

Performance Evaluation of Bigeye Bycatch Reduction Device in the Seas off Cochin, India

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Trawling is one of the most non-selective methods of fish capture. Incidental bycatch and discards are serious issues related to trawling, leading to the depletion of the resources and biodiversity. Devices used to reduce bycatch from fishing gear are known as Bycatch Reduction Devices (BRDs). Bigeye BRD consists of a horizontal slit in the upper part of the codend or hind belly, where the opening is maintained by means of floats and sinkers. Comparative performance evaluation of Bigeye BRDs fixed at two different positions on shrimp trawl codends was conducted off Cochin, during 2006-2007. Bigeye BRDs positioned at (i) 0.5 m from the leading edge of the codend (Bigeye-0.5) and (ii) 1.5 m from the distal end of codend (Bigeye-1.5) were constructed on 20 mm diamond mesh codends. Comparative field trials with Bigeye-0.5 and Bigeye-1.5 BRDs in the seas off Cochin have given bycatch exclusion rates ranging from 8 to 11% and shrimp loss ranging from 1 to 2%. Among the two Bigeye BRDs evaluated, Bigeye-1.5 performed comparatively better in terms of bycatch exclusion. Bigeye BRD is simple in design, easy to fabricate and incurs low cost. Considering these advantages, Bigeye BRD positioned at 1.5 m from the distal end of the codend has potential for adoption by the shrimp trawling industry in India to reduce finfish bycatch from shrimp trawls.

Keywords: Trawling, bycatch, discards, bycatch reduction devices, bigeye BRD

Bottom trawling is widely employed for catching shrimps. Bycatch and discards is a serious problem leading to the depletion of the resources and biodiversity (Alverson *et al.*, 1994; Clucas, 1997; Harrington *et al.*, 2005; Alverson & Hughes., 1996, Boopendranath, 2009). The term bycatch means that portion of catch other than target species caught while fishing, which are either retained or discarded (Alverson *et al.*, 1994). Average annual global discards, has been estimated to be 7.3 million tonnes (Kelleher, 2004). Davies *et al.* (2009) gave a new definition "bycatch is catch that is either unused or unmanaged" and estimated global marine fisheries bycatch as 40.3 million tonnes based on the new definition. Due to the multi species nature of Indian fisheries, bottom trawling accounts for considerable amount of non-shrimp resources. About 40% of the trawl bycatch landed in India consisted of

juveniles (Pillai, 1998). Devices used to reduce bycatch from fishing gear are known as Bycatch Reduction Devices (BRDs) (Mitchell *et al.*, 1995; Broadhurst, 2000; Boopendranath *et al.*, 2008; 2010). 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 (Mitchell *et al.*, 1995; Boopendranath *et al.*, 2006, 2008, 2010; Boopendranath, 2007; Gibinkumar, 2008; Sabu, 2008).

Bigeye BRD consists of a simple horizontal slit in the upper part of the codend or hind belly, where the opening is maintained by means of floats and sinkers or by binding with twine. Differences in the behaviour of fish and shrimp are utilized in the design of this category of BRDs. Fishes that enter the codend are given opportunity

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to swim back and escape by providing slits in the netting on the top side of the codend or hind belly, while shrimps are retained in the codend. The Bigeye BRD is very simple in design and can be easily incorporated in an existing commercial trawl. Size of the slit can be easily adjusted according to the size of the animals, which need to be excluded (Robins *et al.*, 1999). Large slits on the top of the codend or side panels are used to exclude turtles and large species like sting rays and sharks in Australia's Northern prawn trawl fisheries and this device is referred to as John Thomas Bigeye TED (Day, 2000). A Bigeye BRD having 300 mm wide opening with floats and chain weight positioned at 1.6 m from the distal end of the codend was used in the Northern Prawn Trawl Fishery, Australia (DPI-NSW, 2010).

