily adapted for Indian fisheries. 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 mortality of juveniles during shrimp trawling.

Among the two sieve nets evaluated, Sieve net-60D (with 60 mm diamond mesh funnel inside the net with 80 mm diamond mesh outlet codend) has been able to exclude significant quantities of juveniles and bycatch while keeping shrimp loss at about 4.5% and retaining larger marketable bycatch species. In addition, it is also possible to adapt the Seine-net to efficiently exclude jellyfish when they abound in the shrimp fishing grounds, by keeping the outlet codend open and retain the shrimp catch.

Sieve net-50D (50 mm diamond mesh funnel and outlet codend of 60 mm mesh size) has functioned poorly in terms target catch retention which was only about 80%, making this design unacceptable for commercial use. Sieve net-60D has potential for adoption in tropical trawl fisheries, in order to minimize the impact of shrimp trawling on juveniles and non-targeted bycatch species

12.0 Performance Evaluation of Separator Panel BRDs

12.1 Introduction

The separator panel BRD designs use panels of netting placed in the mouth, throat, or along the wings of the trawl to lead fish towards escape openings, allowing shrimp to pass through relatively large panel meshes in to the codends (FAO, 1973, Watson et al., 1986; Broadhurst, and Kennelly, 1996; Tokai, 1998; Quevedo, 2001; Lowry, 2008). 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. Large mesh triangular netting panels placed in the trawl net in upward sloping position to exclude turtles and large animals from the nets are called soft Turtle Excluder Devices (TED). The Morrison TED, Parker TED and Andrews TED are efficient soft TEDs (Christian et al., 1988; Andrew et al., 1993). Separator panels with different dimensions and mesh sizes are used to exclude bycatch such as cetaceans, turtles and fishes. In this Chapter, results of experiments conducted with two designs of separator panel BRDs are discussed.

12.2 Materials and Methods

Ten pairs of experimental hauls were undertaken using two designs of Separator panel BRDs during February-March 2007, off Cochin.

12.2.1 Separator panel with 60 mm diamond mesh netting

An oval separator panel was fabricated of polyethylene diamond netting (60 mm mesh size and 1.25 mm dia twine size) of 19 meshes in depth and 25 meshes in width and hung to an 8 mm rope frame (Separator panel-60D). The oval shaped netting panel was fixed inside the throat section of the trawl net at 45º angle. A triangular exit opening (15 bars) was provided in the top panel of throat so that the organisms diverted by the panel are able to escape (Fig 12.1). A small meshed cover codend (25 mm diamond mesh) was provided to retain the excluded catch from the Separator panel BRD in order to study the exclusion and selectivity characteristics.

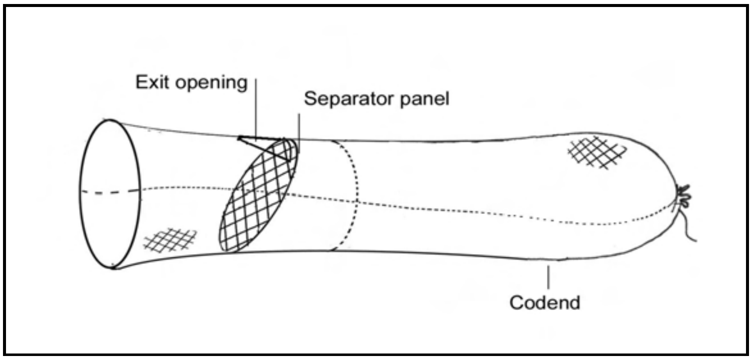


Fig 12.1 Perspective view of Separator panel BRD

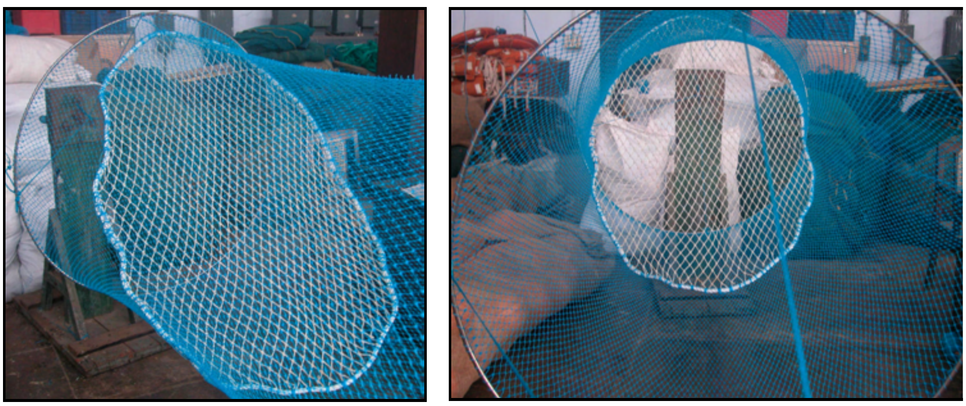


Fig 12.2 Views of Separator panel BRD fixed to the throat section of shrimp trawl

12.2.2 Separator panel with 40 mm square mesh netting

Another Separator panel (Separator panel-40S) was constructed using 40 mm square mesh netting (1.25 mm twine size) and hung to a 8 mm rope frame along the perimeter. The depth of the panel was 52 mesh bars and width of the panel was 42 mesh bars. The oval shaped netting panel was fixed inside the throat section of the net in front of the codend. A 15 mesh bar triangular opening and small meshed cover codend were provided as described earlier.

12.3 Results and Discussion

Results of experiments using two designs of Separator panels are given in Table 12.1. A total of 78.17 kg was landed during the period of experimental fishing trails.

12.3.1 Separator panel-60D

Total catch obtained during the Separator panel-60D installed operations was 36.25 kg of which only 35.55% was retained in the codend and 64.45% was excluded (Table 12.1). Out of the 80 species encountered during the experiments, 19 species *viz*., *Mene maculate, Acanthurus* sp., *Saurida undosquamis, Terapon jarbua, Drepene punctatus, Sphyraena forsteri, Ilisha filigera, Bufonaria echinata, Pellona ditchella, Encrasicholina heteroloba, Johnius dussumieri, Sardinella fimbriatus, Scomberoides tala, Alectis indicus, Cynoglossus macrostomus, Pelates quadrilineatus, Sardinella albella, Secutor ruconius* and *Sillago sihama* were fully excluded through the Separator panel BRD. Twenty-four species showed exclusion at rates exceeding 50% and another 24 species showed exclusion rates ranging from 0 to 50%. Thirteen species including *Apogon fasciatus, Caranx ignobilis, Charybdis lucifera, Encrasicholina punctifer, Lagocephalus inermis, Leiognathus brevirostris, Oxyurichthys paulae, Thryssa dussumieri, Thryssa malabarica, Upeneus sulphureus, Upeneus vittatus, Fenneropenaeus indicus* and *Turitella attenuate* were not seen excluded through the BRD.

Table 12.1 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 (%)	22.73	35.55
Excluded catch (%)	77.27	64.45
Shrimp catch (kg)	3.85	3.41
Retained shrimp catch (%)	47.29	56.01
Excluded shrimp catch (%)	52.71	43.99
Bycatch (catch other than shrimps) (kg)	39.04	31.84
Retained bycatch (%)	20.29	33.36
Excluded bycatch (%)	79.71	66.64
Species encountered (No.)	77	80
Fish species (No.)	64	66
Shrimp species (No.)	5	5
Other species (No.)	8	10
100% exclusion (No.)	22	19
>50% exclusion (No.)	38	24
Up to 50% exclusion (No.)	4	24
0% exclusion ((No.)	13	13

Shrimp loss from Separator panel-60D was observed to be unacceptably high (44%). *Metapenaeus dobsonii* dominated the shrimp landings (95%); however, over 43% was excluded through BRD. *Pampus argenteus* and *Uroteuthis duvauceli* were seen to excluded at levels exceeding 73%. Bycatch reduction due to installation of Separator panel BRD-60D was 66.64%.

12.3.2 Separator panel-40S

During the comparative operations a total catch of 42.92 kg was obtained in the Separator panel-40S of which only 22.73% was retained in the codend and 77.27% was excluded. Twenty-two species *Caranx sexfasciatus, Dussumieria acuta, Epinepheleus diacanthus, Fenneropenaeus indicus, Gerrus oyena, Ilisha filigera, Johnius amblycephalus, Liza parsia, Mene maculata, Nemipterus mesoprion, Parastromateus niger, Pellona ditchella, Platycephalus indicus, Sardinella albella, Sardinella fimbriatus, Scomberoides tala, Scylla serrata, Selar crumenophthalmus, Terapon jarbua, Uronconger lepturus, Valamugil cunnesius* and *Valamugil speigleri.* showed 100% escapement. Thirty-eight species showed exclusion rates at rates exceeding 50%, 4 species up to 50% and 13 species *viz.*, *Opisthopterus tardoore, Parapenaeopsis stylifera, Sepiella inermis, Leiognathus bindus, Alectis ciliaris, Congresox talabonoides, Cynoglossus bilineatus, Filimanus heptadactylus, Johnius carouna, Kathala axilaris, Leiognathus splendens, Oxyurichthys paulae, Secutor ruconius, Sillago sihama, Thryssa malabarica, Upeneus sulphureus* and *Turitella acutangula* were not seen excluded.

Fig 12.2 Picture showing blockage in 40 mm square mesh panel

Shrimp loss from this BRD was observed to be very high forming 52.71% of total shrimp catch. *Metapenaeus dobsonii* dominated the shrimp catch contributing 91.49%; however 53.52% was seen to be excluded. *Pampus argenteus* and *Uroteuthis duvauceli* mostly consisting of juveniles were excluded at rates of 97.34% and 65.09%, respectively, during the period of observations. Bycatch reduction due to installation of Separator panel BRD-40S was 79.71%. Occasional clogging of the separator panel which could be contributing to the poor sorting effect was observed in the case of Separator panel-40S (Fig. 12.2).

Statistical analysis using Student *t*-test has shown that exclusion rates in respect of four species viz., *Lactarius lactarius*, *Opisthopterus tardoore*, *Siganus canaliculatus* and *Valamugil cunnesius* were significantly high ($p<0.05$) in Separator panel-40S compared to Separator panel-60D.

12.4 Conclusions

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%). Results indicate that the present design of Separator panel BRDs will not be appropriate for Indian fisheries conditions. Separator panel BRDs are also seen vulnerable to clogging leading to ineffectual sorting.

13.0 Performance Evaluation of Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD)

13.1. Introduction

Shrimp trawling is a major economic activity in India and elsewhere in the tropical fisheries. It is well known that the shrimp trawling is a non-selective fishing gear. Due to multi-species nature of the fisheries and also due to economic considerations, the fishermen in India and elsewhere in tropical fisheries do not accept complete exclusion of fish and cephalopods during shrimp trawling Finfish species, crabs and cephalopods are also contributing significantly to the fishermen's income. However, they accept the necessity for the exclusion of juveniles and non-targeted, non-marketable size groups and species, from the landings. Shrimp fishermen also spend a lot of time for sorting the catch onboard after they are landed, which cuts into their productive fishing time. Accumulation of large fishes in the codend along with shrimp also lead to damage due to the struggle of the large species, which may cause physical stress leading to reduction in quality of the shrimp catch.

The main inspiration for the development of JFE-SSD has been the felt need to address the twin issues of improving selectivity of shrimp trawl in terms of protection of juveniles as a conservation imperative and the need for reducing sorting time expended during fishing, at the same time keeping shrimp trawling an economically viable activity. There have been many designs of bycatch reduction devices developed in different parts of the world, for shrimp fisheries. However, these are all geared towards retention of shrimp and exclusion of finfish bycatch, only.

In the present innovation titled Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD), exclusion of juveniles, is facilitated while retaining larger size groups of commercial species, and in addition, the separation of the catch is also effected, during shrimp trawling. This makes it unique and distinct from other bycatch reduction devices used in shrimp trawling, as it improves the selectivity of shrimp trawl, by innovatively incorporating the principles of bycatch reduction and shrimp sorting in a single device.

Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) replaces the conventional codend of the trawl net. The device consists of an oval grid provided with a top opening which leads to an upper codend with large square meshes. A funnel accelerates the flow of water and guides the catch components towards the oval grid kept at 45° angle to the horizontal which separates the shrimp from the rest of the animals. Shrimps pass through the grid spacing and are retained in the lower codend made up of square mesh netting and juvenile shrimps escape through square meshes. The fishes, crabs and cephalopods are deflected upwards to the opening provided at the top of the grid and enter into the upper codend with large square meshes which retains marketable size fishes and excludes juveniles.

13.2. Materials and Methods

Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) replaces the conventional codend of the trawl net (Fig. 13.1). The device consists of an oval grid made of stainless steel rods having bar spacing of 22 mm kept at 45° angle to the horizontal (Fig. 13.2-13.4). The grid is provided with a 250 x 680 mm top opening which leads to an upper codend with large square meshes (60 mm). A funnel made of netting (20 mm mesh size) accelerates the flow of water and guides the catch components towards the lower side of the oval grid kept at 45° angle to the horizontal which separates the shrimp from the rest of the catch. Shrimps pass through the grid spacing and are retained in the lower codend made up of 20 mm square mesh netting. Juvenile shrimps escape through 20 mm size square meshes of the lower codend. The large fishes and cephalopods are deflected upwards to the 250x680 mm opening provided at the top of the grid and enter into the upper codend with large square meshes (60 mm). Juveniles of finfishes and cephalopods, and low value small sized finfishes, which have entered the upper codend escape through large square meshes in the upper codend.

First set of experimental field trials using Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) was conducted off Cochin, south-west coast of India, during November-December 2005 season. The JFE-SSD was fitted to a shrimp trawl of 29.6 m head rope rigged with 87 kg V-form otter boards and operated from Research Vessel MFB Matsyakumari (17.5 m LOA; 277 hp). Covered codend technique was used for performance evaluation with respect to juvenile exclusion. About 40 trawl caught species were monitored during 34 hauls. Second set of 12 field trials were carried out during January 2007 season in the same fishing area and 98 species were monitored for exclusion and sorting characteristics. Covered codend method was used to retain excluded catch components.

Method of installation of JFE-SSD in the shrimp trawl is shown in Fig. 13.1. Schematic diagram of JFE-SSD is given in Fig. 13.2 and design drawing of the grid is given in Fig. 13.3. A perspective view of JFE-SSD showing the principle of operation is given Fig. 13.4. Fabrication of JFE-SSD is shown in Fig. 13.5 and a finished JFE-SSD ready for installation is shown in Fig. 13.6. A scene from the JFE-SSD installed trawl operations off Cochin is given in Fig. 13.7 and typical landings are given in Fig. 13.8.

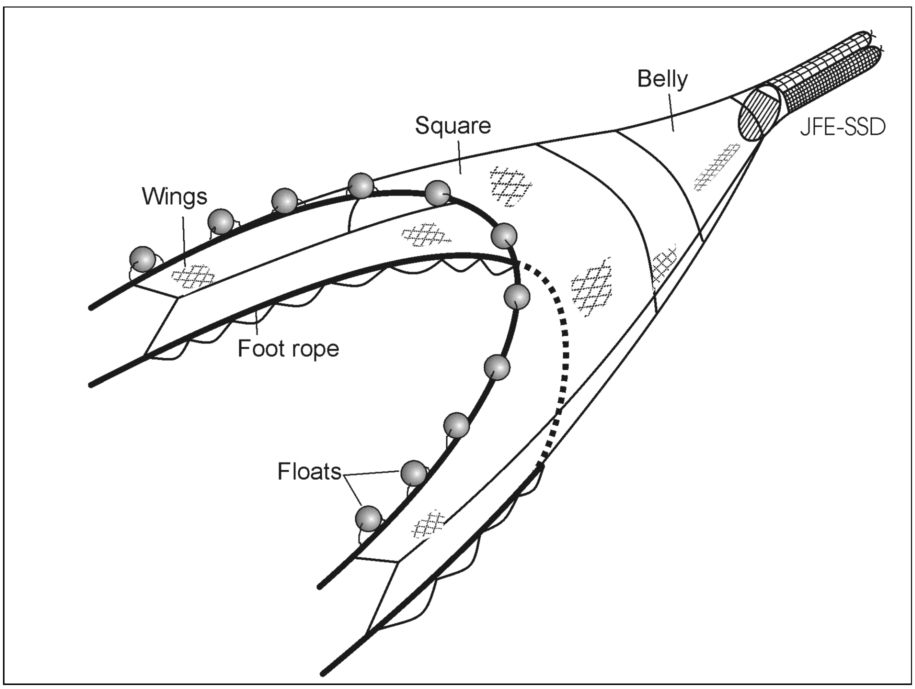


Fig. 13.1 Installation of JFE-SSD in shrimp trawl

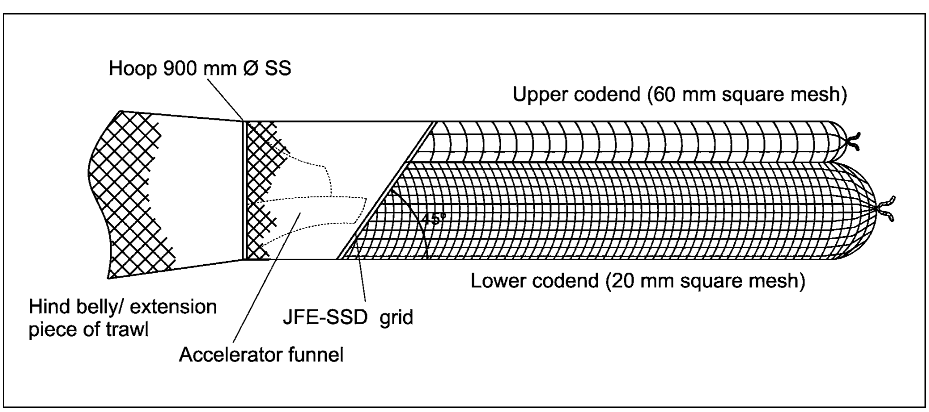


Fig. 13.2 Schematic diagram of JFE-SSD

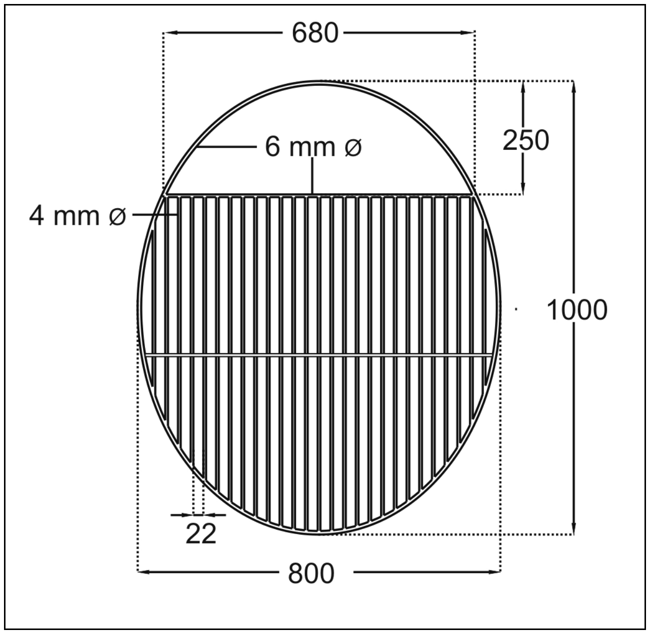


Fig. 13.3 Oval Grid with 22 mm bar spacing

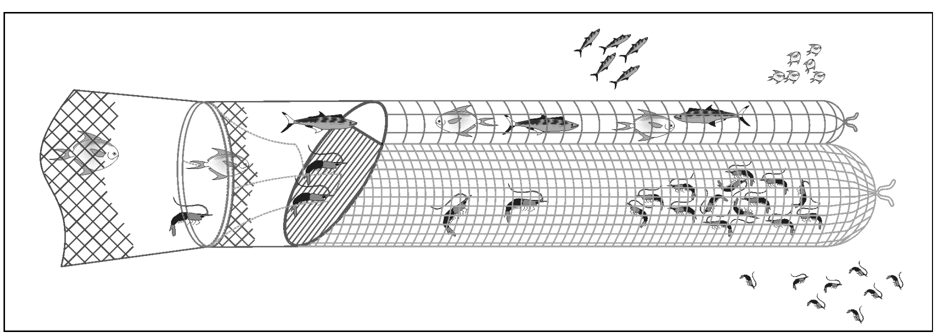


Fig. 13.4 Perspective view of JFE-SSD showing escaping juveniles

Fig. 13.5 Fabrication of Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD)

Fig. 13.6 JFE-SSD ready for installation

Fig. 13.7 JFE-SSD operation onboard CIFT Research Vessel MFB Matsyakumari, off Cochin

Fig. 13.8 Views of catch from JFE-SSD operations: Upper codend (top), Lower codend (middle) and Upper codend cover (excluded catch) (bottom).

13.3 Results and Discussion

13.3.1 Results of experiments with JFE-SSD, during November-December 2005

Results of performance evaluation of JFE-SSD in terms of bycatch exclusion and pre-sorting of the catch are given in Tables 13.1 to 13.4. Out of a total of 317.07 kg encountered in the JFE-SSD installed trawl, 58.22% was retained in the lower codend, 17.53% in the upper codend and 24.25% mostly consisting of juveniles and sub-adults of finfish and shellfish was excluded (Table 13.1).

