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Selectivity characteristics of 35 mm diamond and square mesh cod-ends with respect to *Johnius macrorhynus* and *Photopectoralis bindus* from east coast of India

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Abstract

Selectivity characteristics of 35 mm diamond and square mesh cod-ends were studied from commercial trawlers off Kakinada, Andhra Pradesh. The L_{25}, L_{50} and L_{75} of *Johnius macrorhynus* were 4.54, 7.04, 9.54 cm respectively for 35 mm diamond mesh cod-end, and 4.83, 7.17, 9.50 for square mesh cod-end. The selection ranges were 5.0 and 4.67 for *J. macrorhynus* for diamond and square mesh cod-end respectively. Selection factors for diamond and square were 2.01 and 2.04 respectively. The L_{25}, L_{50}, L_{75} values of *Photopectoralis bindus* were 2.30, 5.63, 8.96 cm respectively for diamond mesh cod-end and 3.85, 7.53, 11.21cm for square mesh cod-end. Selection ranges were 6.66 and 7.36 for diamond and square mesh cod-end respectively. Selection factor and selection ratio were 1.60 and 1.90 for diamond and 2.15 and 2.10 for square mesh cod-ends respectively. Overall, square mesh showed better selectivity over diamond mesh cod-end trawl net during the investigation.

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Introduction

Globally, prevailing fish stocks are threatened due to commercial and indiscriminate harvest of target and non-targeted species (Pauly *et al.,* 2002; Worm *et al.,* 2006). High efficiency and low selectivity nature of trawl net often generate large quantities of bycatch, leading to huge quantity of discards (Kennelly, 1995; Hill and Wassenberg, 2000; Ye *et al.,* 2000; Gamito and Cabral, 2003; Heales *et al.,* 2007; Boopendranath *et al.,* 2008). Though trawling contributes to the major part of marine fish landings in India (Thomas, 2016), Davies *et al.* (2009) estimated bycatch of 56.3% from Indian trawlers especially targeting shrimps. Alverson *et al.* (2004) estimated 17.9 to 39.5 million t of global marine resources discard each year. Perez Roda *et al.* (2019) estimated 9.1 million t of annual discards from global marine capture fisheries during 2010 to 2014. The discards generated by shrimp trawling were quantified as 18.6 million t, accounting for 27.3% of the total estimated discards (Kelleher, 2005). Boopendranath and Pravin (2005) cited responsible fishing gears regime as the need of the hour for suitable management strategies.

Selectivity characteristics of trawl net are determined by trawl selectivity experiments, considering that fishes retained and escaped are same with available population structure in ambient environment (Boopendranath and Pravin, 2005). Selectivity is determined from fishes that entered the net and escaped but retained by providing a cover cod-end with smaller mesh size at the trawl cod-end portion (Beverton and Holt, 1957; Pope *et al.,* 1975; Jones, 1976). Most researchers shifted their investigations towards selectivity from cod-end as majority of escapement occurs through cod-end portion (Boopendranath and Pravin, 2005). However, escapement of various species has been reported to occur through throat, bellies or lower panel of trawl net and hence it is significant to estimate escapement from the whole trawl net (Clark, 1963; Ellis, 1963; Bennett, 1984; Godo and Walsh, 1992). Boopendranath and Pravin (2005) cited that a covered cod-end method is reliable and suitable

for experiment in commercial trawling and additionally minimise sorting time and reduce non-targeted catches particularly in shrimp trawling.

Conversion of square to diamond mesh cod-end in trawl nets improves selectivity of cylindrical shape fishes but reduce selection on flat shape fishes (Walsh *et al.,* 1992; Millar and Fryer, 1999). Selectivity experiments with square mesh cod-end for different mesh sizes of various species have proven to be superior in Indian waters (Varghese *et al.,* 1988, 1996; Pillai *et al.,* 1998; Rajeswari *et al.,* 1998; Kunjipalu *et al.,* 2001; Raghu Prakash *et al.,* 2008; Madhu *et al.,* 2011; Boopendranath *et al.,* 2012; Edwin *et al.,* 2013; Madhu *et al.,* 2013, 2021). Hence, change over from the use of existing conventional diamond to square mesh cod-end of trawl nets will help to rejuvenate the overexploited marine resources.