Experimental and commercial trawl fishing with Bigeye BRDs have been conducted in various fisheries (GBR-MPA, 2003; Brewer *et al.*, 2006; Robins *et al.*, 1999; Day, 2000; DPI-NSW, 2010). The present study was conducted to assess the performance of Bigeye bycatch reduction device and its optimum position in the codend, for use in mechanized shrimp trawls operated in Indian waters.

Materials and Methods

Comparative performance evaluation of Bigeye BRDs fixed at two different positions on shrimp trawl codends was conducted off Cochin, southwest coast of India, during May to July 2006 and April 2007 onboard the research vessel, MFV Sagar Shakthi (wooden trawler 15.24 m L_{OA} , 30 GRT, 223 bhp @ 1800 rpm Ruston MWM engine), Central Institute of Fisheries Technology, Cochin, India. The experimental fishing operations were conducted during daytime, in the traditional shrimp fishing grounds at a depth ranging between 9 and 32 m in the seas off Cochin (India) (Fig. 1). Bigeye BRDs positioned at (i) 0.5 m from the leading edge of the codend (Bigeye-0.5) and (ii) 1.5 m from the distal end of codend (Bigeye-1.5) were constructed on 20 mm diamond mesh codends (Fig. 2). A slit was provided on the top of the codend by cutting 15 meshes in the twine-wise direction across the net section. The Bigeye BRD was positioned in a commercial type codend of 5 m length constructed of 20 mm mesh polyethylene (PE) netting. Four sinkers (2x30 g and 2x125 g) and four floats with sufficient extra-buoyancy were used to keep the slit vertically open (Fig. 2). Comparative fishing experiments were conducted using a commercial shrimp trawl design of 28.8 m

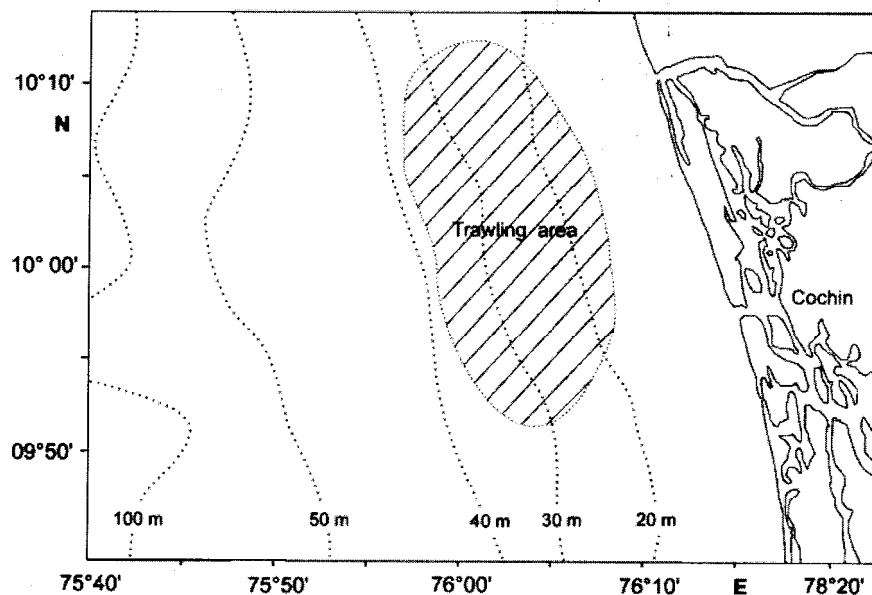


Fig. 1. Fishing area

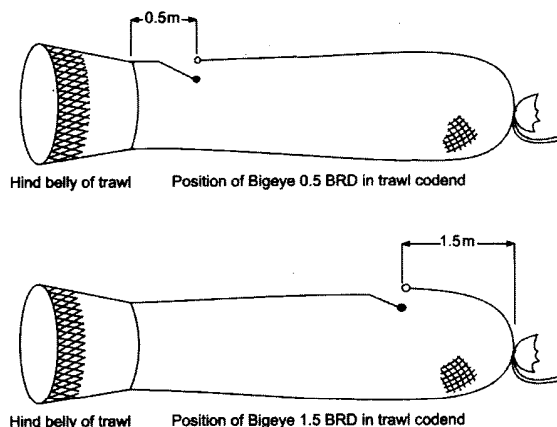


Fig. 2. Positioning of the Bigeye-0.5 (top) and Bigeye-1.5 (bottom) BRDs in trawl codend

head rope length. The shrimp trawl was rigged with V-type steel otter boards of size 1420x790 mm size (80 kg each) and 20 m double bridles. The net was made of knotted PE netting with nominal mesh size of 35 mm in the front trawl sections decreasing to 30 mm in the aft part of the net.