Bycatch exclusion characteristics of JFE-SSD

Non-shrimp bycatch excluded through JFE-SSD was 28.88%. Among the species encountered, four species *viz*., *Cynoglossus arel, Megalaspis cordyla, Lactarius lactarius* and *Liza parsia* showed exclusion rates in excess of 50%. Nineteen species *viz*., *Otolithes ruber*, *Alepes kleinii*, *Leiognathus dussumieri*, *Sardinella longiceps*, *Epinephelus diacanthus*, *Pellona ditchella*, *Ambassis ambassis*, *Dolcea ovis*, *Esculosa thoracata*, *Rastrelliger kanagurta*, *Secutor insidiator*, *Sardinella albella*, *Thryssa mystax*, *Portunus sanguinolentus*, *Gerres erythrourus*, *Leiognathus equulus*, *Johnius borneensis*, *Johnius carouna* and *Johnius carutta*, showed exclusion rates between 25 and 50% by weight. Species such as *Cynoglossus macrostomus*, *Charybdis ferriatus*, *Arius jella*, *Leiognathus splendens*, *Trypauchen vagina*, *Mugil cephalus*, *Anadontostoma chacunda*, *Stolephorus waitei*, *Oratosquilla nepa*, *Penaeus monodon*, *Metapenaeus dobsoni*, *Opisthopterus tardoore*, *Parapenaeopsis stylifera* and molluscan shells, showed exclusion rates up to 25% by weight (Table 13.2). Two finfish species *viz*., *Pampus argenteus* and *Scoliodon laticaudus* was not excluded through JFE-SSD. Mean shrimp loss during the period of field trials was 2.69%, constituted by juveniles.

Sorting characteristics of JFE-SSD

Installation of JFE-SSD had a pronounced sorting effect on several species, particularly shrimps. Out of a total retained catch of 240.19 kg, about 77% was retained in the lower codend and the balance in the upper codend. Of the retained catch of non-shrimp resources (130.78 kg), about 70% was retained in the lower codend and nearly 30% in upper codend. The sorting effect was most pronounced in the shrimp species. Out of a total of 54.63 kg of retained shrimp catch, nearly 99% was retained in the lower codend (Table 13.3).

Table 13.1 Species-wise catch distribution in upper and lower codends and codend cover in JFE-SSD installed operations, during November–December 2005

	Encountered catch, kg	Lower codend, %	Upper codend, %	Upper codend cover, %
Alepes kleinii	3.35	47.01	4.93	48.06
Ambassis ambassis	4.33	42.38	11.89	45.73
Anadontostoma chacunda	1.15	28.70	56.52	14.78
Arius jella	2.67	28.09	51.87	20.04
Charybdis ferriatus	0.88	17.71	61.14	21.14
Cynoglossus arel	0.86	23.98	14.62	61.40
Cynoglossus macrostomus	7.06	65.58	12.39	22.03
Epinephelus diacanthus	4.84	31.40	22.21	46.38
Esculosa thoracata	1.46	59.79	2.41	37.80
Gerres erythrourus	1.13	46.22	21.33	32.44
Johnius borneensis	7.63	46.85	24.64	28.51
Johnius carouna	0.78	14.10	57.69	28.21
Johnius carutta	2.23	18.88	54.38	26.74
Lactarius lactarius	1.10	30.14	16.89	52.97
Leiognathus dussumieri	1.00	42.21	10.05	47.74
Leiognathus equulus	1.03	65.37	4.88	29.76
Leiognathus splendens	8.66	57.65	22.82	19.53
Dolcea ovis	9.57	30.93	26.91	42.16
Liza parsia	1.02	32.84	14.71	52.45
Megalaspis cordyla	3.65	11.10	34.11	54.79
Metapenaeus dobsoni	49.67	95.62	1.57	2.80
Mugil cephalus	2.71	82.29	2.21	15.50
Opisthopterus tardoore	1.58	40.63	57.14	2.22
Oratosquilla nepa	19.98	96.47	0.25	3.28
Otolithes ruber	1.49	20.81	30.87	48.32
Pampus argenteus	3.18	0.00	100.00	0.00
Parapenaeopsis stylifera	6.47	97.74	0.43	1.82
Pellona ditchella	1.53	45.75	8.50	45.75
Penaeus monodon	0.80	2.52	94.34	3.14
Portunus sanguinolentus	8.95	25.21	41.25	33.54
Rastrelliger kanagurta	8.93	30.52	32.53	36.95
Sardinella albella	1.79	46.78	17.93	35.29
Sardinella longiceps	43.64	37.03	15.96	47.00
Scoliodon laticaudus	0.35	0.00	100.00	0.00
Secutor insidiator	5.27	32.86	30.77	36.37
Molluscan shells	79.38	63.21	17.09	19.70
Stolephorus waitei	1.10	73.52	13.70	12.79
Thryssa mystax	3.37	35.91	29.38	34.72
Trypauchen vagina	0.85	5.88	76.47	17.65
Miscellaneous species	11.71	43.21	22.37	34.42
All species	317.07	58.22	17.53	24.25

Table 13.2 Species-wise exclusion rates in JFE-SSD installed operations, during November–December 2005

	Catch encountered, kg	Exclusion rate, %
Cynoglossus arel	0.855	61.40
Megalaspis cordyla	3.650	54.79
Lactarius lactarius	1.095	52.97
Liza parsia	1.020	52.45
Otolithes rubber	1.490	48.32
Alepes kleinii	3.350	48.06
Leiognathus dussumieri	0.995	47.74
Sardinella longiceps	43.635	47.00
Epinephelus diacanthus	4.840	46.38
Pellona ditchella	1.530	45.75
Ambassis ambassis	4.330	45.73
Dolcea ovis	9.570	42.16
Esculosa thoracata	1.455	37.80
Rastrelliger kanagurta	8.930	36.95
Secutor insidiator	5.265	36.37
Sardinella albella	1.785	35.29
Thryssa mystax	3.370	34.72
Portunus sanguinolentus	8.945	33.54
Gerres erythrourus	1.125	32.44
Leiognathus equulus	1.025	29.76
Johnius borneensis	7.630	28.51
Johnius carouna	0.780	28.21
Johnius carutta	2.225	26.74
Cynoglossus macrostomus	7.060	22.03
Charybdis ferriatus	0.875	21.14
Arius jella	2.670	20.04
Molluscan shells	79.380	19.70
Leiognathus splendens	8.655	19.53
Trypauchen vagina	0.850	17.65
Mugil cephalus	2.710	15.50
Anadontostoma chacunda	1.150	14.78
Stolephorus waitei	1.095	12.79
Oratosquilla neap	19.978	3.28
Penaeus monodon	0.795	3.14
Metapenaeus dobsoni	49.668	2.80
Opisthopterus tardoore	1.575	2.22
Parapenaeopsis stylifera	6.474	1.82
Pampus argenteus	3.175	0.00
Scoliodon laticaudus	0.350	0.00
Miscellaneous species	11.710	34.42
All species	317.065	24.25

Pampus argenteus and *Scoliodon laticaudus* was retained 100% in the upper codend. Finfishes such as *Trypauchen vagina*, *Johnius carouna*, *Megalaspis cordyla*, *Johnius carutta*, *Anadontostoma chacunda*, *Arius jella*, *Portunus sanguinolentus, Otolithes ruber*, *Opisthopterus tardoore* and *Rastrelliger kanagurta* and crab species *Charybdis ferriatus* were retained in the upper codend at rates exceeding 50%. *Penaeus monodon* also has shown preference to the upper codend, though overall catch volume for this species was low during the period of operations. Shrimp species such as *Parapenaeopsis stylifera* and *Metapenaeus dobsoni*; squilla *Oratosquilla nepa*; finfishes such as *Mugil cephalus*, *Esculosa thoracata*, *Leiognathus equulus*, *Alepes kleinii*, *Pellona ditchella*, *Stolephorus waitei*, *Cynoglossus macrostomus*, *Leiognathus dussumieri*, *Ambassis ambassis*, *Sardinella albella*, *Leiognathus splendens, Sardinella longiceps*, *Liza parsia*, *Gerres erythrourus*, *Johnius borneensis*, *Lactarius lactarius*, *Cynoglossus arel*, *Epinephelus diacanthus*, *Thryssa mystax*, *Dolcea ovis* and *Secutor insidiator*; and molluscan shells preferentially accumulated in the lower codend (Table 13.4).

Table 13.3 *In-situ* sorting effect on species groups due to installation of JFE-SSD, during November–December 2005

Species groups	Retained catch, kg	Lower codend, % of retained catch	Upper codend, % of retained catch
All species	240.19	76.86	23.14
Shrimp species	54.63	98.52	1.48
Non-shrimp species	130.78	70.48	29.52

Table 13.4 Sorting effect on trawl caught species in JFE-SSD installed operations, during November–December 2005

Species	Retained catch, kg	Lower codend, % of retained catch	Upper codend, % of retained catch
Oratosquilla nepa	19.32	99.74	0.26
Parapenaeopsis stylifera	6.36	99.56	0.44
Metapenaeus dobsoni	48.28	98.38	1.62
Mugil cephalus	2.29	97.38	2.62
Esculosa thoracata	0.91	96.13	3.87
Leiognathus equulus	0.72	93.06	6.94
Alepes kleinii	1.74	90.52	9.48
Pellona ditchella	0.83	84.34	15.66
Stolephorus waitei	0.96	84.29	15.71
Cynoglossus macrostomus	5.51	84.11	15.89

Leiognathus dussumieri	0.52	80.77	19.23
Molluscan shells	63.75	78.71	21.29
Ambassis ambassis	2.35	78.09	21.91
Sardinella albella	1.16	72.29	27.71
Leiognathus splendens	6.97	71.64	28.36
Sardinella longiceps	23.13	69.88	30.12
Liza parsia	0.49	69.07	30.93
Gerres erythrourus	0.76	68.42	31.58
Johnius borneensis	5.46	65.54	34.46
Lactarius lactarius	0.52	64.08	35.92
Cynoglossus arel	0.33	62.12	37.88
Epinephelus diacanthus	2.60	58.57	41.43
Thryssa mystax	2.20	55.00	45.00
Dolcea ovis	5.54	53.48	46.52
Secutor insidiator	3.35	51.64	48.36
Rastrelliger kanagurta	5.63	48.40	51.60
Opisthopterus tardoore	1.54	41.56	58.44
Otolithes ruber	0.77	40.26	59.74
Portunus sanguinolentus	5.95	37.93	62.07
Arius jella	2.14	35.13	64.87
Anadontostoma chacunda	0.98	33.67	66.33
Johnius carutta	1.63	25.77	74.23
Megalaspis cordyla	1.65	24.55	75.45
Charybdis ferriatus	0.69	22.46	77.54
Johnius carouna	0.56	19.64	80.36
Trypauchen vagina	0.70	7.14	92.86
Penaeus monodon	0.77	2.60	97.40
Pampus argenteus	3.18	0.00	100.00
Scoliodon laticaudus	0.35	0.00	100.00
Miscellaneous species	7.68	65.89	34.11
All species	**240.19**	**76.86**	**23.14**

Selectivity characteristics of JFE-SSD

Selectivity and length-wise exclusion characteristics in respect of selected trawl caught species were studied in the JFE-SSD installed operations. Length-wise exclusion characteristics of different length classes of *Alepes kleinii*, *Escualosa thoracata*, *Otolithes ruber*, *Rastrelliger kanagurta*, *Epinephelus diacanthus*, *Cynoglossus macrostomus*, *Sardinella albella*, *Secutor insidiator*, *Stolephorus waitei* and *Thryssa mystax* are given in Fig. 13.9a and 13.9b. In the case of *Alepes kleinii*, 52-80% of the juveniles of the different length classes (71-110 mm TL) encountered during the field trials were excluded. Length classes of 71-100 mm was completely excluded in the case of *Escualosa thoracata,* while length classes from 101-120 mm was excluded at levels of 42-58% and length classes >120 mm TL were fully retained. Juveniles of *Otolithes ruber* in the length range of 51-170 mm TL showed exclusion rates of 40-

68%. *Rastrelliger kanagurta* above 161 mm TL were retained while length classes of juveniles below 160 mm TL were excluded at levels of 77-90%. Juveniles of *Epinephelus diacanthus* below 110 mm TL were ecluded, while length classes between 111-160 mm TL were excluded at levels from 46 to 75%. Length classes of *Cynoglossus macrostomus* above 151 mm TL were fully retained while those in 81-150 mm range were excluded at levels from 13 to 54% and those in 71-80 mm length class was excluded at level of 75%. Adult *Sardinella albella* in the length class of 156-160 mm were retained while length classes in the 126-155 mm range were excluded at levels ranging from 39 to 70%. Length classes of *Secutor insidiator* from 51 to 100 were excluded at rates ranging from 40 to 93%, while length class below this range (41-50 mm TL) was fully excluded. Length classes of *Stolephorus waitei* in the range of 61-90 mm TL were excluded at rates ranging from 4 to 16% while adult length class above this (91-96 mm TL) was fully retained. In the case of *Thryssa mystax* length class 101-110 mm TL showed 100% exclusion while length classes above it (111-170 mm TL) showed exclusion rates of 25-68%.

An estimate of the mean size at capture or mean selection length is given by the length at which 50%t of the fish entering the trawl is retained by the gear (50% retention length or L_{50}). Selection curve differ in their sharpness depending on whether selection occurs over small or wide range of sizes. This is usually measured by the selection range, which is the difference between the 25% and 75% retention lengths (L_{25} and L_{75}). Selectivity curves and parameters L_{25}, L_{50} and L_{75} and the selection range values in respect of *Ambassis ambassis*, *Cynoglossus macrostomus*, *Epinephelus diacanthus*, *Johnius borneensis*, *Lepturocanthus savala*, *Megalaspis cordyla, Sardinella albella, Sardinella longiceps, Secutor insidiator*, *Stolephorus waitei* and *Thryssa mystax* are given in Fig. 13.10a and 13.10b and Table 13.5. Selectivity curves and mean selection lengths (Table 13.5) indicate that JFE-SSD is able to provide escape opportunities to the juveniles and sub-adults. L_{50} values higher 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 retained fractions in the selectivity estimates. L_{50} vlaues in respect of *Ambassis ambassis* and *Thryssa mystax* were higher than L_m values reported.

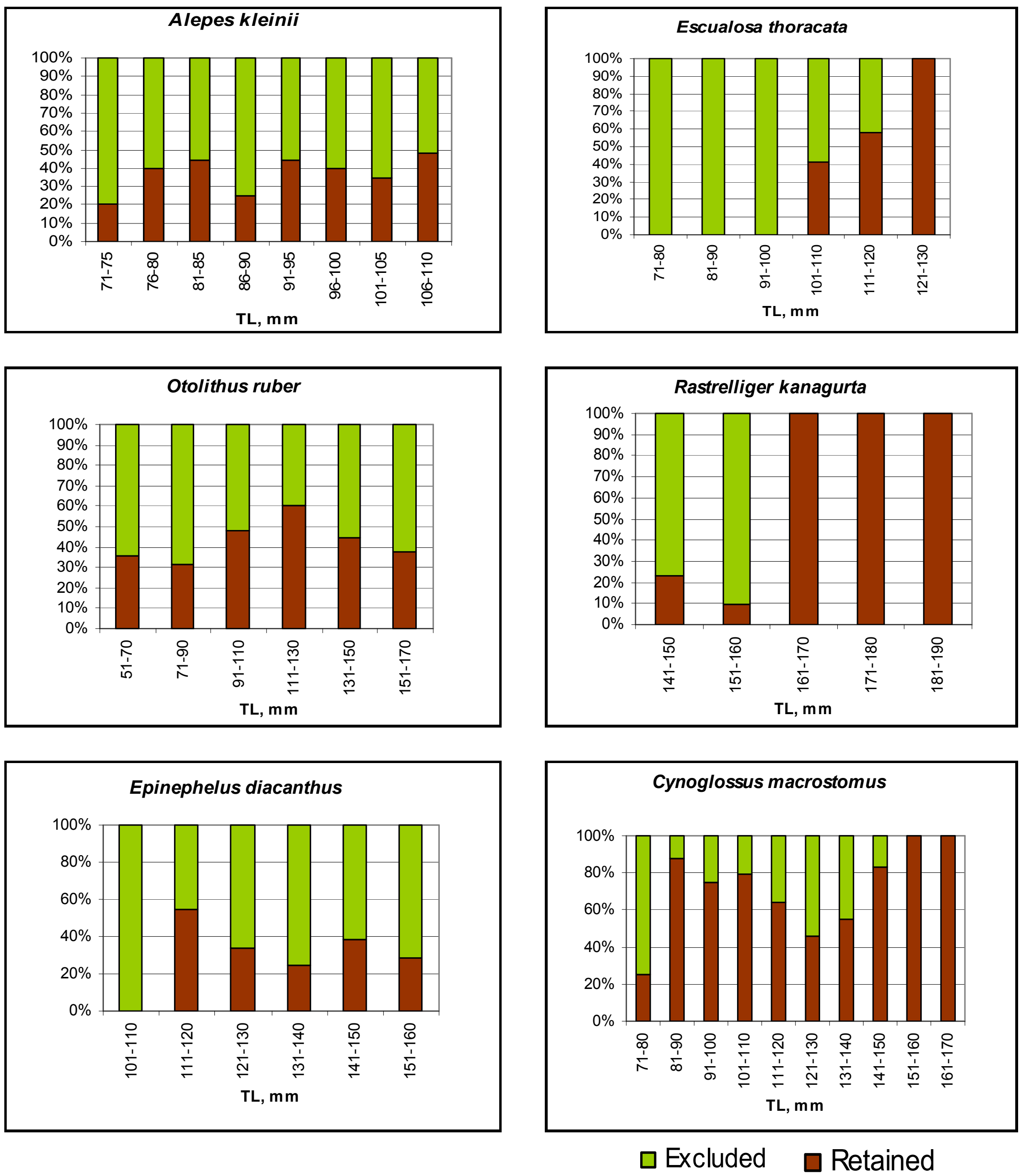


Fig. 13.9a Retention and exclusion rates of different length classes of selected species

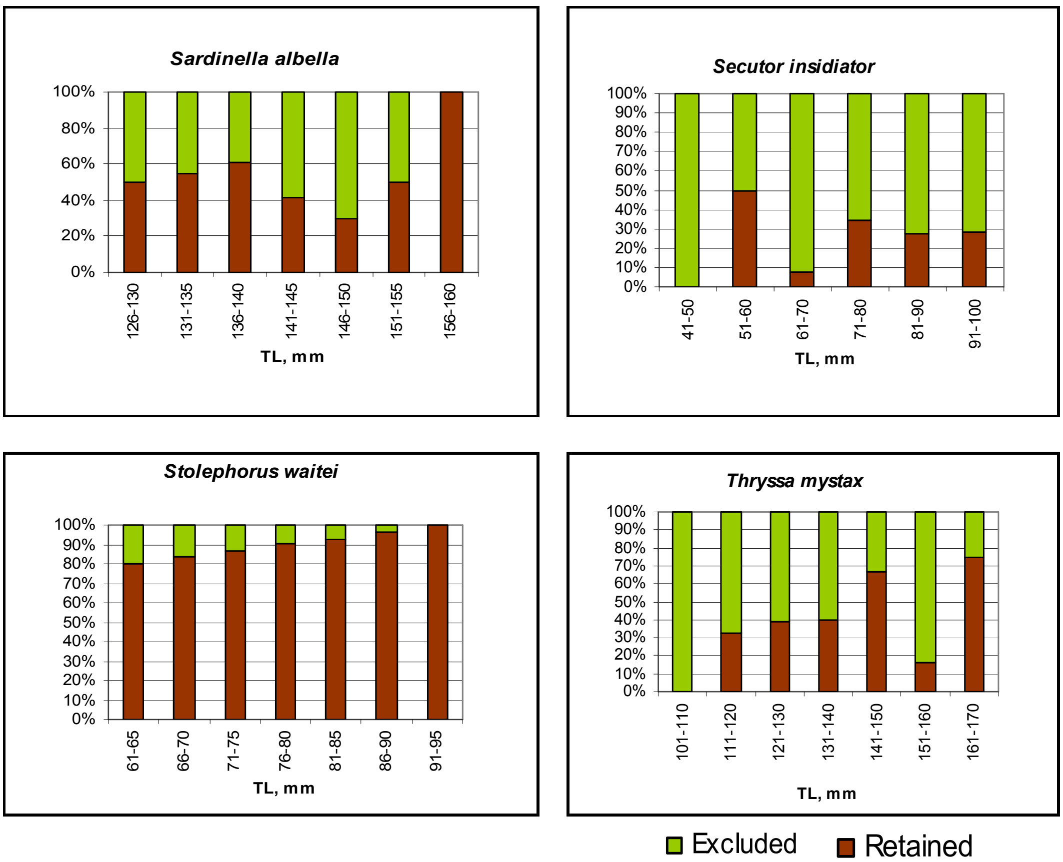


Fig. 13.9b Retention and exclusion rates of different length classes of selected species