Results of fourteen paired hauls of 1 to 1.5 h duration with an average vessel speed of 2.5 knots were used for the analysis. Both retained and excluded catches were sorted and identified up to species level and length statistics were recorded, in order to determine selectivity parameters such as selection lengths (L_{50} , L_{25} and L_{75}), selection range (SR) and selection ogive and bycatch exclusion characteristics of the BRD. In the case of large volumes of catch, sub-samples were taken for analysis. In the case of fishes and shrimps, total length (TL) was measured and for cephalopods, mantle length (ML) and for crabs, carapace length (CL) were measured. Covered codend method, adapted from Sparre *et al.* (1989) and Wileman *et al.* (1996) using small mesh (12 mm polyamide netting) cover over BRD exit opening (CIFT, 2003) was adopted for selectivity experiments.

Results and Discussion

Performance of Bigeye-0.5 BRD

The total catch obtained by the codend fixed with Bigeye-0.5 BRD was 71.79 kg and

Table 1. Results of experiments with Bigeye BRDs

Parameters	Bigeye-0.5	Bigeye-1.5
No. of hauls	14	14
Total catch (kg)	71.79	81.49
CPUE (kg.h ⁻¹)	5.60	6.15
Retained catch (%)	93.87	90.83
Excluded catch (%)	6.13	9.17
Retained shrimp catch (%)	99.19	97.73
Excluded shrimp catch (%)	0.81	2.27
Retained bycatch (catch other than shrimps) (%)	92.17	88.58
Excluded bycatch (catch other than shrimps) (%)	7.83	11.42
No. of species caught	61	70
Fish species	48	55
Shrimp species	6	5
Other species	7	10
100% exclusion (No. of species)	0	6
>50% exclusion (No. of species)	0	5
Up to 50% exclusion (No. of species)	20	25
0% exclusion (No. of species)	41	34

mean CPUE was 5.6 kg.h⁻¹. Of the total catch, 93.87% was retained in the codend and 6.13% was excluded (Tables 1, 2). Bycatch (catch other than shrimp) exclusion from the BRD was 7.83% of total catch and the shrimp loss was only 0.81% in terms of weight. The overall catch during this period while using this BRD consisted of 48 species of finfishes, 6 species of shrimps, 3 species of crabs, 1 species of cephalopod, 1 species of stomatopod, 1 species of echinoderm and 1 species of jellyfish. No species showed more than 50% exclusion from this BRD (Table 1).

Among the 61 species encountered, 20 species, *viz.* *Stolephorus indicus*, *Leiognathus bindus*, *Esculosa thoracata*, *Stolephorus commersonnii*, *Sardinella longiceps*, *Stolephorus waitei*, *Thryssa mystax*, *Encrasicholina devisii*, *Anadontostoma chacunda*, *Megalaspis cordyla*, *Dussumieria acuta*, *Pampus argenteus*, *Pomadasys maculata*, *Johnius carouna*, *Johnius borneensis*, *Secutor insidiator*, *Charybdis natator*, *Portunus sanguinolentus*, *Metapenaeus dobsoni* and

Table 2. Group-wise exclusion rate due to the installation of Bigeye BRD

Bigeye type	Species groups	Encountered catch, kg	Retained catch, %	Excluded catch, %
Bigeye-0.5	All species	71.79	93.87	6.13
	Finfishes	39.29	89.19	10.81
	Shrimps	17.35	99.19	0.81
	Crabs	1.03	98.54	1.46
	Cephalopods	5.08	100.00	0.00
	Miscellaneous	8.89	100.00	0.00
Bigeye-1.5	All species	81.49	90.83	9.17
	Finfishes	42.60	83.62	16.38
	Shrimps	20.01	97.73	2.27
	Crabs	0.34	100.00	0.00
	Cephalopods	2.00	99.25	0.75
	Miscellaneous	16.54	100.00	0.00