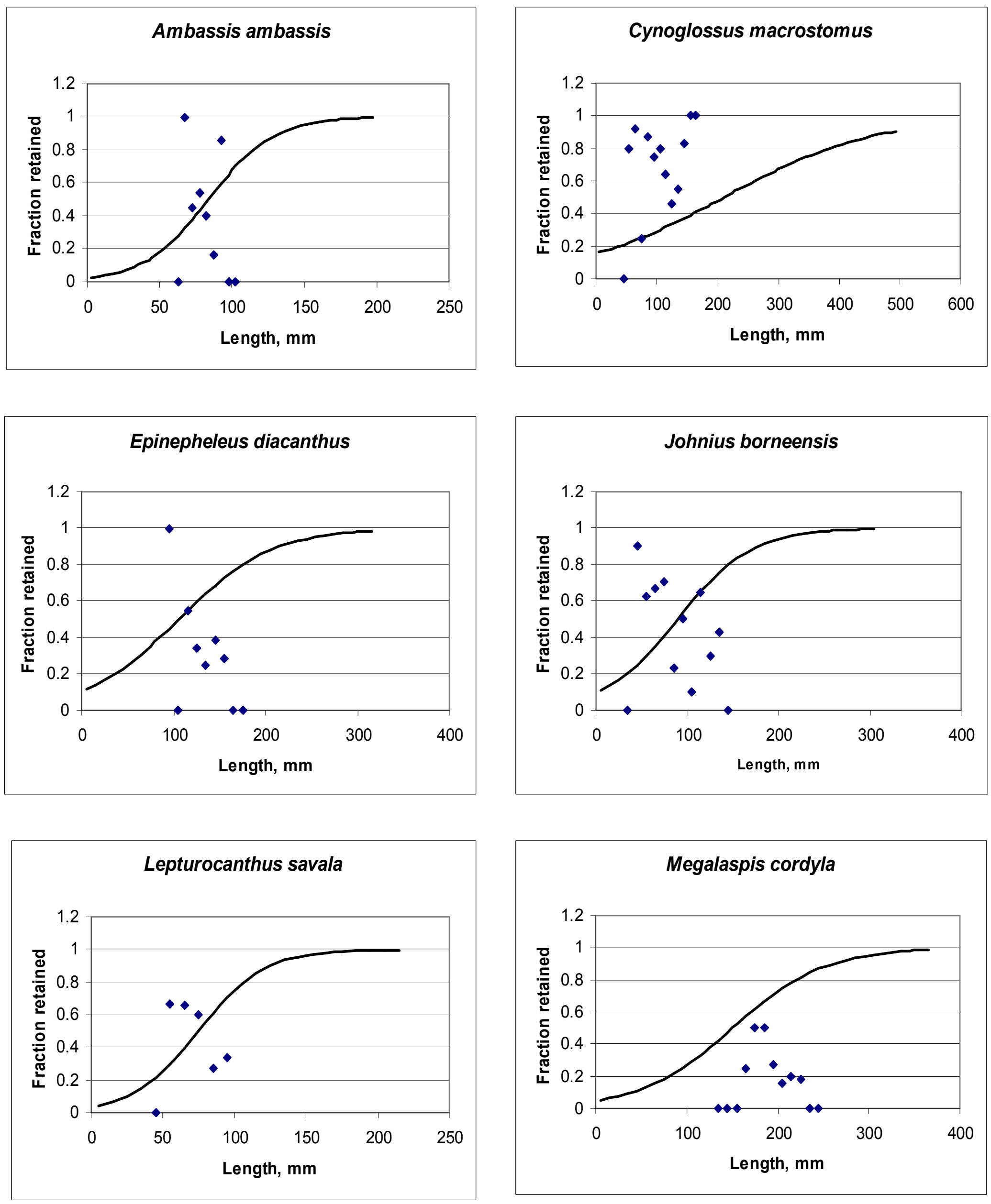


Fig. 13.10a Selectivity curves of selected species excluded through JFE-SSD

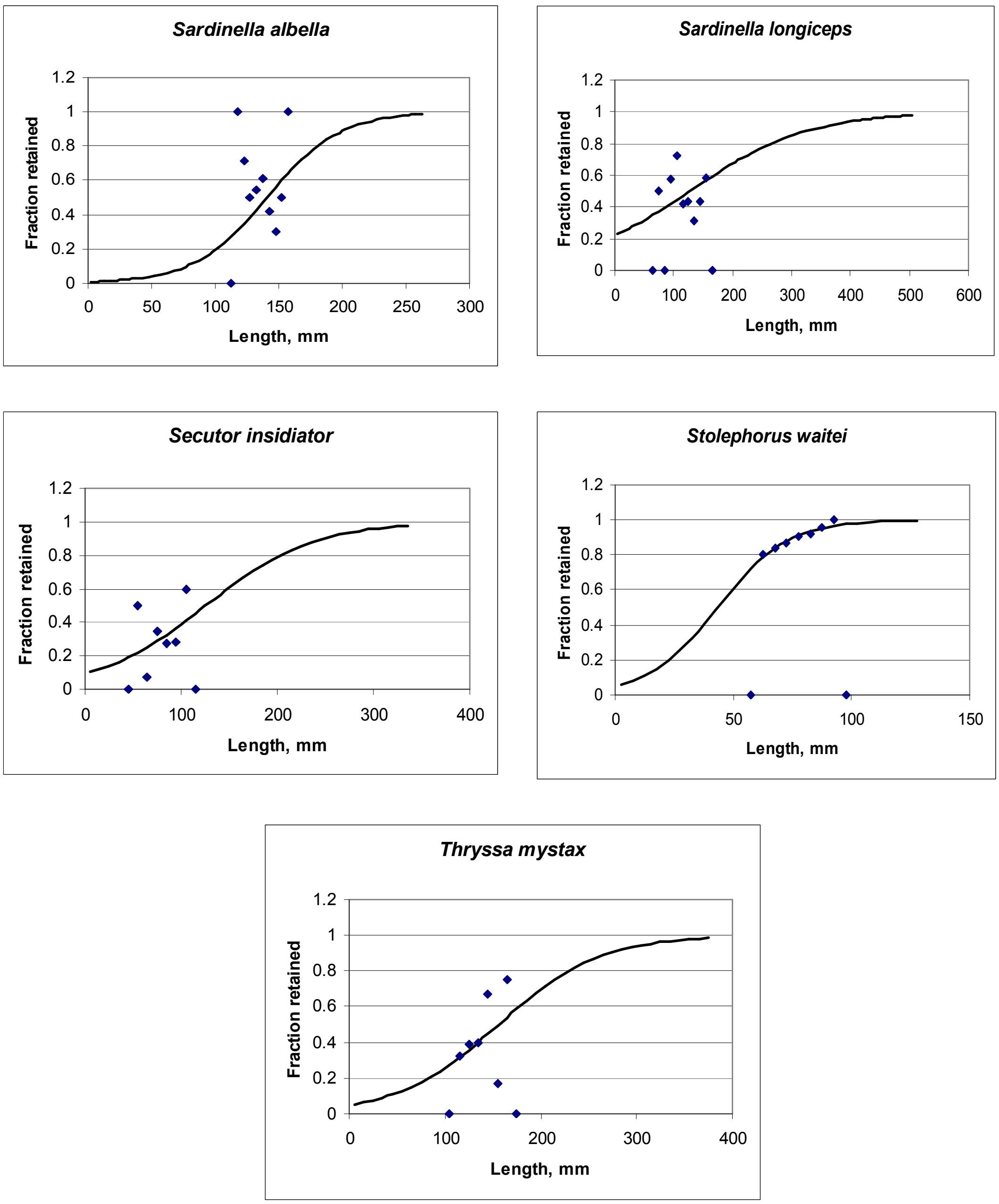


Fig. 13.10b Selectivity curves of selected species excluded through JFE-SSD

Table 13.5 Selectivity parameters in respect of selected trawl caught species in JFE-SSD installed operations, during November–December 2005

Species	L_{25} (TL, mm)	L_{50} (TL, mm)	L_{75} (TL, mm)	Selection range (TL, mm)	L_m (TL, mm)
Ambassis ambassis	59.44	83.86	108.27	48.83	55-75
Cynoglossus macrostomus	73.92	211.25	348.58	274.65	NA
Epinephelus diacanthus	50.97	105.9	160.83	109.86	210-377
Johnius borneensis	46.42	91.27	136.11	89.68	140-160
Lepturocanthus savala	50.05	75.02	99.99	49.94	418-750
Megalaspis cordyla	95.67	150.6	205.53	109.86	220-264
Sardinella albella	109.35	140.74	172.13	62.78	90
Sardinella longiceps	17.04	126.9	236.76	219.72	150-162
Secutor insidiator	64.63	125.67	186.70	122.07	67
Stolephorus waitei	27.18	43.34	59.49	32.31	81-84
Thryssa mystax	98.55	156.37	214.19	115.64	130

13.3.2 Results of experiments with JFE-SSD, during January 2007

During experimental fishing trials with JFE-SSD conducted in January 2007 season, 12 hauls were taken realizing a total catch of 81.17 kg in the codends and cover, and a mean CPUE of 6.76 $kg.h^{-1}$. Results are given in Tables 13.6 to 13.9. Of the total catch encountered, 48.25% was retained in the lower codend, 12.01% in the upper codend and 39.75% was excluded (Table 13.6).

Among the 98 species encountered, 6 species *viz.*, *Carangoides malabaricus*, *Liza parsia*, *Pomadassys maculates*, *Sepiella inermis*, *Sillago sihama* and *Sphyraena obtusata* showed 100% exclusion by weight through JFE-SSD. Thirteen species *viz.*, *Alepes kleinii*, *Alepes djedaba*, *Megalaspis cordyla*, *Sardinella gibbosa*, *Pelates quadrilineatus*, *Leiognathus brevirostris*, *Scomberoides lysan*, *Scomberoides tala*, *Sphyraena jello*, *Caranx sexfasciatus*, *Sardinella longiceps*, *Leiognathus splendens* and *Valamugil speigleri* showed exclusion between 50 and 100% in terms of weight and nineteen species consisting of *Cynoglossus macrostomus*, *Secutor insidiator*, *Stolephorus indicus*, *Johnius carouna*, *Otolithes ruber*. *Rastrelliger kanagurta, Johnius borneensis, Encrasicholina devisi, Fenneropenaeus indicus*, *Dussumieria acuta*, *Valamugil cunnesius*, *Nemipterus japonicus*, *Pellona ditchella*, *Gerres* *limbatus*, *Kathala axillaris*, *Thryssa mystax*, *Stolephorus waitei*, *Caranx ignobilis* and *Leiognathus equulus* showed exclusion rates between 25 and 50% in terms of weight. Eighteen species *viz.*, *Johnius dussumieri*, *Lagocephalus spadiceus*, *Encrasicholina heteroloba*, *Siganus canaliculatus*, *Stolephorus commersonnii*, *Portunus sanguinolentus*, *Gazza minuta*, *Uroteuthis* (*P*) *duvauceli*, *Oratosquilla nepa*, *Turritella acutangula*, *Turritella attenuata*, *Leiognathus dussumieri*, *Johnius amblycephalus*, *Parapenaeopsis stylifera*, *Metapenaeus monoceros*, *Opisthopterus tardoore*, *Metapenaeus dobsoni* and *Scomberomorus commerson* showed exclusion rates up to 25%, in terms of weight. Forty-three species including species such as *Mene maculata*, *Pampus argenteus*, *Atropus atropos*, *Charybdis lucifera*, *Lepturacanthus savala*, *Scatophagus argus*, *Babylonia spirata* and *Alectis ciliaris* were not seen excluded through JFE-SSD, however, the catch of most of these species were very low (Table 13.7). Mean bycatch reduction due to installation JFE-SSD was estimated to be 42.92%. Mean shrimp loss during the period of observations was 5.23%, which included mostly juveniles.

Table 13.6 Species-wise catch distribution in upper and lower codends and codend cover in JFE-SSD installed operations, during January 2007

	Encountered catch, kg	Lower codend, %	Upper codend, %	Upper codend cover, %
Acanthurus spp	0.01	100.00	0.00	0.00
Alectis ciliaris	0.10	0.00	100.00	0.00
Alectis indicus	0.04	100.00	0.00	0.00
Alepes djedaba	1.54	19.16	0.97	79.87
Alepes kleinii	0.36	16.67	0.00	83.33
Ambassis ambassis	0.01	100.00	0.00	0.00
Anadontostoma chacunda	0.08	40.00	60.00	0.00
Apogon fasciatus	0.01	100.00	0.00	0.00
Arius jella	0.01	100.00	0.00	0.00
Atropus atropos	0.23	0.00	100.00	0.00
Babylonia spirata	0.11	100.00	0.00	0.00
Babylonia zeylanica	0.07	50.00	50.00	0.00
Bufonaria echinata	0.04	0.00	100.00	0.00
Carangoides malabaricus	0.01	0.00	0.00	100.00
Caranx ignobilis	0.16	38.71	32.26	29.03
Caranx sexfasciatus	0.06	45.45	0.00	54.55
Charybdis feriatus	0.05	100.00	0.00	0.00
Charybdis lucifera	0.15	65.52	34.48	0.00
Charybdis natator	0.02	100.00	0.00	0.00
Chirocentrus dorab	0.03	100.00	0.00	0.00

Circular javana	0.05	100.00	0.00	0.00
Cynoglossus dubius	0.04	100.00	0.00	0.00
Cynoglossus macrostomus	0.48	51.04	1.04	47.92
Dasciaena albida	0.05	0.00	100.00	0.00
Donax scrotum	0.01	100.00	0.00	0.00
Dussumieria acuta	1.61	45.34	14.91	39.75
Encrasicholina heteroloba	0.05	55.56	22.22	22.22
Encrasicholina devisi	0.25	54.00	6.00	40.00
Epinephelus diacanthus	0.08	0.00	100.00	0.00
Fenneropenaeus indicus	0.03	0.00	60.00	40.00
Gazza minuta	0.18	72.68	10.93	16.39
Gerres limbatus	0.02	66.67	0.00	33.33
Holothuria spp.	0.02	100.00	0.00	0.00
Johnius amblycephalus	0.25	92.00	0.00	8.00
Johnius borneensis	0.26	25.49	33.33	41.18
Johnius carouna	0.43	54.65	3.49	41.86
Johnius dussumieri	4.15	75.90	0.00	24.10
Kathala axillaris	0.23	62.22	4.44	33.33
Lagocephalus spadiceus	0.95	69.84	7.41	22.75
Leiognathus brevirostris	0.09	41.18	0.00	58.82
Leiognathus dussumieri	0.68	2.22	88.89	8.89
Leiognathus equulus	0.39	19.23	52.56	28.21
Leiognathus splendens	0.04	0.00	50.00	50.00
Lepturacanthus savala	0.14	62.96	37.04	0.00
Dolcea ovis	0.08	0.00	100.00	0.00
Liza parsia	0.03	0.00	0.00	100.00
Megalaspis cordyla	3.51	16.95	11.11	71.94
Mene maculata	1.06	7.11	92.89	0.00
Metapenaeus affinis	0.01	100.00	0.00	0.00
Metapenaeus dobsoni	6.27	92.58	2.39	5.03
Metapenaeus monoceros	0.06	85.94	7.81	6.25
Mugil cephalus	0.02	100.00	0.00	0.00
Murex spp.	0.03	100.00	0.00	0.00
Natica vitellus	0.05	100.00	0.00	0.00
Nemipterus japonicus	0.22	18.18	45.45	36.36
Octpous spp.	0.05	100.00	0.00	0.00
Opisthopterus tardoore	0.48	56.94	37.27	5.80
Oratosquilla nepa	1.66	83.73	4.82	11.45
Otolithes cuvieri	0.07	76.92	23.08	0.00
Otolithes ruber	0.15	31.03	27.59	41.38
Oxiurichthys paulae	0.01	100.00	0.00	0.00
Pampus argenteus	0.45	0.00	100.00	0.00
Parapenaeopsis stylifera	0.45	93.72	0.00	6.28
Pelates quadrilineatus	0.07	38.46	0.00	61.54
Pellona ditchella	0.33	60.61	4.55	34.85
Penaeus semisulcatus	0.02	100.00	0.00	0.00
Platicephalus indicus	0.01	100.00	0.00	0.00

Pomadassys maculates	0.01	0.00	0.00	100.00
Portunus sanguinolentus	0.03	33.33	50.00	16.67
Pterois russelli	0.01	100.00	0.00	0.00
Rastrelliger kanagurta	1.50	6.67	52.00	41.33
Sardinella gibbosa	0.85	28.99	0.00	71.01
Sardinella longiceps	39.13	44.73	4.22	51.05
Saurida tumbil	0.02	0.00	100.00	0.00
Scatophagus argus	0.13	0.00	100.00	0.00
Scomberoides lysan	0.33	33.85	9.23	56.92
Scomberoides tala	0.05	44.44	0.00	55.56
Scomberomorus commerson	1.61	36.14	62.00	1.86
Secutor insidiator	0.14	48.15	7.41	44.44
Sepiella inermis	0.03	0.00	0.00	100.00
Siganus canaliculatus	0.07	78.57	0.00	21.43
Sillago sihama	0.08	0.00	0.00	100.00
Sphyraena jello	0.41	45.12	0.00	54.88
Sphyraena obtusata	0.75	0.00	0.00	100.00
Stolephorus commersonnii	1.15	68.26	10.43	21.30
Stolephorus indicus	0.09	50.00	5.56	44.44
Stolephorus waitei	0.16	66.45	3.23	30.32
Thryssa dussumieri	0.02	100.00	0.00	0.00
Thryssa malabarica	0.08	100.00	0.00	0.00
Thryssa mystax	2.35	32.10	36.99	30.91
Thryssa purava	0.06	83.33	16.67	0.00
Toad fish	0.01	100.00	0.00	0.00
Turritella acutangula	0.45	77.78	11.11	11.11
Turritella attenuata	0.47	85.11	5.32	9.57
Upeneus sulphurus	0.01	100.00	0.00	0.00
Uroteuthis (P) duvauceli	1.99	60.11	24.14	15.74
Valamugi speigleri	0.16	31.25	18.75	50.00
Valamugil cunnesius	0.57	60.53	0.00	39.47
All species	**81.17**	**48.25**	**12.01**	**39.75**

Table 13.7 Species-wise exclusion rates in JFE-SSD installed operations, during January 2007

Species	Catch encountered, kg	Exclusion rate, %
Sphyraena obtusata	0.75	100.00
Sillago sihama	0.08	100.00
Liza parsia	0.03	100.00
Sepiella inermis	0.03	100.00
Carangoides malabaricus	0.01	100.00
Pomadassys maculates	0.01	100.00
Alepes kleinii	0.36	83.33
Alepes djedaba	1.54	79.87
Megalaspis cordyla	3.51	71.94
Sardinella gibbosa	0.85	71.01
Pelates quadrilineatus	0.07	61.54
Leiognathus brevirostris	0.09	58.82
Scomberoides lysan	0.33	56.92
Scomberoides tala	0.05	55.56
Sphyraena jello	0.41	54.88
Caranx sexfasciatus	0.06	54.55
Sardinella longiceps	39.13	51.05
Valamugi speigleri	0.16	50.00
Leiognathus splendens	0.04	50.00
Cynoglossus macrostomus	0.48	47.92
Secutor insidiator	0.14	44.44
Stolephorus indicus	0.09	44.44
Johnius carouna	0.43	41.86
Otolithes ruber	0.15	41.38
Rastrelliger kanagurta	1.50	41.33
Johnius borneensis	0.26	41.18
Encrasicholina devisi	0.25	40.00
Fenneropenaeus indicus	0.03	40.00
Dussumieria acuta	1.61	39.75
Valamugil cunnesius	0.57	39.47
Nemipterus japonicus	0.22	36.36
Pellona ditchella	0.33	34.85
Kathala axillaris	0.23	33.33
Gerres limbatus	0.02	33.33
Thryssa mystax	2.35	30.91
Stolephorus waitei	0.16	30.32
Caranx ignobilis	0.16	29.03
Leiognathus equulus	0.39	28.21
Johnius dussumieri	4.15	24.10
Lagocephalus spadiceus	0.95	22.75
Encrasicholina heteroloba	0.05	22.22
Siganus canaliculatus	0.07	21.43
Stolephorus commersonnii	1.15	21.30
Portunus sanguinolentus	0.03	16.67

Gazza minuta	0.18	16.39
Uroteuthis (P) duvauceli	1.99	15.74
Oratosquilla nepa	1.66	11.45
Turritella acutangula	0.45	11.11
Turritella attenuata	0.47	9.57
Leiognathus dussumieri	0.68	8.89
Johnius amblycephalus	0.25	8.00
Parapenaeopsis stylifera	0.45	6.28
Metapenaeus monoceros	0.06	6.25
Opisthopterus tardoore	0.48	5.80
Metapenaeus dobsoni	6.27	5.03
Scomberomorus commerson	1.61	1.86
Mene maculata	1.06	0.00
Pampus argenteus	0.45	0.00
Atropus atropos	0.23	0.00
Charybdis lucifera	0.15	0.00
Lepturacanthus savala	0.14	0.00
Scatophagus argus	0.13	0.00
Babylonia spirata	0.11	0.00
Alectis ciliaris	0.10	0.00
Anadontostoma chacunda	0.08	0.00
Epinephelus diacanthus	0.08	0.00
Dolcea ovis	0.08	0.00
Thryssa malabarica	0.08	0.00
Babylonia zeylanica	0.07	0.00
Otolithes cuvieri	0.07	0.00
Thryssa purava	0.06	0.00
Charybdis feriatus	0.05	0.00
Circular javana	0.05	0.00
Dasciaena albida	0.05	0.00
Natica vitellus	0.05	0.00
Octpous spp.	0.05	0.00
Alectis indicus	0.04	0.00
Bufonaria echinata	0.04	0.00
Cynoglossus dubius	0.04	0.00
Chirocentrus dorab	0.03	0.00
Murex spp.	0.03	0.00
Charybdis natator	0.02	0.00
Holothuria spp.	0.02	0.00
Mugil cephalus	0.02	0.00
Penaeus semisulcatus	0.02	0.00
Saurida tumbil	0.02	0.00
Thryssa dussumieri	0.02	0.00
Acanthurus spp.	0.01	0.00
Ambassis ambassis	0.01	0.00
Apogon fasciatus	0.01	0.00
Arius jella	0.01	0.00
Donax scrotum	0.01	0.00
Metapenaeus affinis	0.01	0.00

Oxiurichthys paulae	0.01	0.00
Platicephalus indicus	0.01	0.00
Pterois russelli	0.01	0.00
Toad fish	0.01	0.00
Upeneus sulphurus	0.01	0.00
All species	**81.17**	**39.75**

Out of a total retained catch of 48.91 kg, about 80% was retained in the lower codend and the balance in the upper codend. Of the retained catch of non-shrimp resources (42.44 kg), about 77% was retained in the lower codend. The sorting effect was most pronounced in the shrimp species. Out of a total of 6.47 kg of retained shrimp catch, over 97% was retained in the lower codend (Table 13.8).

Among the 92 species retained, 11 species *viz*., *Alectis ciliaris*, *Atropus atropos*, *Bufonaria echinata*, *Dasciaena albida*, *Epinephelus diacanthus*, *Fenneropenaeus indicus*, *Leiognathus splendens*, *Dolcea ovis*, *Pampus argenteus*, *Saurida tumbil* and *Scatophagus argus* were retained 100% in the upper codend in terms of weight. Thirty-nine species including *Acanthurus* spp., *Alectis indicus*, *Alepes kleinii*, *Ambassis ambassis*, *Apogon fasciatus*, *Arius jella*, *Babylonia spirata*, *Caranx sexfasciatus*, *Charybdis feriatus*, *Charybdis natator*, *Chirocentrus dorab*, *Circular javana*, *Cynoglossus dubius*, *Donax scrotum*, *Gerres limbatus*, *Holothuria* spp., *Johnius amblycephalus*, *Johnius dussumieri*, *Leiognathus brevirostris*, *Metapenaeus affinis*, *Mugil cephalus*, *Murex* spp., *Natica vitellus*, *Octpous* spp., *Oxiurichthys paulae*, *Parapenaeopsis stylifera*, *Pelates quadrilineatus*, *Penaeus semisulcatus*, *Platicephalus indicus*, *Pterois russelli*, *Sardinella gibbosa*, *Scomberoides tala*, *Siganus canaliculatus*, *Sphyraena jello*, *Thryssa dussumieri*, *Thryssa malabarica*, Toad fish, *Upeneus sulphurus* and *Valamugil cunnesius* was 100% retained in the lower codend, in terms of weight.

Species such as *Leiognathus dussumieri*, *Mene maculata*, *Rastrelliger kanagurta*, *Leiognathus equulus*, *Nemipterus japonicus*, *Scomberomorus commerson*, *Anadontostoma chacunda*, *Portunus sanguinolentus*, *Johnius borneensis* and *Thryssa mystax* were retained in the upper codend at levels exceeding 50% in terms of weight. Thirty-two species *viz*., *Babylonia zeylanica*, *Otolithes ruber*, *Caranx ignobilis*, *Megalaspis cordyla*, *Opisthopterus tardoore*, *Valamugil speigleri*, *Lepturacanthus savala*, *Charybdis lucifera*, *Uroteuthis (P) duvauceli*, *Encrasicholina heteroloba*, *Dussumieria acuta*, *Otolithes cuvieri*, *Scomberoides lysan*, *Thryssa purava*, *Secutor insidiator*, *Stolephorus commersonnii*, *Gazza minuta*, *Turritella acutangula*, *Encrasicholina devisi*, *Stolephorus indicus*, *Lagocephalus spadiceus*, *Sardinella longiceps*, *Metapenaeus monoceros*, *Pellona ditchella*, *Kathala axillaris*, *Johnius carouna*. *Turritella attenuata*, *Oratosquilla nepa*, *Alepes djedaba*, *Stolephorus waitei*, *Metapenaeus dobsoni* and *Cynoglossus macrostomus* showed preference to lower codend with retention levels exceeding 50% (Table 13.9).

Table 13.8 *In-situ* sorting effect due to installation of JFE-SSD, during January 2007

Species groups	Retained catch, kg	Lower codend, % of retained catch	Upper codend, % of retained catch
All species	48.91	80.07	19.93
Shrimp species	6.47	97.36	2.64
Non-shrimp species	42.44	77.43	22.57

Table 13.9 Sorting effect and exclusion behaviour of trawl caught species in JFE-SSD installed operations, during January 2007

Species	Retained catch, kg	Lower codend, % of retained catch	Upper codend, % of retained catch
Acanthurus spp	0.01	100.00	0.00
Alectis indicus	0.04	100.00	0.00
Alepes kleinii	0.06	100.00	0.00
Ambassis ambassis	0.01	100.00	0.00
Apogon fasciatus	0.01	100.00	0.00
Arius jella	0.01	100.00	0.00
Babylonia spirata	0.11	100.00	0.00
Caranx sexfasciatus	0.03	100.00	0.00
Charybdis feriatus	0.05	100.00	0.00
Charybdis natator	0.02	100.00	0.00
Chirocentrus dorab	0.03	100.00	0.00
Circular javana	0.05	100.00	0.00
Cynoglossus dubius	0.04	100.00	0.00
Donax scrotum	0.01	100.00	0.00
Gerres limbatus	0.01	100.00	0.00
Holothuria spp.	0.02	100.00	0.00
Johnius amblycephalus	0.23	100.00	0.00
Johnius dussumieri	3.15	100.00	0.00
Leiognathus brevirostris	0.04	100.00	0.00
Metapenaeus affinis	0.01	100.00	0.00
Mugil cephalus	0.02	100.00	0.00
Murex spp.	0.03	100.00	0.00
Natica vitellus	0.05	100.00	0.00

Octpous spp.	0.05	100.00	0.00
Oxiurichthys paulae	0.01	100.00	0.00
Parapenaeopsis stylifera	0.42	100.00	0.00
Pelates quadrilineatus	0.03	100.00	0.00
Penaeus semisulcatus	0.02	100.00	0.00
Platicephalus indicus	0.01	100.00	0.00
Pterois russelli	0.01	100.00	0.00
Sardinella gibbosa	0.25	100.00	0.00
Scomberoides tala	0.02	100.00	0.00
Siganus canaliculatus	0.06	100.00	0.00
Sphyraena jello	0.19	100.00	0.00
Thryssa dussumieri	0.02	100.00	0.00
Thryssa malabarica	0.08	100.00	0.00
Toad fish	0.01	100.00	0.00
Upeneus sulphurus	0.01	100.00	0.00
Valamugil cunnesius	0.35	100.00	0.00
Cynoglossus macrostomus	0.25	98.00	2.00
Metapenaeus dobsoni	5.95	97.48	2.52
Stolephorus waitei	0.11	95.37	4.63
Alepes djedaba	0.31	95.16	4.84
Oratosquilla nepa	1.47	94.56	5.44
Turritella attenuata	0.43	94.12	5.88
Johnius carouna	0.25	94.00	6.00
Kathala axillaris	0.15	93.33	6.67
Pellona ditchella	0.22	93.02	6.98
Metapenaeus monoceros	0.06	91.67	8.33
Sardinella longiceps	19.15	91.38	8.62
Lagocephalus spadiceus	0.73	90.41	9.59
Encrasicholina devisi	0.15	90.00	10.00
Stolephorus indicus	0.05	90.00	10.00
Turritella acutangula	0.40	87.50	12.50
Gazza minuta	0.15	86.93	13.07
Stolephorus commersonnii	0.91	86.74	13.26
Secutor insidiator	0.08	86.67	13.33
Thryssa purava	0.06	83.33	16.67
Scomberoides lysan	0.14	78.57	21.43
Otolithes cuvieri	0.07	76.92	23.08
Dussumieria acuta	0.97	75.26	24.74
Encrasicholina heteroloba	0.04	71.43	28.57
Uroteuthis (P) duvauceli	1.68	71.34	28.66
Charybdis lucifera	0.15	65.52	34.48
Lepturacanthus savala	0.14	62.96	37.04

Valamugi speigleri	0.08	62.50	37.50
Opisthopterus tardoore	0.46	60.44	39.56
Megalaspis cordyla	0.99	60.41	39.59
Caranx ignobilis	0.11	54.55	45.45
Otolithes ruber	0.09	52.94	47.06
Babylonia zeylanica	0.07	50.00	50.00
Thryssa mystax	1.63	46.46	53.54
Johnius borneensis	0.15	43.33	56.67
Anadontostoma chacunda	0.08	40.00	60.00
Portunus sanguinolentus	0.03	40.00	60.00
Scomberomorus commerson	1.58	36.83	63.17
Nemipterus japonicus	0.14	28.57	71.43
Leiognathus equulus	0.28	26.79	73.21
Rastrelliger kanagurta	0.88	11.36	88.64
Mene maculata	1.06	7.11	92.89
Leiognathus dussumieri	0.62	2.44	97.56
Alectis ciliaris	0.10	0.00	100.00
Atropus atropos	0.23	0.00	100.00
Bufonaria echinata	0.04	0.00	100.00
Dasciaena albida	0.05	0.00	100.00
Epinephelus diacanthus	0.08	0.00	100.00
Fenneropenaeus indicus	0.02	0.00	100.00
Leiognathus splendens	0.02	0.00	100.00
Dolcea ovis	0.08	0.00	100.00
Pampus argenteus	0.45	0.00	100.00
Saurida tumbil	0.02	0.00	100.00
Scatophagus argus	0.13	0.00	100.00

Clogging of the grid spacing due to plastic refuse or decaying vegetation when they are prevalent in the fishing grounds has been observed to influence the efficiency of sorting and target catch retention, as they tend to block the grid bar interspaces.

13.4 Conclusions

Results of the investigations indicate JFE-SSD has excellent juvenile bycatch reduction and pre-sorting capabilities. The JFE-SSD has the following advantages:

- Conventional codend in a shrimp trawl could be easily replaced by JFE-SSD without any alteration in the net design.

- The device reduces the bycatch of juveniles of finfishes, shrimps, crabs and cephalopods, and small sized fishes of low commercial value, contributing to sustainability of the resources and protection of biodiveristy.
- The fishermen are able to retain large fishes of higher market value, which will enhance the overall revenue realized from trawling operations.
- Quality of the shrimps would be better due to the prevention of physical pressure caused by accumulation of larger fishes, which takes place in conventional codends. This would increase the unit price realized for the shrimp catch.
- The *in situ* sorting effect and separation of shrimps from finfishes and cephalopods help to reduce the sorting time and increase useful fishing time of the trawler fishermen and thus enhance the profitability of fishing operations.
- Increase in towing time can be expected due to slow filling of the codend as a result of reduction of non target fishes and juveniles.
- Fuel saving can be expected due to drag reduction caused by the escapement of non-target species.
- Training requirements by fishers for fabrication, installation and operation of JFE-SSD is minimal.
- By adopting the JFE-SSD, trawler fishermen would be less prone to criticism from conservation groups and environmentalists.

The design concept of JFE-SSD proposed by the project team has won the coveted International Smart Gear Award-2005, in the category 'Other Non-target Species (Including fish)' (please see Annexure 2). World Wildlife Fund (WWF) instituted the International Smart Gear Competition in May 2004, to bring together partners representing fisheries, policy, and science to find solutions for the problem of accidental catch of non-target species and reverse the decline of vulnerable species accidentally caught in nets and other fishing gear.

14.0 Bycatch Characterization of Shrimp Trawl Landings

14.1 Introduction

Bycatch taken by the shrimp fishery is an important issue in the management of fisheries resources given the perceived high mortality of the different fish stocks other than shrimp. In tropical countries like India bycatch issue is more complex due to the multi-species, multi-gear and free and open access nature of the fisheries. The changing perspective of bycatch itself offers the greatest challenge, as yesterday's bycatch becomes today's target catch (Boyce, 1996). Quantum of bycatch landed or discarded may depend on factors affecting selectivity of trawl (such as codend mesh size, mesh sizes of the wings and belly, vertical opening of the trawl mouth, ground rope rigging and bottom contact, overall length of the trawl, otter boards and bridle arrangements, speed and duration of tow), trip duration (single-day or multi-day fishing), storage and preservation facilities available onboard, variation in seasonal abundance of bycatch species and juveniles and variations in export and domestic market demands for target and bycatch species.

Studies on trawl bycatch has been attempted by several authors in India (Gordon,1991; Sujatha, 1995; Pravin and Manoharadoss, 1996; Sujatha, 1996; Pillai, 1998; Rao,1998; Kurup et al., 2003; Dixitulu, 2004; Jagadis et al., 2004; Kurup et al., 2004; Sujatha, 2005; Zacharia et al., 2006). In Kerala state (India), quantity of discards was estimated at 262000 t during 2000-2001 and 225000 t during 2001-2002 (Kurup et al., 2003; 2004). The diversity of species found in tropical waters is the main cause of the higher magnitude of discards found there and in tropical regions the trawl nets used to catch over 400 species in their nets. With the decline of the shrimp catch the bycatch began to contribute significantly to the overall income of the shrimp trawlers. Along the west-coast of India, especially in Gujarat, most of the bycatch is landed and utilized for fish-meal and manure production. It is significant to note that among the bycatch about 40 % consisted of juveniles and those in the early stages of development which are invariably discarded leading to the depletion of the resources (Pillai, 1998). In this study, an investigation on the bycatch issues and concerns in trawl fishing, off Cochin coast is attempted.

14.2 Materials and Methods

Bycatch samples were collected from the traditional trawling areas in coastal waters off Cochin at a depth ranging between 9 and 32 m, using shrimp trawls (Fig. 3.3 and 3.4) operated from the research vessels of

Central Institute of Fisheries Technology, during the period from April 2004 to December 2006. The duration of trawling varied from 0.75 to 2.0 h. The catch was identified up to species level using Fischer & Bianchi (1984), online databases such as www.fishbase.org, www.cephbase.org, and www.indian-ocean.org and other relevant taxonomic reference sources. Weight and numbers of each species were recorded and in the case of large catch volumes, sub-samples were used for analysis.

14.3 Results and Discussion

Bycatch was generated at levels exceeding 15 $kg.h^{-1}$ during the months of March and August-September, 5-15 $kg.h^{-1}$ during January-February, April, July and December and at levels <5 $kg.h^{-1}$ during the months of May-June (Fig. 14.1). Organisms other than fish dominated in the bycatch during the months of May, August and September, while fishes dominated (>50%) during other months (Fig. 14.1). On an average, shrimps formed 7.27% and bycatch 92.73% of the shrimp trawl landings, during the period of observations. Monthly mean trawl bycatch varied from a minimum of 39.85% in the month of May to a maximum of 99.98% in the month of July (Fig. 14.2).

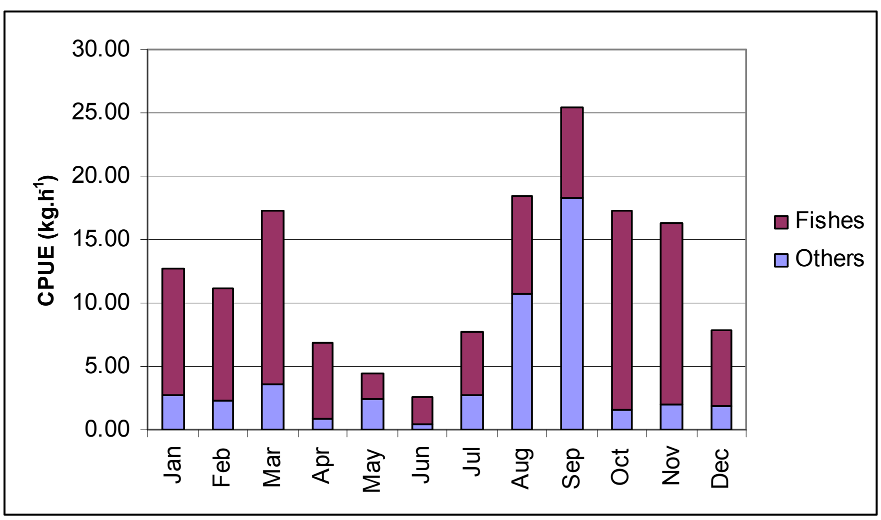


Fig. 14.1 Month-wise variations in shrimp trawl bycatch, off Cochin

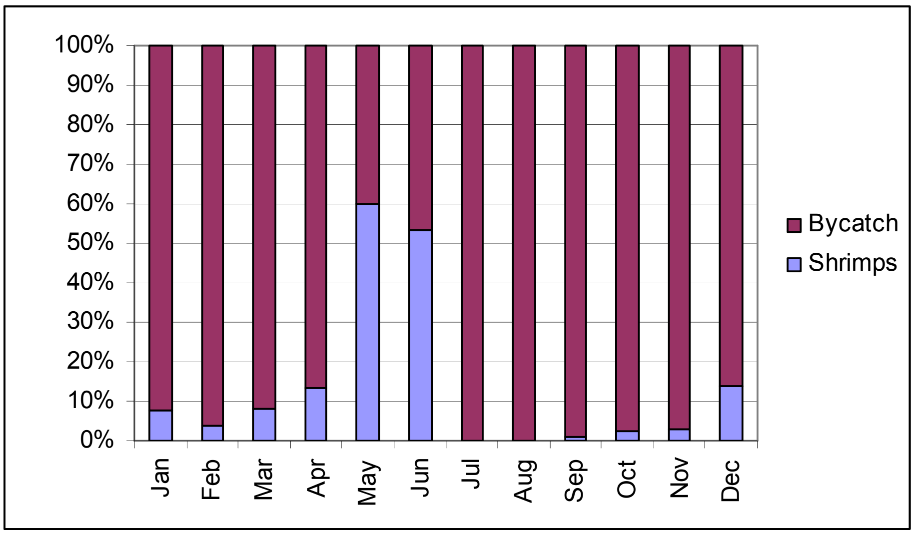


Fig. 14.2 Month-wise variations in shrimp-bycatch proportions in shrimp trawl catches, off Cochin

Shrimps of marketable size accounted for a small percentage of the total trawl landings. The rest of the catch consisted of bycatch consisting of a variety of fishes, cnidarians, molluscs, crustaceans and echinoderms which fetch relatively low value.

During this study on trawl bycatch components off Cochin, 281 marine species were encountered in the trawl catch (Table 14.1). The catch included 191 species of fishes, 11 species of shrimps, 3 species of lobsters, 13 species of crabs, 11 species of cephalopods, 44 species of molluscan shells, 2 species of echinoderms, 2 species jelly fishes, 2 species stomatopod and one species each sea snake and sea turtle. 191 species of fishes belonged to 12 orders and 59 families and 109 genera. 11 shrimp species belonging to 4 families and 13 crab species belonging to 4 families have been identified. 11 cephalopod species belonged to 3 orders and 3 families. Molluscan species belonged to 22 families and jelly fishes belonged to 2 families.