Parapenaopsis stylifera showed exclusion upto 50% from the Big eye BRD. Forty-one species did not show any exclusion through the BRD. Among the target shrimps, *Metapenaeus dobsoni* showed 98.35% retention and other shrimps, viz. *Parapenaopsis stylifera*, *Fenneropenaeus indicus*, *Metapenaeus monoceros* and *Metapenaeus affinis* showed 100% retention in the main codend (Table 3).

Among the species encountered, finfishes showed an overall exclusion of 10.77%, followed by crabs (1.46%) and shrimps (0.81%) (Table 2).

Performance of Bigeye-1.5 BRD

The total catch obtained during Bigeye-1.5 BRD installed operations was 81.49 kg with a mean CPUE of 6.15 kg.h⁻¹. Of the total catch, 90.83% was retained in the codend and 9.17% was excluded. Bycatch (catch other than shrimp) exclusion from this BRD was 11.42% of total catch and shrimp loss was 2.27%. Among the target catch *Parapenaopsis stylifera*, *Fenneropenaeus indicus*, *Metapenaeus affinis* and *Metapenaeus dobsoni* showed more than 97% retention in the codend. The overall catch during the period of observations consisted of 55 species of finfishes, 5 species of shrimps, 3 species of crabs, molluscan shells of 2 species, 1 species

Table 3. Species-wise exclusion rate in Bigeye-0.5 BRD

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
<i>Stolephorus indicus</i>	0.21	51.64	48.36
<i>Leiognathus bindus</i>	0.22	63.64	36.36
<i>Escualosa thoracata</i>	0.08	75.00	25.00
<i>Stolephorus commersonnii</i>	2.82	76.24	23.76
<i>Sardinella longiceps</i>	14.04	82.48	17.52
<i>Stolephorus waitei</i>	2.28	85.09	14.91
<i>Thryssa mystax</i>	0.23	86.96	13.04
<i>Encrasicholina devisii</i>	0.12	87.50	12.50
<i>Anadontostoma chacunda</i>	0.35	88.57	11.43
<i>Megalaspis cordyla</i>	3.90	92.05	7.95
<i>Charybdis natator</i>	0.07	92.31	7.69
<i>Dussumieria acuta</i>	0.62	95.16	4.84
<i>Pampus argenteus</i>	3.58	93.02	2.79
<i>Pomadasys maculate</i>	0.19	97.37	2.63
<i>Johnius carouna</i>	0.51	98.04	1.96
<i>Metapenaeus dobsoni</i>	4.25	98.35	1.65
<i>Johnius borneensis</i>	1.03	98.54	1.46
<i>Portunus sanguinolentus</i>	0.95	98.95	1.05
<i>Secutor insidiator</i>	2.56	99.22	0.78
<i>Parapenaopsis stylifera</i>	12.13	99.42	0.58
<i>Alepes djedaba</i>	1.23	100.00	0.00
Miscellaneous species	20.61	100.00	0.00
All species	71.79	93.87	6.13