Fig. 14.3 Views of unsorted catch of shrimp trawls

Fig. 14.4 Views of sorted shrimp catch

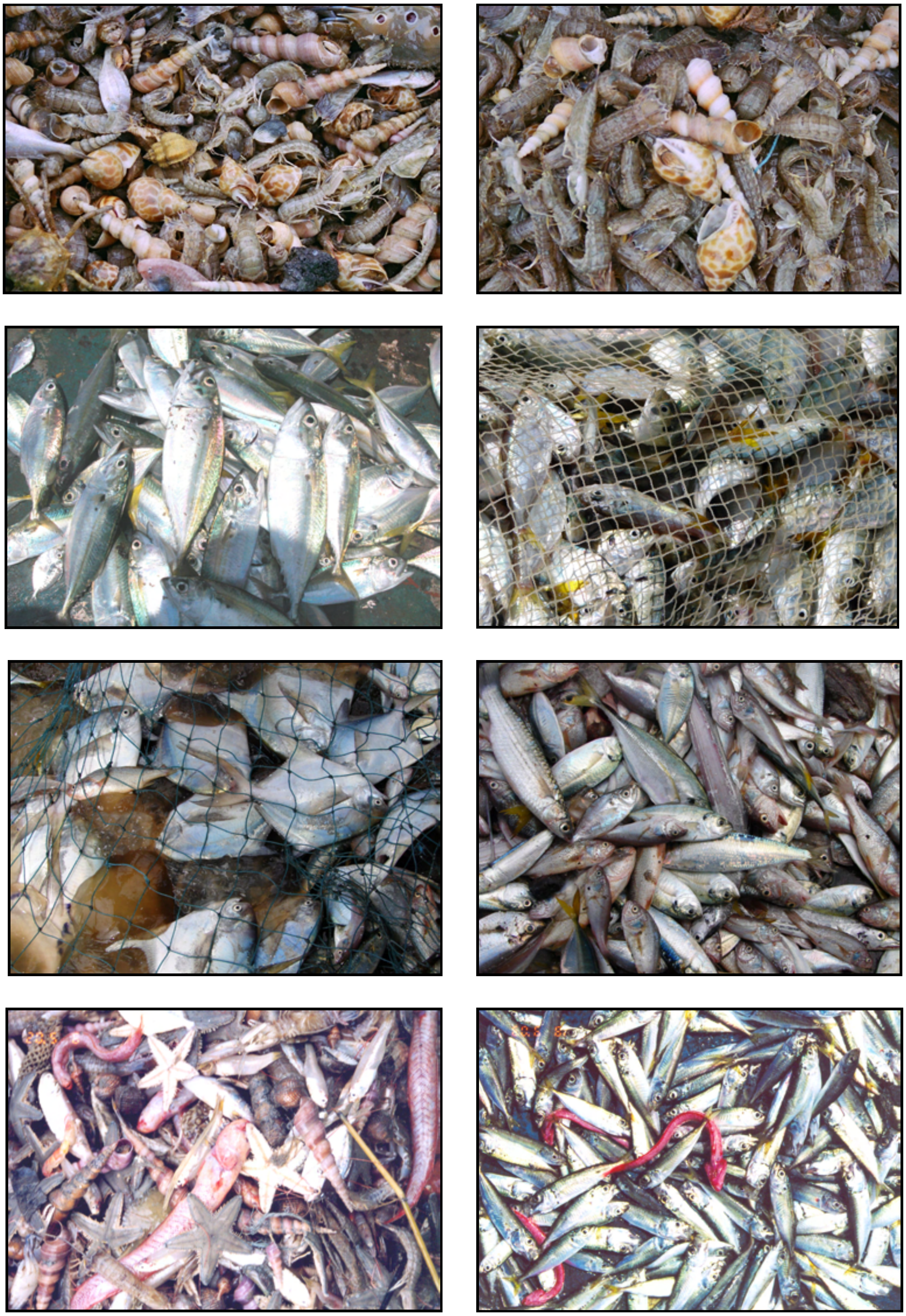


Fig. 14.5a Views of bycatch of shrimp trawls

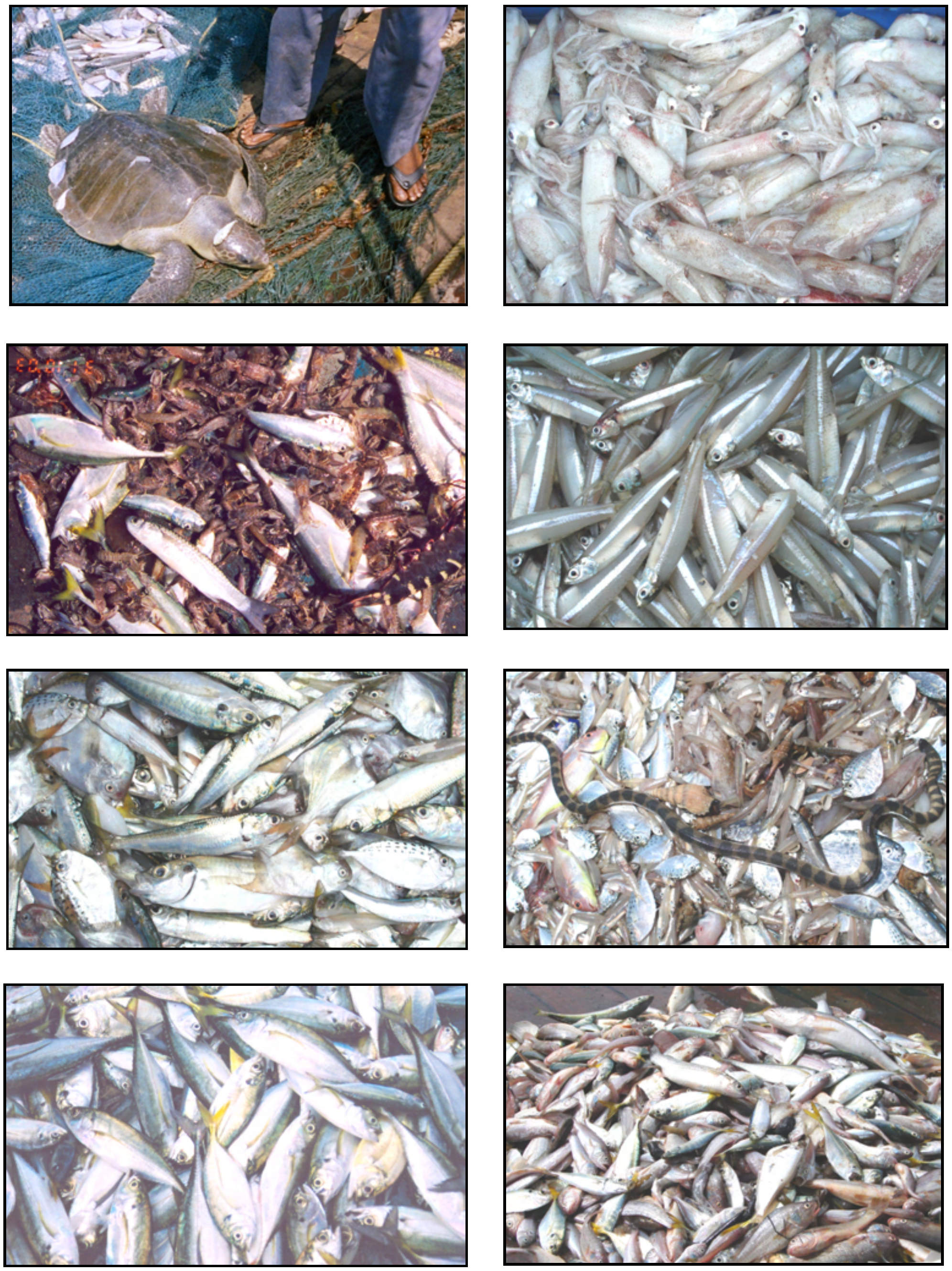


Fig. 14.6b Views of bycatch of shrimp trawls

Fig. 14.7 Views of bycatch of juveniles

Table. 14.1 List of species occurring in trawl bycatch off Cochin

FINFISHES

Order : **RAJIFORMES**

Family : **Dasyatidae**

1. *Dasyatis kuhlii* (Muller & Henle, 1841)
2. *Himantura bleekeri* (Blyth, 1860)
3. *Himantura uarnak* (Forsskal, 1775)
4. *Himantura gerrardi* (Gray, 1851)

Family : **Myliobatidae**

5. *Aetobatus narinari* (Euphrasen, 1790)

Order : **CARCHARHINIFORMES**

Family : **Carcharhinidae**

6. *Rhizoprionodon acutus* (Ruppell, 1837)
7. *Scoliodon laticaudus* (Muller & Henle, 1838)

Family : **Sphyrnidae**

8. *Eusphyra blochii* (Cuvier, 1816)
9. *Sphyrna zygaena* (Linnaeus, 1758)

Order : **ANGUILLIFORMES**

Family : **Congridae**

10. *Uroconger lepturus* (Richardson, 1845)

Family : **Ophichthidae**

11. *Pisodonophis cancrivorus* (Richardson, 1848)
12. *Leiuranus semicinctus* (Lay & Bennett, 1839)
13. *Lamnostoma orientalis* (Mc Clelland, 1844)

Family : **Muraenesocidae**

14. *Congresox talabonoides* (Bleeker, 1853)

Order : **CLUPEIFORMES**

Family : **Chirocentridae**

15. *Chirocentrus dorab* (Forsskal, 1775)
16. *Chirocentrus nudus* (Swainson, 1839)

Family : **Clupeidae**

17. *Anodontostoma chacunda* (Hamilton, 1822)
18. *Dussumieria acuta* (Valenciennes, 1847)
19. *Escualosa thoracata* (Valenciennes, 1847)
20. *Opisthopterus tardoore* (Cuvier, 1829)
21. *Sardinella albella* (Valenciennes, 1847)

22. *Sardinella fimbriata* (Valenciennes, 1847)
23. *Sardinella gibbosa* (Bleeker, 1849)
24. *Sardinella longiceps* (Valenciennes, 1847)

Family : **Pristigasteridae**

25. *Ilisha elongate* (Anonymous [Bennett], 1830)
26. *Ilisha filigera* (Valenciennes, 1847)
27. *Pellona ditchella* (Valenciennes, 1847)

Family : **Engraulidae**

28. *Encrasicholina devisi* (Whitley, 1940)
29. *Encrasicholina heteroloba* (Ruppell, 1837)
30. *Encrasicholina punctifer* (Fowler, 1938)
31. *Stolephorus commersonnii* (Lacepede, 1803)
32. *Stolephorus indicus* (Van Hasselt, 1823)
33. *Stolephorus insularis* (Hardenberg, 1933)
34. *Stolephorus waitei* (Jordan & Seale, 1926)
35. *Thryssa dussumieri* (Valenciennes, 1848)
36. *Thryssa kammalensis* (Bleeker, 1849)
37. *Thryssa malabarica* (Bloch, 1795)
38. *Thryssa mystax* (Bloch & Schneider, 1801)
39. *Thryssa purava* (Hamilton, 1822)
40. *Thryssa setirostris* (Broussonet, 1782)

Order : **SILURIFORMES**

Family : **Ariidae**

41. *Arius arius* (Hamilton, 1822)
42. *Arius jella* (Day, 1877)
43. *Arius sona* (Hamilton, 1822)
44. *Arius maculatus* (Thunberg, 1792)
45. *Arius caelatus* (Valenciennes, 1840)
46. *Arius thalasinus* (Ruppell, 1837)

Family : **Plotosidae**

47. *Plotosus lineatus* (Thunberg, 1787)

Family : **Synodontidae**

48. *Saurida undosquamis* (Richardson, 1848)
49. *Saurida tumbil* (Bloch, 1795)

Order : **SYNGNATHIFORMES**

Family : **Fistularidae**

50. *Fistularia petimba* (Lacepede, 1803)

Order **SCORPAENIFORMES**

Family : **Scorpaenidae**

51. *Pterois volitans* (Linnaeus, 1758)
52. *Pterois russelii* (Bennett, 1831)

Family : **Platycephalidae**

53. Platycephalus indicus (Linnaeus, 1978)
54. *Grammoplites scaber* (Linnaeus, 1758)
55. *Thysanophrys celebica* (Bleeker, 1854)
56. *Cociella crocodila* (Tilesius, 1812)

Family : **Dactylopteridae**

57. Dactyloptena macracantha (Bleeker, 1854)

Family : **Synanceiidae**

58. *Minous monodactylus* (Bloch & Schneider, 1801)
59. *Minous dempsterae* (Eschmeyer, Hallacher & Rama-Rao, 1979)
60. *Synanceia horrida* (Linnaeus, 1766)
61. *Leptosynanceia asteroblepa* (Richardson, 1844)

Order : **BERYCIFORMES**

Family : **Holocentridae**

62. *Myripristis adusta* (Bleeker, 1853)

Order : **PERCIFORMES**

Family : **Teraponidae**

63. *Terapon jarbua* (Forsskal, 1775)
64. *Terapon theraps* (Cuvier, 1829)
65. *Terapon puta* (Cuvier, 1829)
66. *Pelates quadrilineatus* (Bloch, 1790)

Family : **Serranidae**

67. *Epinephelus latifasciatus* (Temminck & Schlegel, 1842)
68. *Epinephelus diacanthus* (Valenciennes, 1828)
69. *Epinephelus merra* (Bloch, 1793)
70. *Epinephelus tauvina* (Forsskal, 1775)
71. *Epinephelus areolatus* (Forsskal, 1775)
72. *Epinephelus chlorostigma* (Valenciennes, 1828)

Family : **Priacanthidae**

73. *Priacanthus hamrur* (Forsskal, 1775)

Family : **Apogonidae**

74. *Apogon aureus* (Lacepede, 1802)
75. *Apogon fasciatus* (White, 1790)

Family : **Pomacentridae**

76. *Neopomacentrus sindensis* (Day, 1873)

Family : **Haemulidae**

77. *Pomadasys maculatum* (Bloch, 1793)

Family : **Lutjanidae**

78. *Lutjanus malabaricus* (Bloch & Schneider, 1801)
79. *Pinjalo pinjalo* (Bleeker, 1850)
80. *Lutjanus argentimaculatus* (Forsskal ,1975)
81. *Lutjanus lutjanus* (Bloch ,1790)

Family : **Lethrinidae**

82. *Lethrinus nebulosus* (Forsskal, 1775)
83. *Lethrinus ornatus* (Valenciennes, 1830)
84. *Lethrinus miniatus* (Bloch & Schneider, 1801)

Family : **Nemipteridae**

85. *Nemipterus japonicus* (Bloch, 1791)
86. *Nemipterus mesoprion* (Bleeker, 1853)

Family : **Gerreidae**

87. *Gerres oyena* (Forsskal, 1775)
88. *Gerres filamentosus* (Cuvier, 1829)
89. *Gerres erythrourus* (Bloch, 1791)
90. *Gerres limbatus* (Cuvier, 1830)

Family : **Mullidae**

91. *Upeneus sulphureus* (Cuvier, 1829)
92. *Upeneus vittatus* (Forsskal, 1775)
93. *Upeneus tragula* (Richardson, 1846)

Family : **Sillaginidae**

94. *Sillago sihama* (Forsskal, 1775)

Family : **Lactariidae**

95. *Lactarius lactarius* (Bloch & Schneider, 1801)

Family : **Sciaenidae**

96. *Johnius amblycephalus* (Bleeker, 1855)
97. *Johnius borneensis* (Bleeker, 1851)
98. *Johnius carouna* (Cuvier, 1830)
99. *Johnius carutta* (Bloch, 1793)
100. *Johnius dussumieri* (Cuvier, 1830)
101. *Kathala axillaris* (Cuvier, 1830)
102. *Nibea maculata* (Bloch & Schneider, 1801)
103. *Otolithes cuvieri* (Trewavas, 1974)

104. *Otolithes ruber* (Bloch & Schneider, 1801)
105. Otolithoides biauritus (Cantor, 1849)
106. *Protonibea diacanthus* (Lacepede, 1802)
107. *Daysciaena albida* (Cuvier, 1830)

Family : **Leiognathidae**

108. *Gazza minuta* (Bloch, 1795)
109. *Leiognathus bindus* (Valenciennes, 1835)
110. *Leiognathus brevirostris* (Valenciennes, 1835)
111. *Leiognathus daura* (Cuvier, 1829)
112. *Leiognathus dussumieri* (Valenciennes, 1835)
113. *Leiognathus elongatus* (Gunther, 1874)
114. *Leiognathus equlus* (Forsskal, 1775)
115. *Leiognathus splendens* (Cuvier, 1829)
116. *Secutor insidiator* (Bloch, 1787)
117. *Secutor ruconius* (Hamilton, 1822)

Family : **Carangidae**

118. *Alectis ciliaris* (Bloch, 1787)
119. *Alectis indicus* (Ruppell, 1830)
120. *Alepes djedaba* (Forsskal, 1775)
121. *Alepes kleinii* (Bloch, 1793)
122. *Atropus atropus* (Bloch & Schneider, 1801)
123. *Atule mate* (Cuvier, 1833)
124. *Carangoides armatus* (Ruppell, 1830)
125. *Carangoides malabaricus* (Bloch & Schneider, 1801)
126. *Carangoides oblongus* (Cuvier, 1833)
127. *Carangoides praeustus* (Anonymous [Bennett], 1830)
128. *Caranx ignobilis* (Forsskal, 1775)
129. *Caranx sexfasciatus* (Quoy & Gaimard, 1825)
130. *Decapterus russelli* (Ruppell, 1830)
131. *Gnathanodon speciosus* (Forsskal, 1775)
132. *Megalaspis cordyla* (Linnaeus, 1758)
133. *Parastromateus niger* (Bloch, 1795)
134. *Scomberoides lysan* (Forsskal, 1775)
135. *Scomberoides tala* (Cuvier, 1832)
136. *Scomberoides tol* (Cuvier, 1832)
137. *Selar crumenophthalmus* (Bloch, 1793)
138. *Trachinotus blochii* (Lacepede, 1801)
139. *Uraspis uraspis* (Gunther, 1860)

Family : **Polynemidae**

140. *Leptomelanosoma indicum* (Shaw, 1804)

141. *Eleutheronema tetradactylum* (Shaw, 1804)
142. *Filimanus heptadactyla* (Cuvier, 1829)
143. *Filimanus similis* (Feltes, 1991)

Family : **Sphyraenidae**

144. *Sphyraena forsteri* (Cuvier, 1829)
145. *Sphyraena jella* (Cuvier, 1829)
146. *Sphyraena obtusata* (Cuvier, 1829)
147. *Sphyraena barracuda* (Walbaum, 1792)

Family : **Gobiidae**

148. *Oxyurichthys paulae* (Pezold, 1998)
149. *Trypauchen vagina* (Bloch & Schneider, 1801)

Family : **Trichiuridae**

150. *Trichiurus lepturus* (Linnaeus, 1758)
151. *Lepturacanthus savala* (Cuvier, 1829)

Family : **Stromateidae**

152. *Pampus argenteus* (Euphrasen, 1788)
153. *Pamus chinensis* (Euphrasen, 1788)

Family : **Ambassidae**

154. *Ambassis ambassis* (Lacepede, 1802)
155. *Ambassis gymnocephalus* (Bloch, 1790)
156. *Ambassis commersonnii* (Cuvier, 1828)

Family : **Mugilidae**

157. *Mugil cephalus* (Linnaeus, 1758)
158. *Liza subviridis* (Valenciennes, 1835)
159. *Liza parsia* (Hamilton, 1822)
160. *Liza tade* (Forsskal, 1775)
161. *Valamugil speigleri* (Bleeker, 1858-59)
162. *Valamugil cunnesius* (Valenciennes, 1836)
163. *Chelon microlepis* (Smith, 1846)

Family : **Menidae**

164. *Mene maculata* (Bloch & Schneider, 1801)

Family : **Scatophagidae**

165. *Sactophagus argus* (Linnaeus, 1766)

Family : **Scombridae**

166. *Rastrelliger kanagurta* (Cuvier, 1816)
167. *Scomberomorus commerson* (Lacepede, 1800)
168. *Scomberomorus lineolatus* (Cuvier, 1829)
169. *Scomberomorus guttatus* (Bloch & Schneider, 1801)

Family : **Siganidae**

170. *Siganus canaliculatus* (Richardson, 1845)
171. *Siganus javus* (Linnaeus, 1766)

Family : **Acanthuridae**

172. *Acanthurus mata* (Cuvier, 1829)

Family : **Uranoscopidae**

173. *Uranoscopus marmoratus* (Cuvier, 1829)

Family : **Drepaneidae**

174. *Drepane punctata* (Linnaeus, 1758)

Family : **Pempheridae**

175. *Pempheris mangula* (Cuvier, 1829)
176. *Pempheris oualensis* (Cuvier, 1831)

Order : **BELONIFORMES**

Family : **Hemirhamphidae**

177. *Rhynchorhamphus georgii* (Valenciennes, 1847)

Order : **PLEURONECTIFORMES**

Family : **Samaridae**

178. *Samaris cristatus* (Gray, 1931)

Family : **Cynoglossidae**

179. *Cynoglossus arel* (Schneider, 1801)
180. *Cynoglossus bilineatus* (Lacepede, 1802)
181. *Cynoglossus macrostornus* (Norman, 1928)
182. *Cynoglossus dubius* (Day, 1873)

Family : **Soleidae**

183. *Zebrias quagga* (Kaup, 1858)

Family : **Paralichthyidae**

184. *Pseudorhombus arsius* (Hamilton, 1822)

Order : **TETRAODONTIFORMES**

Family : **Triacanthidae**

185. *Triacanthus biaculeatus* (Bloch, 1786)
186. *Triacanthus nieuhofii* (Bleeker, 1852)
187. *Pseudotriacanthus strigilifer* (Cantor, 1849)

Family : **Diodontidae**

188. *Cyclichthys orbicularis* (Boch, 1785)

Family : **Tetraodontidae**

189. *Lagocephalus spadiceus* (Richardson, 1845)
190. *Lagocephalus inermis* (Temminck & Schlegel, 1850)
191. *Chelonodon patoca* (Hamilton, 1822)

SHRIMPS

Order**: DECAPODA**

Family : **Penaeidae**

192. *Penaeus (penaeus) monodon* (Fabricius, 1798)
193. *Penaeus (penaeus) semisulcatus* (De Hann, 1844)
194. *Penaeus (Fenneropenaeus) indicus* (H Milne Edwards, 1837))
195. *Metapenaeus dobsoni* (Miers, 1878)
196. *Metapenaeus monoceros* (Fabricius, 1798)
197. *Metapenaeus affinis* (H Milne Edwards, 1837)
198. *Parapenaeopsis stylifera* (H Milne Edwards, 1837)
199. *Trachypenaeus curvirostris* (Stimpson, 1860)

Family : **Hippolytidae**

200. *Exhippolysmata ensirostris* (Kemp, 1914)

Family : **Sergestidae**

201. *Acetes indicus* (H Milne Edwards, 1830)

Family : **Alphidae**

202. *Alpheus malabaricus* (Fabricius, 1798)

LOBSTERS

Family : **Palinuridae**

203. *Palinurus homarus* (Linnaeus, 1758)
204. *Palinurus ornatus* (Fabricius)

Family : **Scyllaridae**

205. *Thenus orientalis* (Lund, 1793)

CRABS

Order **: DECAPODA**

Family **: Lucosidae**

206. *Philyra scabriuscula* (Fabricius, 1798)

Family **: Portunidae**

207. *Scylla serrata* (Forskal, 1775)
208. *Portunus sanguinolentus* (Herbst, 1783)
209. *Portunus pelagicus* (Linnaeus, 1766)
210. *Charybdis feriatus* (Linnaeus, 1758)
211. *Charybdis lucifeara* (Fabricius, 1798)
212. *Charybdis natator* (Herbst, 1789)
213. *Callapha lophos* (Herbst, 1782)
214. *Podophthalmus vigil* (Fabricius, 1798)

Family **: Calappidae**

215. *Matuta lunaris* (Fabricius, 1798)
216. *Matuta planipes* (Forskal, 1775)

Family **: Majidae**

217. *Dolcea ovis* (Herbst)
218. *Doclea gracilipes* (Stimpson)

CEPHALOPODS

Order **: SEPIIDA**

Family **: Sepiidae**

219. *Sepia pharonis* (Ehrenberg, 1831)
220. *Sepiella inermis* (Van Hasselt, 1835)
221. *Sepia aculeata* (Orbigny, 1848)

Order : **TEUTHIDA**

Family : **Loliginidae**

222. *Uroteuthis (Photololigo) duvauceli* (Orbigny, 1835)
223. *Doryteuthis singalensis* (Ortmann, 1891)

Order : **OCTOPODA**

Family : **Octopodidae**

224. *Cistopus indicus* (Orbigny, 1848)
225. *Octpous dollfusi* (Robinson, 1928)
226. *Octopus membranaceous* (Quoy & Gaimard, 1832)
227. *Octopus globosus* (Appelof, 1886)
228. *Octopus vulgaris* (Lamark, 1798)
229. *Octopus aegina* (Gray, 1849)

STOMATOPODS

230. *Oratosquilla nepa* (Muller, 1994)
231. *Squilla* sp.

SHELLS

Family : **Arcidae**

232. *Barbatia (Merocibota) bistrigata* (Dunker, 1866)
233. *Anadara granosa* (Linnaeus, 1758)
234. *Anadara rhombea* (Born, 1780)
235. *Scapharca* (Anadara) inaequivalvis (Bruguire, 1789)
236. *Trisodus tortuosa* (Linnaeus)

Family : **Babyloniidae**

237. *Babylonia spirata* (Linnaeus, 1758)
238. *Babylonia zeylanica* (Bruguire, 1789)

Family : **Bursidae**

239. *Bufonaria echinata* (Link, 1807)

Family : **Buccinidae**

240. *Cantharus spiratus* (Gray)

Family : **Turridae**

241. *Lophitoma indica* (Roding, 1798)
242. *Surcula amicta* (Smith)
243. *Surcula javana* (Linnaeus)

Family : **Veneridae**

244. *Marcia opima* (Gmelin, 1791)
245. *Meretrix casta* (Chemnitz)
246. *Meretrix meretrix* (Linnaeus, 1758)
247. *Paphia malabarica* (Chemnitz)
248. *Paphia textile* (Gmelin, 1798)
249. *Dosinia cretacea* (Reeve, 1851)
250. *Sonnata scripta* (Linnaeus, 1758)

Family : **Donacidae**

251. *Donax scrotum* (Linnaeus)

Family : **Ficidae**

252. *Ficus ficucs* (Linnaeus, 1758)
253. *Ficus gracilis* (Sowerby, G. B. I, 1825)

Family : **Harpidae**

254. *Harpa conoidalis* (Lamarck, 1843)

Family : **Muricidae**

255. *Murex carbonnieri* (Jousseaume, 1881)
256. *Murex virgineus* (Roding)

Family : **Fasciolariidae**

257. *Fusinus nicobaricus*

Family : **Naticidae**

258. *Natica lineata* (Roding, 1798)
259. *Natica vitellus* (Linnaeus, 1758)
260. *Natica didyma* (Roding, 1798)

Family : **Cassidae**

261. *Phalium canaliculatum* (Bruguire, 1792)
262. *Phalium bisulcatum* (Schubert & Wagner)

Family : **Pholadidae**

263. *Pholas orientalis* (Gmelin)

Family : **Cardiidae**

264. *Cardium flavum* (Linne)

Family : **Muricidae**

265. *Rapana rapiformis* (Born, 1778)
266. *Rapana bulbosa* (Born, 1778)

Family : **Strombidae**	
267.	*Tibia curta* (Sowerby)
268.	*Strombus plicatus sibbaldi* (Sowerby)
Family : **Tonnidae**	
269.	*Tona dolium* (Linnaeus, 1758)
Family : **Turritellidae**	
270.	*Turitella acutangula* (Linnaeus)
271.	*Turritella attenuata* (Reeve, 1849)
Family : **Volemidae**	
272.	*Hemifusus cochlidium* (Linnaeus)
273.	*Hemifusus pulgilinus* (Born)
Family : **Patellidae**	
274.	*Umbonium vestiarium* (Linne)
Family : **Dentaliidae**	
275.	*Dentalium octangulatum* (Donovan)
ECHINODERMS	
276.	*Astropecten* spp
277.	*Laganum depressum* (Lesson)
JELLY FISH	
Family : **Catostylidae**	
278.	*Crambionella stuhlmanni* (Chun 1896)
Family : **Pelagidae**	
279.	*Aurelia solida* (Browne)
TURTLES	
280.	*Lepidochelus olivacea*
SEA SNAKES	
281.	*Aipysurus laevis*

14.4 Conclusions

Mean bycatch generated by shrimp trawling off Cochin ranged from 3 to 25 $kg.h^{-1}$, in different seasons with an overall average of 14.38 $kg.h^{-1}$. Shrimp-Bycatch ratio ranged from 1:0.7 to 1:4857, during different seasons, with an overall ratio of 1:12.7. About 281 species including juveniles of commercially important fishes and shellfishes were represented in the shrimp trawl bycatch. The study highlighted the imperative need for improving the selectivity of the trawl system, in order to mitigate its impacts on non-targeted resources.

15.0 Effect of BRD incorporated Trawl Systems in Operational Fuel Consumption

15.1Introduction

Modern fishing is one of the most energy intensive methods of food production. Mechanised trawling is dependent on fossil fuels, which are non-renewable and limited. Fossil fuels produces increased levels of carbon dioxide in atmosphere contributing to green house effect and other pollutants which are detrimental to the environment and human health. Green house effect leads to global warming and irreversible climatic and oceanographic changes. Moreover spiraling oil prices may severely affect the economic viability of fishing as a means of fish production. Many nations around the world have undertaken large-scale programmes in energy conservation in consideration of these implications. In FAO Code of Conduct for Responsible Fisheries (FAO, 1995), Section 8.6 on Energy optimization, seek to promote appropriate standards, guidelines and practices which would lead to efficient use of energy in harvest and post-harvest activities.

According to a recent estimate, in world capture fisheries, 50 billion litres of fuel is consumed annually, which forms 1.2% of the global fuel consumption (Tyedmers et al., 2005). In India, energy security issues assume greater significance on account of increasing demand-supply gap and escalating dependence on imports. Annual consumption of fuel by the mechanized and motorized fishing fleet of India has been estimated at about 1220 million l (Aegisson, and Endal, 1993; Boopendranath, 2000; 2004).

Fuel conservation initiatives have taken centre-stage in developmental efforts, considering its non-renewable nature, limited availability and effects of its use on environment. Approaches to energy conservation in fish harvesting include measures such as (i) fishing gear and methods, (ii) vessel technology, (iii) engines, (iv) reduction gear, propeller and nozzle; (v) sail-assisted propulsion; (vi) adoption of advanced technology, and (v) conservation and enhancement of resources (Boopendranath, 2000; 2004).

Trawling is the most energy intensive fishing activity. It consumes nearly 5 times more fuel compared to passive fishing methods such as longlining and gillnetting and over 11 times more fuel compared to purse seining for every kilogram of fish produced (Gulbrandson 1986). Percentage of fuel cost in the operational expenditure of trawlers may vary between 45 and 75 %, depending on installed engine power and duration of voyage. Hence most potential for fuel conservation exist in trawling. In trawling typically a substantial portion of the time is spent on towing the gear. During the tow, resistance of the vessel is insignificant compared to the resistance of the gear. The gear resistance therefore has a large effect up on overall fuel economy. Fuel cost can be over 50 percent of the total expenses on a fishing trip.

The drag of trawl gear components vary considerably according to the design and rigging and depending on the operating conditions. Wileman (1984) has given a typical set of values for Nordic trawl designs wherein warp contribute 5 percent, sweeps 4 percent, otter boards 20 percent, floats 3 percent, foot rope 10 percent and netting 58 percent of the total drag. In this Chapter, significance of additional drag created by the installation of BRDs is discussed.

15.2 Materials and Methods

Design details of BRDs are given in Chapters 5-6 and 13. The hydrodynamic drag of different BRDs were estimated using the method of Fridman (1986) using the formula:

$$R_x = C_x.q.A$$

where, R_x = measured water force or resistance (kgf)

C_x = hydrodynamic drag co-efficient (for circular cylinder with flow direction normal to the axis, $C_x = 1.2$)

$q = \rho V^2/2$ = hydrodynamic stagnation pressure (kgf m^{-2})

ρ = water density (~105 for seawater)

V = velocity of gear relative to the water ($m.sec^{-1}$)

A = frontal area of the BRDs (~length x diameter) (m^2)

Drag of the shrimp trawl was estimated using the formula (McLennan, 1981):

$$D = R \{61.2+46.6 V^2 / (1+0.0641 V)\}$$

where D = drag (kgf)

R = twine surface area (m^2)

V = speed (kn)

A commercial shrimp trawl of 28.8 m head rope was used for drag calculations. Twine surface area is calculated according to Fridman (1986), using the following formula:

Twine surface area, TSA = $2 \pi r (r+h)$

where r = radius of the netting twine
π = a constant (22/7)
h = length of twine in different panel sections of the trawl (m)

Length of twine in different panel sections (h) was determined by the following formula:

$$h = (2.m_s+k_y.D_t).(M_1+M_2).N.10^{-3}$$

where m_s = mesh siz (mm)
K_y = knot yarn coefficient (16)
D_t = twine thickness (mm)
M_1 = number of meshes along leading edge of the netting panel
M_2 = number of meshes in the hind edge of the netting panel
N = number of meshes in depth

Fuel consumption profile of the trawler (MFB Matsyakumari) was measured using fuel flow meters (Rockwin Kral Screw Volumeter Model OMG-13 with panel mounted flow indicator/totaliser model 7000 mtrd) installed onboard MFB Matsyakumari.

15.3 Results and Discussions

Fuel consumption profile of the trawler, MFB matsyakumari is given in Fig. 15.1. As the differene in drag due to the installation of BRDs and the effect on fuel consumption were too small to be measured during the short duration of experimental hauls (1-1.5 h), such studies were discontinued.

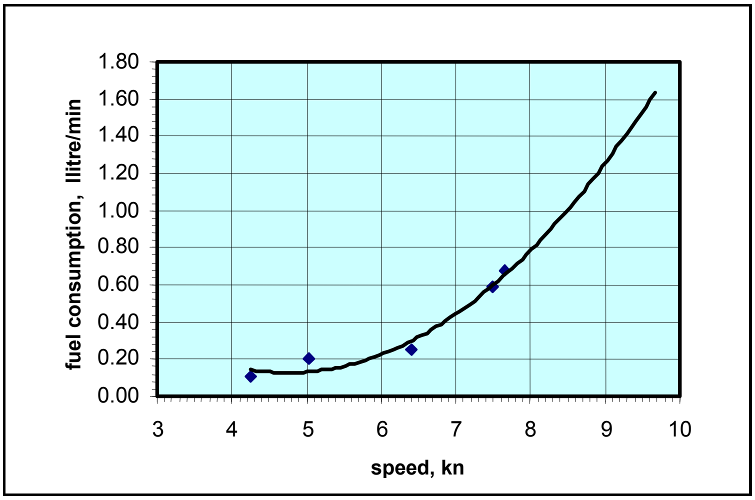


Fig. 15.1 Fuel consumption of the trawler, MFB Matsyakumari

Results of drag calculations in respect of BRDs and trawl net at three different towing speeds *viz*., 2.0, 2.5 and 3.0 knots are given in Table 15.1. Percentage contribution of BRDs to the total drag of trawl system is given in Table 15.2.

Table 15.1: Drag of BRDs and trawl (kgf) at different towing speeds

BRDs	2 kn	2.5 kn	3 kn
Oval grid with 20 mm bar spacing, 1000x800 mm size	8.54	12.96	19.22
Oval grid with 26 mm bar spacing, 1000x800 mm size	7.370	11.18	16.58
Rectangular grid with 22 mm bar spacing, 1000x800 mm size	10.62	16.11	23.89
Oval grid with 22 mm bar spacing, 1000x800 mm size	8.57	13.00	19.28
Fisheye with 200x300 mm oval exit and horizontal orientation	0.82	1.24	1.84
Fisheye with 300x200 mm oval exit and vertical orientation	0.76	1.153	1.71
Fisheye with 300x200 mm semi-circular exit	0.70	1.06	1.58
JFE SSD grid with 22 mm bar spacing 1000x800 mm size	6.47	9.81	14.55
Total drag of 28.8 m shrimp trawl	3955.49	5474.97	7264.97

Table 15.2: Drag at different towing speeds (%)

BRDs	2 kn	2.5 kn	3 kn
Oval grid with 20 mm bar spacing, 1000x800 mm size	0.22	0.24	0.26
Oval grid with 26 mm bar spacing, 1000x800 mm size	0.19	0.28	0.42
Rectangular grid with 22 mm bar spacing, 1000x800 mm size	0.27	0.41	0.60
Oval grid with 22 mm bar spacing, 1000x800 mm size	0.22	0.24	0.27
Fisheye with 200x300 mm oval exit and horizontal orientation	0.02	0.02	0.03
Fisheye with 300x200 mm oval exit and vertical orientation	0.02	0.02	0.02
Fisheye with 300x200 mm semi-circular exit	0.02	0.02	0.02
JFE-SSD grid with 22 mm bar spacing 1000x800 mm size	0.16	0.18	0.20

Estimated drag of the commercial design of a shrimp trawl of 28.8 m head rope at dragging speeds of 2.0, 2.5 and 3.0 knots were 3956, 5475 and 7265 kgf, respectively. The drag of oval and rectangular rigid grids varied from 8.54 to 23.89 kgf during the different towing speeds and their percentage contribution to total drag ranged from 0.19 to 0.60. The drag of fisheye BRDs ranged from 0.76 to 1.84 kgf during different towing speeds and its percentage contribution to the total drag was in the range of 0.02-0.03. The drag of JFE-SSD ranged from 6.47 to 14.55 kgf at different towing speeds and percentage contribution to the total trawl drag was in the range of 0.16-0.20. As is to be expected, the drag of grid devices was higher than Fisheye BRDs, due to differences in size and drag producing components.

15.4 Conclusion

The percentage contribution of BRDs to the total drag was found to be negligible and hence installation of BRDs will not have any significant effect on the fuel consumption during fishing operations.

16. Summary and Recommendations

The importance of reducing bycatch and minimizing ecological impacts of fishing operations has been emphasized by scientists and fishery managers and recognized by fishermen. The FAO Code of Conduct for Responsible Fisheries (FAO, 1995), has given priority status to development and improvement of fishing technology that minimizes bycatch and stresses the need for developing selective fishing gears in order to conserve resources, protect non-targeted resources, juveniles and endangered species like sea turtles. Trawl nets are towed gear consisting of funnel shaped body of netting closed by a bag or codend and having extended sides in the front to form wings. The trawls in general and shrimp trawl in particular exhibit poor gear selectivity and commonly have an associated catch of non-targeted organisms such as finfish and miscellaneous invertebrates. 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, particularly trawling. Main objectives of the Project on *Bycatch Reduction Devices for Selective Shrimp Trawling* (Project Code No. 0644003) sanctioned under A.P. Cess Fund Ad-hoc Research Scheme of ICAR have been (i) Design, development and evaluation of Bycatch Reduction Devices (BRDs) appropriate for shrimp trawls operated in small-scale mechanized sector, (ii) Development of selective shrimp trawls, incorporating optimized Bycatch Reduction Devices, (iii) Evaluation of the effect of BRD incorporated trawl systems in operational fuel consumption, (iv) Characterization of shrimp trawl bycatch. The content of the Final Project Report is organized into 16 Chapters.

The first Chapter gives the background of the topic of project, its relevance and significance, and reviews the literature. Devices developed to reduce the non-targeted species and other unwanted catch in shrimp trawling and exclude the endangered species like turtle, and are collectively known as Bycatch Reduction Devices (BRDs). BRDs have been developed taking into consideration the differential behavior patterns or size of shrimp and fish inside the net. Various types of BRDs have been developed in the fishing industry around the world. The salient features and operational features of some of the important BRDs have been Chapter 2. About 50 designs of BRDs and TEDs developed for different resource groups and fishing areas are in vogue either in experimental or commercial operations. BRDs and TEDs most appropriate to the regional fishery conditions should be adopted and enforced legally, after careful scientific evaluation and commercial trials, in order to ensure long-term sustainability of fishery resources and protect the biodiversity. Materials and methods used for the investigations are described in Chapter 3 and further elaborated in the concerned Chapters.

Present status of trawl systems, off southwest cost is reviewed in Chapter 4. Significant changes in design features of trawls were noted, when compared with earlier reports. Due to reducing catch volumes per unit effort and impacts of economic overfishing, the boat owners are compelled to construct larger trawlers capable of undertaking multi-day fishing and are expanding fishing activities to deeper waters targeting a diverse group of finfishes and shellfishes. A significant shift from traditional wood to steel as the preferred boat building materials is noticeable, with the hulls of almost all new constructions being built exclusively using steel. The use of electronic navigation equipment such as GPS and acoustic fish detection devices such as echosounder has significantly contributed to precision fishing and use of communication equipment (VHF radio-telephone) has improved the safety in operations. There have been significant changes in the number of trawl nets carried on board and in the diversity of trawl designs used for targeting an increasingly wider range of finfish and shellfish species. The dimensions of the trawls have been increasing commensurate with the increase in size of the vessel and installed engine power. Use of large mesh trawls in the front trawl sections which reduce the drag and facilitate construction of trawl with significant larger mouth area has become widespread in the case of fish trawls, due to direct and indirect of impact of R&D efforts of CIFT in this area. There has been no evidence of the use of any bycatch reduction technologies in the trawl fisheries, during the period of investigations.

Fisheye is an important bycatch reduction device which facilitates the escapement of the fish, which try to swim backward from the codend. Device is suitable for excluding actively swimming juveniles and young fishes while retaining the big ones. Results of performance evaluation three designs of Fisheye BRDs are given in Chapter 5. Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation performed better in terms bycatch exclusion efficiency and target catch retention properties (bycatch reduction: 50.58%; shrimp loss: 0.83%), compared to Fisheye BRD with 300x200 mm oval exit of horizontal orientation (bycatch reduction: 45.79%; shrimp loss: 4.87%) and Fisheye BRD with 300x200 mm oval exit of vertical orientation (bycatch reduction: 26.17%; shrimp loss: 44.88%). Juveniles of several species showed good exclusion through the semicircular Fisheye BRDs. Out of 70 non-shrimp species encountered during the field trials, about 56% showed varying levels of exclusion. Comparatively better performance of semicircular Fisheye BRD in reducing the target catch loss is attributed to the low turbulence due to its streamlined design. The higher bycatch exclusion of semicircular Fisheye BRD is attributed to the higher area of the exit opening which has about 9.6% more than other two designs. Based on its performance, Fisheye BRD with 300x200 mm semicircular exit of horizontal orientation is recommended for adoption and use in shrimp trawling in Indian waters, in order to reduce bycatch of finfish species without compromising on shrimp catches.

The flat grid BRDs are installed in the extension piece between throat and codend of a trawl net, at an angle of about 45° from the horizontal. A fish outlet is provided at the top in front of the grid and an accelerator funnel is mounted in front of the grid in order to guide the catch in to the grid. Results of performance evaluation of Oval and Rectangular Grid BRDs of 1000x800 mm size and 22 mm bar spacing are given in Chapter 6. Oval grid provided higher bycatch exclusion (64.09%) compared to rectangular grid (53.90%). Exclusion of higher number of bycatch species at levels exceeding 50%, in the oval grid has indicated its better performance, compared to rectangular grid design. In terms of target catch retention also oval grid performed better (89.69%) than rectangular grid (86.75%). Better performance of oval grid is attributed to the lower turbulence during the tow as it fits into the net cylinder assuming a streamlined shape without causing protuberances by virtue of its oval shape unlike rectangular grid. The higher exclusion rate of 10-13% in the case of shrimps in flat grid BRDs is attributed to the clogging of the grids by debris and due to inadequate bar-spacing. As bar-spacing is a critical parameter influencing the selectivity of grid BRD, further investigations were undertaken on this aspect (Chapter 7).

During comparative evaluation of Oval Grid BRDs and Semicircular Fisheye BRD, bycatch exclusion realised by the Oval grid BRD with 26 mm bar-spacing was about 58% and that by Semicircular Fisheye BRD was about 47% (Chapter 7). More than 50% exclusion in respect of 38 species was observed in the Oval grid BRD compared to 14 species in Semicircular Fisheye. Statistical analysis has shown significantly higher exclusion rates in the Oval grid BRD, in respect of several bycatch species. However, shrimp loss was significantly low ($p<0.01$) in Semicircular Fisheye BRD (1.59%) compared Oval grid BRD with 26 mm bar-spacing (8%). Performance of Oval grid with 26 mm bar-spacing was better compared to the grid with 20 mm bar spacing during comparative field trials (Chapter 7). There was a 55.6% reduction in the shrimp loss when bar spacing was increased from 20 to 26 mm. Oval grid BRD with 26 mm bar spacing excluded on an average 59% of the bycatch and 36 species have shown exclusion at rates exceeding 50%. In the case of 20 mm oval grid BRD, bycatch exclusion obtained was 45% and only 27 species showed exclusion at rates exceeding 50%. Statistical analysis has shown that the difference in performance was significant in respect of five fish species and in terms of shrimp retention in the case of oval grid BRD with 26 mm bar-spacing compared to the Oval grid BRD with 20 mm bar spacing. Oval grid BRD with 26 mm bar-spacing has given excellent results in terms of exclusion of bycatch species during the two sets of experiments (about 58%). Semicircular Fisheye BRD showed promising results in terms of target catch retention (98.41%) which in Oval grid BRD with 26 mm bar-spacing was in the range of 92-94%.