Table 4. Species- wise exclusion rate in Bigeye-1.5 BRD

Species	Encountered catch, kg	Retained catch, %	Excluded catch, %
<i>Ambassis ambassis</i>	0.01	0.00	100.00
<i>Gerres limbatus</i>	0.01	0.00	100.00
<i>Mene maculata</i>	0.02	0.00	100.00
<i>Peletus quadrilineatus</i>	0.02	0.00	100.00
<i>Secutor ruconius</i>	0.23	0.00	100.00
<i>Valamugil cunnesius</i>	0.02	0.00	100.00
<i>Johnius borneensis</i>	0.06	27.27	72.73
<i>Rastrelliger kanagurta</i>	2.94	30.49	69.51
<i>Parastromateus niger</i>	0.04	42.86	57.14
<i>Johnius carutta</i>	0.23	43.48	56.52
<i>Sardinella longiceps</i>	3.68	47.83	52.17
<i>Nemipterus mesoprion</i>	0.03	50.00	50.00
<i>Alepes djedaba</i>	0.37	59.46	40.54
<i>Otolithes ruber</i>	0.45	64.44	35.56
<i>Megalaspis cordyla</i>	1.84	68.48	31.52
<i>Encrasicholina devisii</i>	0.05	70.00	30.00
<i>Trypauchen vagina</i>	1.31	76.63	23.37
<i>Lagocephalus spadiceus</i>	0.87	77.01	22.99
<i>Anadontostoma chacunda</i>	0.79	77.22	22.78
<i>Metapenaeus monoceros</i>	0.14	81.75	18.25
<i>Thryssa mystax</i>	0.34	82.35	17.65
<i>Stolephorus commersonnii</i>	4.44	88.51	11.49
<i>Sphyræna obtusata</i>	0.14	88.89	11.11
<i>Leiognathus bindus</i>	0.20	90.00	10.00
<i>Stolephorus indicus</i>	1.06	92.45	7.55
<i>Scomberoides tala</i>	0.22	95.45	4.55
<i>Stolephorus waitei</i>	3.14	96.82	3.18
<i>Metapenaeus dobsoni</i>	11.53	97.14	2.86
<i>Pampus argenteus</i>	3.13	97.76	2.24
<i>Metapenaeus affinis</i>	1.05	98.10	1.90
<i>Lepturacanthus savala</i>	0.31	98.36	1.64
<i>Parapenaeopsis stylifera</i>	6.87	98.54	1.46
<i>Dussumieria acuta</i>	3.69	98.92	1.08
<i>Fenneropenaeus indicus</i>	0.56	99.11	0.89
<i>Uroteuthis (Photololigo) duwauceli</i>	2.00	99.25	0.75
<i>Secutor insidiator</i>	1.35	99.63	0.37
<i>Alepes kleinii</i>	0.04	100.00	0.00
Miscellaneous species	27.9	100.00	0.00
All species	81.49	90.83	9.17

of cephalopod, 1 species of elasmobranch, 1 species of stomatopod, 1 species of echinoderm and 1 species of jellyfish (Table 1).

Among the 70 species encountered, 6 species of finfishes, viz. *Ambassis ambassis*, *Gerrus limbatus*, *Mene maculata*, *Pelates quadrilineatus*, *Secutor ruconius* and *Valamugil cunnesius* were fully excluded. Five species, viz. *Johnius borneensis*, *Rastrelliger kanagurta*, *Parastromateus niger*, *Johnius carutta*, and *Sardinella longiceps* showed exclusion rates above 50%, and another 25 species showed exclusion up to 50% during the experiment. Thirty-four species did not show any exclusion from this BRD (Table 4). Among the species groups encountered, finfishes showed an overall exclusion of 16.38%, followed by shrimps (2.27%) and cephalopods (0.75%) (Table 2).

Selectivity analysis

In Bigeye BRD, fishes are given opportunity to escape by providing adequate opening at specific locations. The swimming speed is related to the body length of the species. Results of selectivity analysis of Bigeye-0.5 and Bigeye-1.5 BRDs in respect of four species, viz. *Megalaspis cordyla*, *Sardinella longiceps*, *Stolephorus indicus* and *Thryssa mystax* are presented in Table 5 and Fig. 3.

L_{50} values lower than length at first maturity (L_m) values indicate better exclusion opportunities for immature fishes below L_m , as the mid-length classes were plotted against excluded fractions in the selectivity estimates (Fig. 4). L_{50} values in respect of *Megalaspis cordyla*, *Sardinella longiceps*, *Stolephorus indicus* and *Thryssa mystax* were found to be lower than L_m for Bigeye-0.5. L_{50} values in respect of *Megalaspis cordyla*, *Sardinella longiceps* and *Stolephorus indicus* were found to be lower than L_m values for Bigeye-1.5 BRD. Comparatively lower L_{50} values obtained for species excluded through Bigeye-0.5 BRD is indicative of better escapement opportunity for juveniles of these species, compared to Bigeye-1.5 BRD (Table 5).

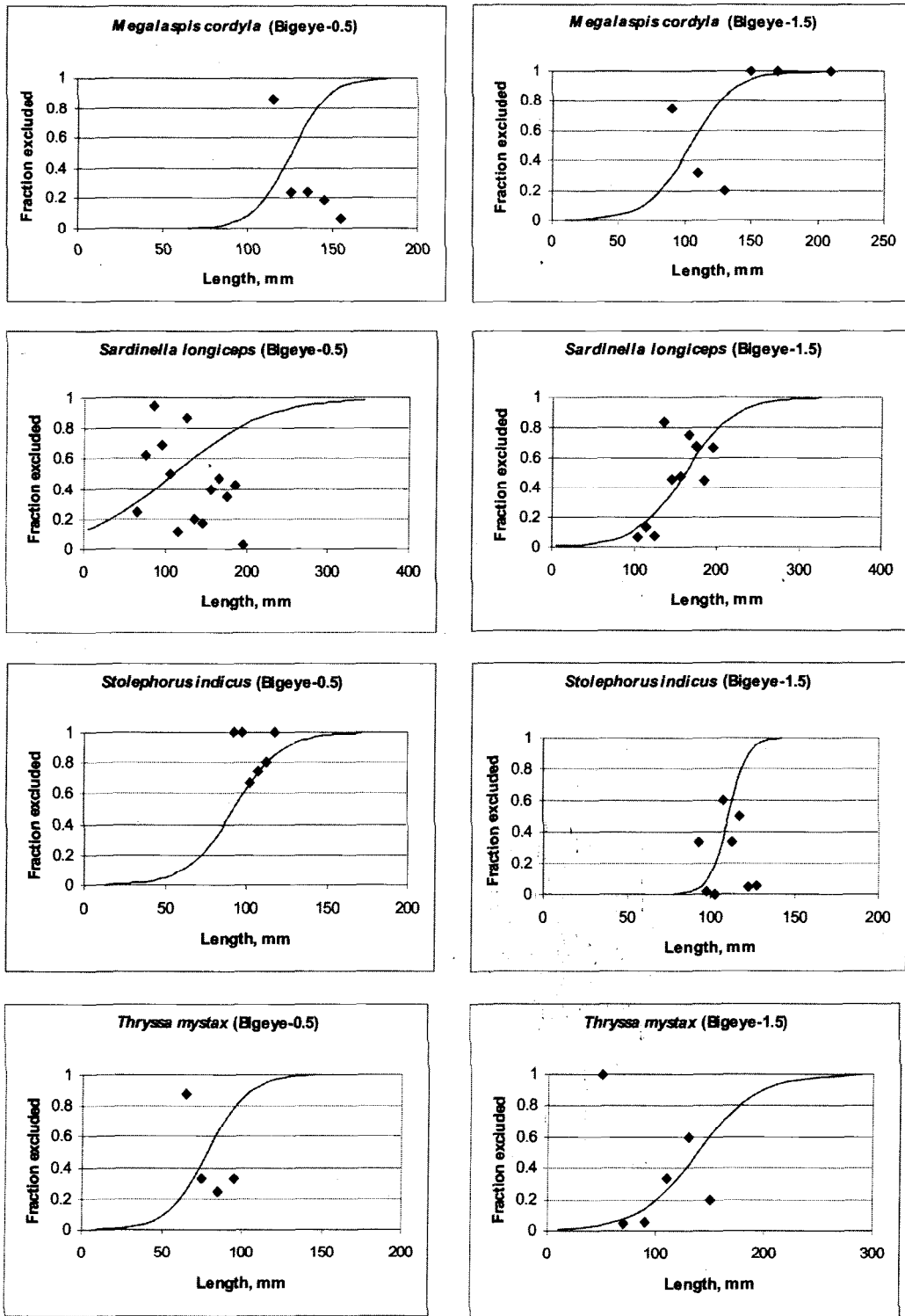


Fig. 3. Selectivity curves in respect of *Megalaspis cordyla*, *Sardinella longiceps*, *Stolephorus indicus* and *Thyrysa mystax*