Radial Escapement Device (RED) consists of a small mesh funnel surrounded by a radial section of large square mesh netting. Shrimps are retained in the codend while fishes swim back and escape through the large square mesh section. Results of performance evaluation of Radial Escapement Devices are discussed in Chapter 8. Exclusion rate of bycatch in RED with 100 mm square mesh escape section was on an average 20% and the shrimp loss was about 24%. Bycatch exclusion from RED with 150 mm square mesh escape section was about 15% and shrimp loss was 20%. Low rates of bycatch exclusion and high shrimp loss indicate that Radial Escapement Device may not be an appropriate BRD for Indian fisheries conditions.

Bigeye BRD is a simple device constructed by making a horizontal slit in the upper part of codend or hind belly, where the opening is maintained by means of float and sinker arrangement (Chapter 9). During the field trials, bycatch exclusion from Bigeye BRDs ranged from 8 to 11% and shrimp loss was less than 2.3%. Bycatch exclusion rates were observed to be low in the Bigeye BRDs, compared to some other BRD designs evaluated. However, performance in terms of shrimp retention was favourable as it was more than 97%. One of the major advantages of the Bigeye BRD is that it is very simple in design and can be easily fabricated and installed.

During comparative field trials using Fisheye BRD of 300x200 mm semicircular exit of horizontal orientation and Bigeye BRD, the mean excluded bycatch was about 33% in the Bigeye BRD and 63% in the Fisheye BRD (Chapter 10). Shrimp loss during the operations was about 4.1% in the Bigeye BRD and 3.8% in the Fisheye BRD. Performance of Fisheye BRD was better compared to the Bigeye BRD, in terms of bycatch exclusion and shrimp retention. However, Bigeye BRD has the comparative advantage of being extremely simple in construction and installation.

Sieve net is a funnel of netting with appropriate mesh size placed in side of trawl net to guide unwanted species to outside (Chapter 11). Sieve net is effectively used by many fisheries around the world to reduce fish, jelly fish and other bycatch species from shrimp trawling and could be easily adapted for Indian fisheries. Sieve nets do not have the same handling problems as grids and are less prone to blockage, because they have a larger sorting area. 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 mortality of juveniles during shrimp trawling. Among the two sieve nets evaluated, Sieve net-60D (with 60 mm diamond mesh funnel inside the net with 80 mm diamond mesh outlet codend) has been able to exclude significant quantities of juveniles and bycatch while keeping shrimp loss at about 4.5% and retaining larger marketable bycatch species (Chapter 11). In addition, it is also possible to adapt the Seine-net to efficiently exclude jellyfish when they abound in the shrimp fishing grounds, by keeping the outlet codend open and retain the shrimp catch. Sieve net-50D (50 mm diamond mesh funnel and outlet codend of 60 mm mesh size) has functioned poorly in terms target catch retention which was only about 80%, making this design unacceptable for commercial use. Sieve net-60D has potential for adoption in tropical trawl fisheries, in order to minimize the impact of shrimp trawling on juveniles and non-targeted bycatch species

The separator panel BRD designs use panels of netting placed in the mouth, throat, or along the wings of the trawl to lead fish towards escape openings, allowing shrimp to pass through relatively large panel meshes in to the codends (Chapter 12). 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 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%). Results indicate that the present design of Separator panel BRDs will not be appropriate for Indian fisheries conditions. Separator panel BRDs are also seen vulnerable to clogging leading to ineffectual sorting.

Results of the investigations on Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) indicated excellent juvenile bycatch reduction and pre-sorting capabilities (Chapter 13). The JFE-SSD has the following advantages: (i) Conventional codend in a shrimp trawl could be easily replaced by JFE-SSD without any alteration in the net design, (ii) The device reduces the bycatch of juveniles of finfishes, shrimps, crabs and cephalopods, and small sized fishes of low commercial value, contributing to sustainability of the resources and protection of biodiversity, (iii) The fishermen are able to retain large fishes of higher market value, which will enhance the overall revenue realized from trawling operations, (iv) Quality of the shrimps would be better due to the prevention of physical pressure caused by accumulation of larger fishes, which takes place in conventional codends, (v) The *in situ* sorting effect and separation of shrimps from finfishes and cephalopods help to reduce the sorting time and increase useful fishing time of the trawler fishermen and thus enhance the profitability of fishing operations, (vi) Increase in towing time can be expected due to slow filling of the codend as a result of reduction of non target fishes and juveniles, (vii), Fuel saving can be expected due to drag reduction caused by the escapement of non-target species, (viii), Training requirements by fishers for fabrication, installation and operation of JFE-SSD is minimal, (ix) By adopting the JFE-SSD, trawler fishermen would be less prone to criticism from conservation groups and environmentalists. The design concept of JFE-SSD proposed by the project team has won the coveted International Smart Gear Award-2005, in the category 'Other Non-target Species (Including fish)'.

Results of investigations on bycatch characterization are discussed in Chapter 14. Mean bycatch generated by shrimp trawling off Cochin ranged from 3 to 25 $kg.h^{-1}$, in different seasons with an overall average of 14.38 $kg.h^{-1}$. Shrimp-Bycatch ratio ranged from 1:0.7 to 1:4857, during different seasons, with an overall ratio of 1:12.7. About 281 species including juveniles of commercially important fishes and shellfishes were represented in the shrimp trawl bycatch. The study highlighted the imperative need for improving the selectivity of the trawl system, in order to mitigate its impacts on non-targeted resources.

Effect of BRD incorporated trawl systems in operational fuel consumption is discussed in Chapter 15. The percentage contribution of BRDs to the total drag was found to be negligible and hence installation of BRDs will not have any significant effect on the fuel consumption during fishing operations.

Reducing trawl bycatch will only be successful with the active involvement of stakeholders in the process, supported by a system of incentives and disincentives and training. Training of trawler fishermen is important in raising awareness regarding bycatch reduction technologies and strategies, as their attitudes are crucial in the success of adoption. Legislation pertaining to mandatory use of bycatch reduction technologies and practices need to be enacted, depending on regional situations and ecosystem requirements. Continued research and improvements in bycatch reduction technologies and strategies for improving survival of excluded species are expected to produce more efficient solutions in future. A National Plan of Action for bycatch reduction in fishing gears, particularly targeting trawling sector, is a necessity for the sustainability of Indian fisheries.

Recommendations

i. Bycatch Reduction Devices (BRDs) are essential for reducing the negative impacts of trawling on sustainability of marine resources and biodiversity. Use of BRDs need to be made mandatory in shrimp trawl nets and proper awareness generated in trawling industry about its necessity. Effective legislation and incentive schemes may be necessary for their popularisation among fishermen.

ii. Once the Bycatch Reduction Devices are made mandatory for the shrimp trawlers, it will lead to responsible trawling with significant reduction in bycatch volume and growth overfishing, with consequent beneficial impact on the long-term sustainability and biodiversity of the marine resources.

iii. Designs of Hard Bycatch Reduction Devices *viz*., Rectangular Grid BRD, Oval Grid BRD, Fisheye BRD have been developed. Among Hard BRDs evaluated, Fisheye BRD with 300x200 mm semicircular exit opening and Oval Grid BRD with 26 mm bar-spacing performed better in terms of bycatch exclusion and target catch retention and hence can be recommended for use in shrimp trawling.

iv. Designs of Soft Bycatch Reduction Devices *viz*., Radial Escapement Device (RED), Sieve Net BRD, Separator Panel BRD and Bigeye BRD have been developed. Soft BRDs have the advantages such as simplicity in design, ease of construction and installation, low cost, ease of handling, amenability to be taken in a net drum and safety in operation onboard. Among the Soft BRDs tested Bigeye BRD positioned at 1.5 m from the distal end of the codend and Sieve Net BRD with 60 mm diamond mesh funnel are potential candidates for bycatch reduction from shrimp trawls and can be popularized among trawler fishermen.

v. A unique International award winning design of Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) has been developed. JFE-SSD, which is designed to exclude juveniles and *in situ* shrimp sorting during trawling, has potential for popularization among fishermen.

vi. A National Plan of Action for bycatch reduction in fishing gears, particularly targeting trawling sector, is necessary for the sustainability of Indian fisheries.

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Annexures

Annexure -1

Bycatch Reduction Devices for Selective Shrimp Trawling
(Project Code No. 0644003)
Budget with Annual Break-up
(Ref: ICAR F. No. 4(67)/2003-ASR-1 dated 8.12.2003)

	Item of expenditure	I year Rs.	II year Rs.	III year+ 3 months Rs.	Total Rs.
1.	**Sr. Research Fellows (Two)** Rs. 8000/ per month per Fellow for 1st year and 2nd year and Rs. 9000/- per Fellow for 3rd year	1,92,000	1,92,000	2,16,000	6,00,000
2.	**HRA** Rs. 1200/- per month for 1st year and 2nd year and Rs. 1350/- per month for 3rd year	28,800	28,800	32,400	90,000
3.	**Recurring contingencies** Rs. 40,000/- per Fellow	80,000	80,000	80,000	2,40,000
	Sub-total	**3,00,800**	**3,00,800**	**3,28,400**	**9,30,000**
4.	**Institutional service charges** (10%)	30,080	30,080	32,840	93,000
5.	**Contract labour**	40,000	30,000	30,000	1,00,000
6.	**Additional contingencies**	1,50,000	-	-	1,50,000
7.	**Non-recurring contingencies** i. CAD system with bundled software, power source and printer: Rs. 2,50,000/-; ii Fuel flow meters: Rs. 2,00,000/-	4,50,000	-	-	4,50,000
	Grand total	**9,70,880**	**3,60,880**	**3,91,240**	**17,23,000**

Annexure -2

International Smart Gear Award

The Project Team consisting of Dr. M.R. Boopendranath (Principal Scientist and Principal Investigator), Dr. P. Pravin (Sr. Scientist), Mr. T.R. Gibinkumar (Sr. Research Fellow) and Mr. S. Sabu (Sr. Research Fellow) of Fishing Technology Division, has won the International Smart Gear Award, in the category 'Other Non-target Species (Including fish)' for a novel concept in juvenile bycatch reduction in shrimp trawls (Please see pages 206-208). World Wildlife Fund (WWF) instituted the International Smart Gear Competition in May 2004, to bring together partners representing fisheries, policy, and science to find solutions for the problem of accidental catch of non-target species (Please see page 207). The selection was made from more than 50 entries from 16 nations by an International Panel of judges made up of gear technologists, fisheries experts, representatives of the seafood industry, scientists and conservationists. The award carries a cash prize of US$ 5,000. The award was received by the Team Leader at a special ceremony organized by WWF, at the National Press Club, Washington DC, USA, on 21 April 2005 (Please see pages 213-214). The deputation for this purpose was approved by Department of Agriculture and Research, New Delhi *vide* letter No. F. No. 10-017/2005-IC(AV) dated 15 April 2005.

The International Award won by the CIFT team has brought international recognition for India's efforts in promoting responsible fishing, involving bycatch reduction, resource sustainability and protection of ecosystem integrity and biodiversity. In this context, the Institute and the project team received compliments from the President of India, the Prime Minister, the Minister of State for Science & Technology and Ocean Development, Government of India and distinguished personalities in the field of fisheries research and development (Please pages 209-212). The event also created wide impact in the print and internet media (Please see pages 215-216).

The award winning design proposal provided an important concept for the reduction of juveniles and non-target species during shrimp trawling and *in-situ* sorting of the catch. The design proposal (JFE-SSD) was evaluated under the ICAR Adhoc Project No 0644003 titled Bycatch Reduction Devices for Selective Shrimp Trawling, pursued at the Central Institute of Fisheries Technology (Cochin) (Please see Chapter 13, this report).

WWF

March 18, 2005

Dr. M.R. Boopendranath
Central Institute of Fisheries Technology
P.O. Matsyapuri, Cochin-682 029
INDIA

Dear Dr. Boopendranath,

I'm delighted to inform you that your entry, Juvenile Fish Exluder cum Shrimp Sorting Device (JFE-SSD), has been selected to receive a $5,000 first prize in the International Smart Gear Competition. The award is a cash prize, to be used in any way your group chooses.

To formally present you with the prize, we would like to bring you to Washington, DC and have you participate in a press conference at the National Press Club on April 21, 2005, as well as honor you at an award reception the same day. We will cover all the expenses associated with your trip. Enclosed is a W-9 *W-8 form of the U.S. Internal Revenue Service. Please fill out the form, providing your Social Security Number or Taxpayer Identification Number; if you are not liable for U.S. taxes, please indicate the reason on the form. WWF cannot make any payments until it has a completed form on file. Tori Mitchell will be in touch with you regarding the process of awarding the prize.

We want to generate as much international attention and recognition as possible for the Smart Gear winners and their ideas. Therefore it's very important that we wait until the official prize presentation ceremony and press conference to inform the media about the results of the competition. I'm sure you'll want to inform your colleagues of your entry being a winner but please wait until after April 21 to speak with the media about your award-winning idea so that our announcement of the outcome of the International Smart Gear Competition will have the maximum impact.

On behalf of WWF and our international panel of Smart Gear judges, I would like to congratulate you on your innovative concept for reducing bycatch, and I hope to meet you in person in April.

Sincerely,

for Ginette Hemley
Vice President
Species Conservation

Enclosures

World Wildlife Fund
1250 Twenty-Fourth St., NW Washington, DC 20037-1132 USA
Tel: (202) 293-4800 Fax: (202) 293-9211
www.worldwildlife.org
Affiliated with World Wide Fund for Nature

International Smart Gear Competition

World Wildlife Fund launched the International Smart Gear Competition in 2004 and brought together the fishing industry, research institutes, universities, and government, to find practical, innovative fishing gear designs that will prevent the accidental maiming and killing of whales, dolphins, sea turtles and juvenile fish entangled in fishing nets, or what is known as "bycatch"

This most pressing threat to marine life needs a wide-ranging, multidisciplinary response, and WWF believes the Smart Gear competition will help catalyze that response by encouraging creative thinkers everywhere to share their ideas. Applicants were asked to submit modified fishing gears and procedures that increase selectivity for target fish species and reduce bycatch in the following categories: cetaceans (whales, dolphins and porpoises), sea turtles, and other non-target species (including fish). The competition was open to anyone, and a diverse group responded, including gear technologists, fishermen, engineers, chemists, and graduate students.

More than 50 entries came in from 16 countries and were judged by an international panel made up of 14 gear technologists, fisheries experts, representatives of the seafood industry, fishermen, scientists, researchers and conservationists. The judges were guided by the following criteria:

- Is the idea innovative and original?
- Does it increase selectivity for the target species?
- Does it reduce bycatch of non-target species?
- Will it allow fishermen to maintain or increase profitability?
- Is the idea practical and is the idea easy to use?

The real, lasting value of the Smart Gear Competition was that it inspired people to seek creative new ways to solve bycatch. Critical examination by the world's leading experts highlighted the best ideas in the world, and the attention these ideas will garner should will hopefully bring attention the bycatch problem overall. The challenge for the Smart Gear judges was to recognize innovative ideas and their potential, and find ways to promote their development and implementation. The following organizations lent their expertise to the judging process:

American Fisheries Society and Fisheries Conservation Foundation, Centre for Environment, Fisheries and Aquaculture Science (U.K.), Centre for Sustainable Aquatic Resources, Memorial University (Canada), Consortium for Wildlife Bycatch Reduction *(includes the New England Aquarium, Maine Lobstermen's Association, Duke University the University of New Hampshire)*, Hubbs-Sea World Research Institute, NOAA Fisheries (U.S. National Marine Fisheries Service), Institute of Marine Research (Norway), Inter-American Tropical Tuna Commission (IATTC), Sealord Group, Ltd. (New Zealand), SeaNet (Australia), Southeast Asian Fisheries Development Centre (Bangkok, Thailand), U.N. Food and Agriculture Organization (Rome, Italy), University of Rio Grande (Brazil)

More information about our partner organizations and the International Smart Gear Competition can be found at www.SmartGear.org.

International Smart Gear Competition
2005 WINNER

Runner Up and $5,000 Award: Prevention of Other Non-Target Species (juvenile fish and shrimp) Bycatch

Dr. Boopendranath, principal scientist, Central Institute of Fisheries Technology, India
Dr. Pravin, scientist, Central Institute of Fisheries Technology, India
Mr. Gibinkumar, senior research fellow, Central Institute of Fisheries Technology, India
Mr. Sabu, senior research fellow, Central Institute of Fisheries Technology, India

Brief Biography

The Central Institute of Fisheries Technology (CIFT) is an Indian research organization that conducts research on harvest and post-harvest fisheries technology. The team that won for "Other Non-Target Species" is made up of a group of scientists who have worked together for more than a year on the "bycatch reduction devices for selective shrimp trawling" project for the Central Fisheries Institute. Dr. M.R. Boopendranath is the principal investigator for the project, Dr. P. Pravin is the associate scientist and Mr. T.R. Gibinkumar and Mr. S. Sabu are senior research fellows for the project.

This team was formed in April 2004 and had already participated in an ad hoc research project for the Indian Council of Agricultural Research. The Indian Council of Agricultural Research seeks to coordinate agricultural research and development programs that enhance the quality of life of the farming community. The Central Institute of Fisheries Technology is the part of the Indian Council of Agricultural Research that oversees and analyzes the harvest and post-harvest technology of fishing in India.

Invention

This team's entry specifically addresses the bycatch problems faced by shrimp trawlers in the Indian Ocean. They developed a system of angled metal grids and net meshes that work to reduce bycatch of undersized shrimp and fish in trawls.

Trawl fishermen in India and other tropical fisheries depend on both finfish catches and shrimp catches to keep the commercial operations economically viable. Christened the Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) by its inventors, this solution traps mature shrimp in the bottom portion of the net while allowing juvenile shrimp to swim out of the mesh net unharmed. The device also retains mature finfish in the upper portion of the net while allowing small fish of low commercial value to safely exit the shrimp trawl.

The sorting of the shrimp and the finfish between the lower and upper parts of the net enhances profitability because it: reduces sorting time on the deck which increases the useful fishing time of the trawler fishermen; and it prevents shrimp from becoming crushed under the weight of fish and bycatch hauled on deck which increases the shrimp's market value.

Increasing profitability while decreasing bycatch through a simple solution could have positive impact on in a heavily populated developing country and the global problem of bycatch.

A.P.J. Abdul Kalam

Rashtrapati Bhavan
New Delhi - 110004

March 24, 2005

Dear Dr. Devadasan,

I am very happy to know the performance of the Central Institute of Fisheries Technology, Kochi, particularly about the development of harvest and post harvest technologies for fish and also the Juvenile Fish Excluder-cum-shrimp Sorting Device (JFE-SSD).

I send my congratulations to you and your group of Scientists working in the Institute and wish the innovations all success.

With regards,

Yours sincerely,

(A.P.J. Abdul Kalam)

Dr. K. Devadasan
Director
Central Institute of Fisheries Technology
Willingdon Island, Matsyapuri P.O.
Kochi – 682 029.

प्रधान मंत्री कार्यालय
नई दिल्ली - 110 011
PRIME MINISTER'S OFFICE
New Delhi - 110 011

सत्यमेव जयते

R. Gopalakrishnan
Joint Secretary to PM

Tel#23015944
e.mail rgopalakrishnan@pmo.nic.in

No. 100/31/c/1/05-ES.II

March 16, 2005

Dear Dr. Devadasan,

Please refer to your letter bringing to the Prime Minister's notice the receipt of an award from WWF, Washington by your organization. The Prime Minister conveys his congratulations to you and to your team on this achievement.

With regards,

Yours sincerely,

(R. Gopalakrishnan)

Dr. K. Devadasan
Director
Cenral Institute of Fisheries Technology
Willingdon Island
Matsyapuri
P.O. Kochi 682 029

कपिल सिब्बल
KAPIL SIBAL

सत्यमेव जयते

विज्ञान एवं प्रौद्योगिकी तथा महासागर विकास
भारत सरकार, नई दिल्ली
MINISTER OF STATE (INDEPENDENT CHARGE) FOR
SCIENCE & TECHNOLOGY AND OCEAN DEVELOPMENT
GOVERNMENT OF INDIA,
NEW DELHI

16 March, 2005

Dear Dr. Devadasan,

I would like to congratulate you on winning the first prize in the International Smart Gear Competition for the Juvenile Fish Excluder cum Shrimp Sorting Device developed by your institute. I am happy to note the good work being done by your institute in developing appropriate technologies in the area of fisheries technology. I am sure that in future also the institute will get several such honours.

With regards,

Yours sincerely,

(Kapil Sibal)

Dr. K. Devadasan,
Director,
Central Institute of Fisheries Technology,
Willingdon Island,
Matsyapuri,
PO Kochi – 682 029.