Length wise exclusion analysis

Length wise exclusion characteristics of selected trawl caught species namely *Anadontostoma chacunda*, *Metapenaeus dobsoni*,

Sardinella longiceps, and *Stolephorus indicus* in Bigeye installed trawl operations are given in Fig. 4. In Bigeye-0.5, length classes from 81 to 100 mm and from 121 to 140 mm of *Anadontostoma chacunda* were 100% retained

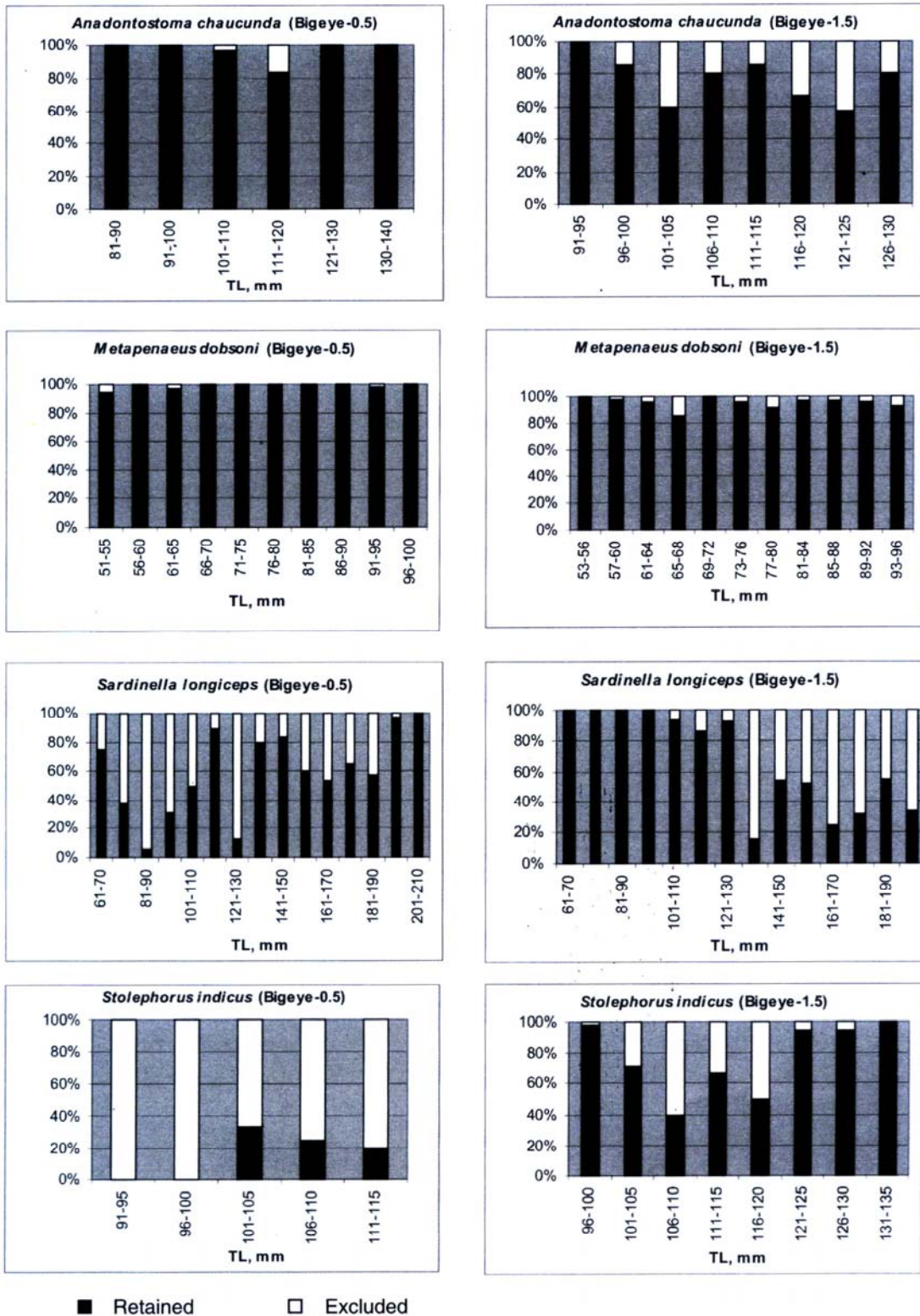


Fig. 4. Length-wise retention and exclusion of selected species in trawls fitted with Bigeye BRDs

and length classes from 101 to 120 mm showed exclusion up to 16%. In the case of Bigeye-1.5, 91-95 mm length class of *Anadontostoma chaucunda* showed 100%

retention and length classes from 96 to 130 mm showed exclusion in the range of 15-40%. In both Bigeye BRDs, length classes of *Metapenaeus dobsoni* from 51 to 100 mm

Table 5. Selectivity parameters for Bigeye BRDs

Species	Bigeye BRD	L _{25%}	L _{50%}	L _{75%}	Selection Range, mm	Length at first maturity (TL), mm
<i>Megalaspis cordyla</i>	Bigeye-0.5	113.40	125.21	137.02	23.61	250
	Bigeye-1.5	86.62	104.31	121.99	35.37	(FishBase, 2008)
<i>Sardinella longiceps</i>	Bigeye-0.5	48.69	109.78	170.87	122.18	150-162
	Bigeye-1.5	127.72	159.74	191.77	64.04	(FishBase, 2008)
<i>Stolephorus indicus</i>	Bigeye-0.5	76.37	92.22	108.07	31.70	120
	Bigeye-1.5	104.42	110.59	116.76	12.35	(FishBase, 2008)
<i>Thryssa mystax</i>	Bigeye-0.5	65.18	78.38	91.58	26.40	130
	Bigeye-1.5	122.41	155.76	189.11	66.70	(FishBase, 2008)

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