डा. एस. अय्यप्पन
उप महानिदेशक (मत्स्य)
Dr. S. AYYAPPAN
Deputy Director General (Fisheries)

भाकृअनुप
ICAR

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन - II
पूसा, नई दिल्ली 110 012
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II
PUSA, NEW DELHI 110 012

D.O.NO.PS/DDG(FY.)/2005/ 96
Dated the 17th March, 2005

Dear Dr. Bhoopendranath,

While reviewing the achievements of the Fisheries Division for the year 2004-05, I have noted that the work on ***'Juvenile escapement cum prawn sorter device in trawl nets'*** carried out by your Team is exemplary. Please accept my compliments on the achievement and convey the same to all concerned. I am sure you would continue with the good work in the years to come.

With best wishes,

Yours sincerely,

[S. Ayyappan]

Dr. M.R. Bhoopendranath
Principal Scientist
Central Institute of Fisheries Technology
Willingdon Island, Matsyapuri P.O.
Cochin – 682 029, Kerala.

Ph : (O) 2584 6738 (R) 2584 3190 FAX: 00-91-11-2584 1955
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Scenes from Press Conference, at National Press Club, Washington DC, 21 April 2005, showing Dr. M.R. Boopendranath, Leader of CIFT Award Winning Team being recognized and congratulated by Mr. Carter Roberts, President and CEO-elect of World Wildlife Fund. (Photo Credit: Jill Hatzai, WWF).

International Smart Gear Award Winners with WWF-US representatives, during visit to US Capitol and Government Agency Offices, Washington DC 22 April 2005. Dr. M.R. Boopendranath (India) - first in the front row from left. (Photo courtesy: Dr. Ed Trippel, Canada).

Reception at Washington DC, 21 April 2005: Award winners being introduced by Mr. Carter Roberts, President and CEO-elect of World Wildlife Fund **(Photo courtesy: Dr. Ed Trippel, Canada).**

The award winning team with JFE-SSD, onboard MFV Sagar Shakthi

From left: Mr. S. Sabu, Mr. T.R. Gibinkumar, Dr. M.R. Boopendranath (Team Leader), Dr. P. Pravin (Photo: CIFT, Cochin)

THE PIONEER

Page - 2

Device to eliminate by-catch bags WWF award

Pioneer News Service

Kochi

THE JUVENILE Fish Excluder-cum-Shrimp Sorting Device (JFE-SSD), a product of Central Institute of Fisheries Technology (CIFT), won the International Smart Gear Award in the small fish category.

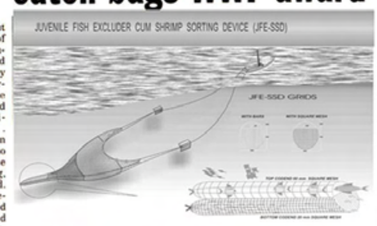
The device that bagged the award constituted by the World Wildlife Fund (WWF) to promote responsible fishing worldwide, would eliminate by-catch, which is around 40 per cent of the total catch and causes an estimated annual loss of 2,200 crore kilograms of fish globally.

The new device assumes significance as population of shrimps, which earns 70 per cent of the Indian foreign exchange, has been decreasing rapidly following destruction of juvenile shrimps as by-catch during trawling.

The JFE-SSD won the award for its unique way of *in situ* shrimp sorting by placing an oval grid at the mouth of the conventional codend of the trawl and thereby sorting fishes and shrimps at the entrance of the net itself. The device also enables juvenile shrimps to escape through the square mesh.

This device has already been adopted by many states including Andhra Pradesh and Gujarat, which has made it mandatory for trawling boats. The CIFT officials stated that the JFE-SSD can be fitted to traditional codends at the cost of around Rs 1,000.

The new contraption can be easily put in place of the traditional codend without any design alteration of the net, said CIFT officials. Fishermen don't have to spend time for sorting, they added. The new device would put an end to decades-long quarrel between traditional fishermen and trawling boat employees, they said.



The device requires only minimal training for fabrication, installation and operation. It will save fuel due to drag reduction, caused by escapement of non-target species, officials stated.

The award-winning team of the CIFT was led by scientist Dr Bhoopendranath. Dr Pravin, Gibinkumar and Sabu were its members. Sixty groups from 16 countries participated in the competition. A panel of 14 judges, including eminent scientists selected the winners.

The New Indian Express

Page - 3

CIFT develops net that lets off small fish

Express News Service

Kochi, June 6: International recognition has come the way of city-based Central Institute of Fisheries Technology (CIFT) for inventing a new fishing device that excludes small fishes from the net, giving them a new lease of life.

Called Juvenile Fish Excluder-cum-Shrimp Sorting Device (JFE-SSD), it prevents accidental catching of non-target species. For designing this novel device, the research team of CIFT has bagged the International Smart Gear Award, in the category 'Other ...

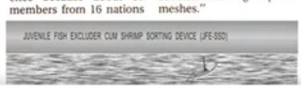
... ention of reversing the decline of vulnerable species accidentally caught in nets and other fishing gears, WWF awarded a cash prize of $5,000 to the research team of CIFT.

"This award is a major fillip to Indian efforts in promoting responsible fishing," Boopendranath told mediapersons here on Monday.

The award is dedicated to the efforts of Indian science because about 60 members from 16 nations ... fishermen, but deep down, about 200-250 species may enter the nets. As a result, juveniles get trapped in them. In India, about 40 percent of the bycatch is contributed by juveniles, he explained.

Explaining the working of the device, he said: "Unlike the conventional codend of the trawl, JFE-SSD consists of an oval grid with a top opening, which leads to an upper codend with large square meshes."

S.Sabu, T.R.Gibinkumar, M.R.Boopendranath and Dr.P.Pravin with their Juvenile Fish Excluder-cum-Shrimp Sorting Device.



... creasing productive fishing time. Moreover, the quality of the shrimp will be better due to the prev...

... continued, "fishermen named it 'kanivekum valakal," (kind fishing nets). Besides, Andhra Pradesh has ...

KOCHI

THE HINDU • THURSDAY, MARCH 8, 2007

Devices to preserve marine resources

Large-scale fishing has affected the marine ecosystem drastically

- By-catch reduction devices (BCDs) are based on the differential behaviour pattern of shrimp and fish
- An indigenous BCD traps mature shrimp while allowing juvenile ones to escape

A COMPELLING study published in the *Science* journal in November last year predicted the end of the fisheries industries by 2050. The researchers led by Prof. Boris Worm of Dalhousie University in Nova Scotia, Canada, came to the shocking ...

... Japan, U.S and Western Europe shrimp remains a favourite.

... world over have seen that the shrimp trawl is a non-selective fishing gear.

... India, except in the case of Turtle Excluder Devices. BRDs are of two types and are developed taking into consideration the differential behaviour pattern of shrimp and fish inside the net.

In India, CIFT has developed a BRD called Juvenile Fish Excluder Shrimp Sorting ...

A sample of print media coverage of International Smart Gear Award and Bycatch Reduction Devices

A sample of print media coverage of International Smart Gear Award

Annexure 3

Awareness cum Demonstration Campaign on Bycatch Reduction Devices

An Awareness cum Demonstration Campaign on Bycatch Reduction Device was conducted during 12-14 April 2008 for the benefit of trawler fishermen at fishing villages in Ratnagiri by Central Institute of Fisheries Technology (Indian Council of Agricultural Research) (Cochin), College of Fisheries (Dr. Balasaheb Swant Konkan Krishi Vidhyapeeth) (Ratnagiri) and Cameron International (Mumbai), under a unique collaborative initiative focussed on conservation of trawl caught resources and reduction on the negative impact of trawling on juveniles.

Awareness cum Demonstration was conducted at Harnai fishing village, Kasaraveli fishing village and Mirkarvada minor fishing harbour, located in Ratnagiri, Maharashtra on 12th, 13th and 14th April 2008, respectively (Please see page 218). Dr. M.R. Boopendranath (Principal Scientist) assisted by Mr. P.N. Sudhakaran (T-4) and Mr. Aravind K. Kalangkuthkar (T-4), from Central Institute of Fisheries Technology (Cochin), conducted the onboard demonstrations, off Harnai and Kaserveli. Onboard demonstrations were followed by discussion meetings in which a total of about 180 fishers participated actively. Questions and doubts raised by fishers were clarified, during the programme.

The programme has been a grand success and evinced keen interest among stakeholders. The event received good print and digital media coverage which enabled the transmission of the message to a wider spectrum of stakeholders (Please see pages 219-220).

The current initiative with the industry participation by CIFT in collaboration with College of Fisheries (Ratnagiri) and Cameron international is expected to bring about a sea change in the attitude of fishers and facilitate the adoption of conservation technologies in shrimp trawling operations, ultimately leading to sustainability of resources and protection biodiversity in Indian waters. Bycatch reduction technologies in the context of managing fishing effort were discussed during the Residential Workshop on Fisheries Resource Management, 13-14 July 2007, Kovalam, for the benefit of staff of South Indian Federation of Fishermen Societies (SIFFS).

Demonstration of JFE-SSD at Harnai fishing village (Ratnagiri, Maharashtra) on 12.4.2008

A scene from onboard demonstration of JFE-SSD at Harnai fishing village on 12.4.2008

Discussion meeting at Kaserveli fishing village (Ratnagiri, Maharashtra) on 13.4.2008

Demonstration of JFE-SSD at Mirkarwada minor fishing harbour (Ratnagiri, Maharashtra) on 14.4.2008

A scene from onboard demonstration at Harnai fishing village on 12.4.2008 [pre-sorted shrimp (deck) and non-shrimp catch (basket)]

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सकाळ
बुधवार

नवे जाळे

केवळ मोठे मासे पकडणारे बीआरडी जाळे

१२ ला हर्णैत प्रात्यक्षिक : छोटे मासे सुखरूप बाहेर, मासळी पुनरुत्पादनाला वरदान

सुनील कदम : सकाळ वृत्तसेवा

दाभोळी : केवळ मोठे मासे पकडणारे बीआरडी जाळ्याचे रेखाचित्र.

दाभोळी, ता. ८ : 'जाळ्यात गावली रे दादा सोनेरी सोनमासळी' असे अभिमानाने गाणे म्हणणारा कोळीराजा पारंपरिक जाळ्यामुळे कोंडीत सापडला होता. जाळ्यात सरसकट लहान-मोठे मासे पकडल्याने गेल्या पाच वर्षांत मत्स्य उत्पादन घटले आहे. परिणामी मच्छीमार समाजाला मासळी दुष्काळाला सामोरे जावे लागत आहे. आता मात्र कोचीनच्या स्वीफ्ट (सेंट्रल इन्स्टिट्यूट ऑफ फिशरीज टेक्नॉलॉजी) या संस्थेचे शास्त्रज्ञ डॉ. भूपेंद्रनाथ यांनी 'बीआरडी' (बायकॅच रिडक्शन डिव्हाईस) नावाचे अभिनव जाळे तयार केले आहे. या जाळ्यात फक्त मोठे मासे अडकतात व लहान सुखरूप बाहेर जातात. या जाळ्याचे भारतातले पहिले प्रात्यक्षिक १२ एप्रिलला हर्णै येथे होणार असून ते मासळी पुनरुत्पादनासाठी वरदान ठरणार आहे.

सद्यःस्थितीत मासळी दुष्काळामुळे मच्छीमार बांधव हतबल झाले आहेत. मत्स्यदुष्काळ जाहीर करावा, अशी जोरदार मागणी केली जात आहे व मच्छीमारांनाही कर्जमाफी मिळावी म्हणून मोर्चे काढले जात आहेत. या परिस्थितीला सागरी प्रदूषण व अन्य कारणांबरोबरच सरसकट होणारी मासेमारी कारणीभूत आहे. जाळ्यात सरसकट लहान-मोठे मासे पकडले जातात. लहान आकाराचे मासे दर न मिळाल्याने वाया जातात. यामुळे प्रजोत्पादन थांबते. त्यामुळे मासळी पुनरुत्पादन कमालीचे घटले आहे. यासाठी आता कोचीनच्या स्वीफ्ट (सेंट्रल इन्स्टिट्यूट ऑफ फिशरीज

पान २ वर ▶

जाळ्याचे वैशिष्ट्य

- मोठे मासेच अडकणार, लहान मासे सुखरूप बाहेर पडणार
- मासे व कोळंबी वेगवेगळ्या भागांत जाणार
- मत्स्य पुनरुत्पादनासाठी वरदान
- भारतातले पहिले प्रात्यक्षिक हर्णैत
- आंतरराष्ट्रीय पातळीवर पाच हजार डॉलरचे बक्षीस

▶ पान १ वरून

टेक्नॉलॉजी) या संस्थेचे शास्त्रज्ञ डॉ. भूपेंद्रनाथ यांनी बीआरडी (बायकॅच रिडक्शन डिव्हाईस) नावाचे अभिनव जाळे तयार केले आहे.

सध्या मासेमारी करताना डोलीलांबी खोल वापरतात. त्याऐवजी बीआरडी बसवला की मोठेच मासे जाळ्यात अडकतील व लहान मासे सुखरूपपणे बाहेर पडतील, अशी रचना करण्यात आली आहे. मासे पकडण्यासाठी जे जाळे वापरतात त्यांचा आकार सर्वसाधारणपणे शंकरपाळीच्या आकाराचा असतो; मात्र बीआरडी जाळ्याचा आकार चौकोनी ठेवला आहे. तसेच याची रचना अशी करण्यात आली आहे, की मासे एका बाजूला जातात व कोळंबी एका बाजूला. त्यामुळे हे जाळे मत्स्य पुनरुत्पादनासाठी वरदान ठरणार आहे. या जाळ्याला नुकतेच आंतरराष्ट्रीय स्तरावर पाच हजार डॉलरचे पारितोषिकही मिळाले आहे. या जाळ्याचे भारतातले पहिले प्रात्यक्षिक १२ एप्रिलला हर्णै बंदरात होणार आहे. स्वीफ्ट, कॅमेरॉन इंटरनॅशनल, मुंबई, मत्स्य महाविद्यालय शिरगाव, रत्नागिरी आणि हर्णै पाज फिटींग ट्रेडिंग अँड क्रेडिट को-ऑप. सोसायटी लिमिटेड, पंदरी यांच्या संयुक्त विद्यमाने हे प्रात्यक्षिक आयोजित करण्यात आले आहे. कॅमेरॉन इंटरनॅशनल, मुंबईचे अमर श्रीधरानी यांनी प्रात्यक्षिक पुरस्कृत केले असून मत्स्य महाविद्यालय, रत्नागिरीचे सहयोगी अधिष्ठाता डॉ. शेखर कोवळे, हर्णैपाज सोसायटीचे माजी अध्यक्ष नारायण रघुवीर, विद्यमान अध्यक्ष विष्णू पावसे यांच्या सहकार्यामुळे भारतात या जाळ्याचे पहिले प्रात्यक्षिक हर्णैमध्ये पार पडणार आहे. १२ एप्रिलला सकाळी ६ वाजता हर्णै बंदरातून दोन मच्छीमारी नौका घेऊन समुद्रात बीआरडी जाळ्याद्वारे मासेमारी करण्यात येणार आहे व मच्छीमारांना प्रात्यक्षिक दाखविण्यात येणार आहे. या जाळ्याबद्दल अधिक माहिती हवी असल्यास हर्णैपाज सोसायटी, दूरध्वनी (०२३५८) २४३२४२, मत्स्य महाविद्यालय, रत्नागिरी (०२३५२) २३२२४१ येथे संपर्क साधावा.

Press coverage of Awareness cum Demonstration Campaign on Bycatch Reduction Device (JFE-SSD), at Ratnagiri, Maharashtra-1

'ऑपरेशन बीआरडी' यशस्वी

मच्छीमार अचंबित : डॉ. भूपेंद्रनाथ यांच्या प्रयत्नांना यश

सुनील कदम : सकाळ वृत्तसेवा

दापोली, ता. १२ : सकाळी सहा वाजता दोन नौका हर्णै बंदरातून सुटल्या. समुद्राच्या लाटा कापत १८ मीटर खोल पाण्यात पोहोचल्या आणि मग टीम कामाला लागली. विकसित केलेले मोठे मासे पकडणारे 'बीआरडी' जाळे जोडण्यात आले आणि 'ऑपरेशन बीआरडी'ला सुरवात झाली. जाळे पाण्यात सोडण्यात आले आणि मासेमारीला सुरवात झाली. ठराविक वेळेनंतर बीआरडी जाळे ओढण्यात आले आणि आत सापडलेले फक्त मोठे मासे पाहून व कोळंबी व मासे वेगवेगळे झालेले पाहून मच्छीमार हरखून गेले. भारतात प्रथमच घेण्यात आलेले बीआरडी जाळ्याचे प्रात्यक्षिक यशस्वी झाले.

सद्यःस्थितीत लहान-मोठे मासे सरसकट पकडल्यामुळे माशांचे पुनरुत्पादन घटल्याने **पान २ वर** ▶

हर्णै : येथील बंदरात शनिवारी बीआरडी जाळ्याच्या यशस्वी प्रात्यक्षिकानंतर डॉ. भूपेंद्रनाथ, डॉ. शेखर कोवळे आदी.

'सकाळ'ला धन्यवाद

या बाबतचे वृत्त 'सकाळ'ने उत्तमरीत्या प्रथम प्रसिद्ध केल्याबद्दल डॉ. भूपेंद्रनाथ, डॉ. शेखर कोवळे यांनी 'सकाळ'ला धन्यवाद दिले. या वृत्तामुळे उत्स्फूर्त प्रतिसाद मिळाल्याचे त्यांनी आवर्जून सांगितले.

'ऑपरेशन बीआरडी' यशस्वी

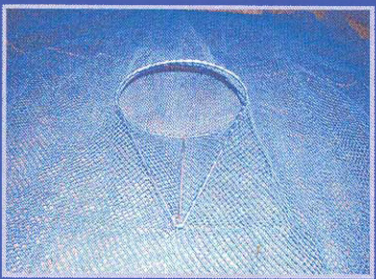
▶ **पान १ वरून**

मच्छीमारांना मासळी दुष्काळाला सामोरे जावे लागत आहे. लहान माशांना किंमत मिळत नाहीत; पण त्यामुळे पुनरुत्पादन थांबते. हे मत्स्य व्यवसायासाठी धोकादायक आहे. यासाठीच कोचीनच्या सिफ्ट (सेंट्रल इन्स्टिट्यूट ऑफ फिशरिज टेक्नॉलॉजी) या संस्थेचे शास्त्रज्ञ डॉ. भूपेंद्रनाथ यांनी फक्त मोठे मासे पकडणारे व कोळंबी व इतर मासे वेगवेगळे करणारे 'बीआरडी' (बायकॅच रिडक्शन डिव्हॉईस) नावाचे अभिनव जाळे तयार केले आहे. मत्स्य महाविद्यालय, शिरगाव व रत्नागिरी, कॅमेरॉन इंटरनॅशनल, मुंबई आणि हर्णै पाज फिशिंग सोसायटी यांच्या संयुक्त विद्यमाने भारतातील या जाळ्याचे पहिले प्रात्यक्षिक आज हर्णै बंदरात आयोजित केले होते. सकाळी सहा वाजता प्रात्यक्षिकाला सुरवात झाली. या जाळ्याचे निर्मिती शास्त्रज्ञ डॉ. भूपेंद्रनाथ, मत्स्य महाविद्यालयाचे सहयोगी अधिष्ठाता डॉ. शेखर कोवळे, डॉ. मोहिते, डॉ. शिरधनकर, कॅमेरॉनचे अभिजित जाधव, मच्छीमार नेते नारायण रघुवीर, हर्णै पाज सोसायटीचे अध्यक्ष विष्णू पावसे, नामदेव पावसे, नामदेव शिरगावकर व मच्छीमार नौकामालक ऑपरेशन बीआरडीमध्ये सहभागी झाले होते. १८ मीटर खोल पाण्यात जाऊन या टीमने बीआरडीची चाचणी घेतली आणि ती यशस्वी झाली. वीस लाख खर्च करून व सतत तीन वर्षे संशोधन करून डॉ. भूपेंद्रनाथ यांनी तयार केलेले हे जाळे शाश्वत मासेमारीसाठी व मासळी पुनरुत्पादनासाठी वरदान ठरणार आहे. आज प्रात्यक्षिक घेताना मच्छीमार नौकामालकांनी या जाळ्यात काही बदल सुचविले आहेत.

मोठे मासे पकडणारे व कोळंबी आणि मासे वेगवेगळे करणाऱ्या या जाळ्याची माहिती समुद्रातून हर्णै बंदरात आल्यावर तेथे जमलेल्या मच्छीमारांना पुन्हा देण्यात आली. या जाळ्याची किंमत साडेचार हजार रुपये आहे. हे जाळे पाहता यावे म्हणून याचे मॉडेल मत्स्य महाविद्यालय, रत्नागिरी, हर्णै पाज सोसायटी, पाजपंढरी व कासारवेली येथील सोसायटीत ठेवण्यात येणार आहे. त्याचबरोबर उद्या कासारवेली येथे प्रात्यक्षिक दाखविण्यात येणार आहे. हे जाळे मासळी पुनरुत्पादनासाठी वरदान ठरणार असल्याचे डॉ. शेखर कोवळे यांनी सांगितले. जाळ्याच्या अधिक माहितीसाठी मच्छीमारांनी मत्स्य महाविद्यालय (दूरध्वनी : ०२३५२- २३२२४१) व हर्णै पाज सोसायटी (०२३५८- २४३३४२) येथे संपर्क साधावा, असे आवाहन त्यांनी केले आहे.

Press coverage of Awareness cum Demonstration Campaign on Bycatch Reduction Device (JFE-SSD), at Ratnagiri, Maharashtra - 2







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