Bigeye BRD has been reported to reduce bycatch by 30 to 40% during day time and 10 to 15% during night or turbid conditions, in shrimp fleet, along Queensland east coast waters (Robins *et al.*, 1999). According to Queensland Fisheries Service (QFS) survey, Bigeye BRD has been the most preferred design to reduce bycatch in the east coast trawl fishery during 2001-2002 period (GBR-MPA, 2003). Experiment with Bigeye BRD having 1 m wide hole in the top of the net fitted forward of the usual TED position excluded 16.7% large elasmobranchs (Brewer *et al.*, 2006). In 2001, 78% of the Australia's Northern Prawn Trawl Fishery (NPF) fleet have been using Bigeye BRD in trawl nets (Brewer *et al.*, 2006).

In conclusion, experiments with two designs of Bigeye BRDs (Bigeye-0.5 and

Bigeye-1.5) in the seas off Cochin have given bycatch exclusion rates ranging from 8 to 11% and shrimp loss ranging from 1 to 2%. Among the two Bigeye BRDs evaluated, Bigeye-1.5 performed comparatively better in terms of bycatch exclusion. Exclusion in excess of 50% was observed in the case of 11 species in respect of Bigeye-1.5 while no species was excluded above 50% through Bigeye-0.5. Species excluded from Bigeye-1.5 was observed to be more diverse compared to Bigeye-0.5. Selectivity results have indicated comparatively better exclusion of juveniles from Bigeye-0.5 than the Bigeye-1.5 BRD.

The performance of the Bigeye BRDs in terms of shrimp retention was favourable as the retention rate was more than 97%. Besides, Bigeye BRD is simple in design, easy to install and costs less. Considering these advantages, Bigeye BRD positioned at 1.5 m from the distal end of the codend has the potential for adoption by the shrimp trawling industry in India to reduce finfish bycatch from shrimp trawls.

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