The size of cod-end mesh opening of net and probability that the fishes come across are said to be main factors for cod-end selectivity of trawl nets (Campos and Fonseca, 2003; Macbeth *et al.,* 2004). Other factors that affect selectivity estimate are towing speed of craft, thickness of the twine used, size of net used, seasonal variation and shape of cod-end, population structure of species and abundance of target species (Wileman *et al.,* 1996; Madsen *et al.,* 1999; Dahm *et al.,* 2002; Ozbilgin and Wardle, 2002; Tokac *et al.,* 2004; He, 2007; Sala *et al.,* 2007; Broadhurst and Millar, 2009). One most common strategy of improving selection in cod-end has been to widen mesh size at the cod-end portion. However, mesh shape, number of twines, thickness and mesh number are factors that need to be considered (O'Neill and Mutch, 2017).

Croakers (Family: Sciaenidae) were landed to the tune of 90045 t in India in 2022 (CMFRI, 2023), which formed 2.6% of the total marine landings in the country. *Johnius macrorhynus* is a common croaker species found in the commercial landings. The size at first maturity for *J. macrorhynus* was indicated as 219.5 mm from Mumbai waters, where it was reported to be landed throughout the year (Telvekar *et al.,* 2006). *Johnius* spp. have less demand in fresh condition in domestic market but there is a high demand for it in salted, sun dried form and it also finds utility in fish meal preparation (Siddique *et al.,* 2012).

Photopectoralis bindus (Valenciennes, 1835) (Family: Leiognathidae) is landed in huge quantity by trawlers in Visakhapatnam, Andhra Pradesh (Raghu Prakash *et al*., 2008) and form an important group of inshore fisheries of India (Balan, 1963). In 2022, 59189 t of silverbellies were landed in India, forming 1.7% of the total marine fish landings during the year (CMFRI, 2023). It is a shallow water fish normally seen within 40 m depth (Raghu Prakash *et al.,* 2008). Silverbellies are beach dried, salt cured and utilised for preparation of fish meal (Balan, 1963). The size at first maturity for *P. bindus* was estimated at 87 mm (Balan, 1963). The present study was undertaken to compare the size selectivity of 35 mm diamond and square mesh cod-ends for *J. macrorhynus,* and *P. bindus* from east coast of India.

Materials and methods

Experimental fishing was conducted along east coast of India during the month of March 2020 onboard commercial trawler off Kakinada, Andhra Pradesh. Diamond and square mesh cod-ends were fabricated using 1 mm diameter twisted Polyethylene (PE) twine. Smaller diamond mesh cover of 20 mm mesh size was fabricated with 1 mm diameter PE twine and rigged at cod-end portion. In all, 24 (12 x 2) hauls were conducted using 35 mm square and diamond mesh cod-end trawl net. Details of craft and gear are given in Table 1. Uniform method of shooting and hauling was adopted in all fishing operation. Shooting and hauling speed were maintained at 0.6-1.2 and 0.2-1.2 knots respectively while towing speed was in the range of 2.3-2.5 knots at depth of 30-45 m. All the experimental fishing operations were carried out during daytime in commercial fishing grounds. The head rope length of the trawl net was 105 m rigged with rectangular shaped pair otter board with a weight of 85 kg and size of 1.5 x 1 m (length x breadth). Twenty-four hauls of 1 h duration were undertaken alternately for diamond and square mesh cod-ends. After each haul, the catch was segregated from main cod-end and cover. It was sorted species-wise and total quantity of catch was recorded from cod-end and cover. The quantity and size of the fishes retained and excluded in both the cod-ends were recorded. Length frequency data were collected for the catch in the cod-end and cover. The logistic model commonly used to describe trawl selectivity ogive (Sparre *et al.,* 1989) was fitted:

$SL = 1/1 + \exp(S1-S2*L)$

where SL is the function of the ogive defining for each length L, the fraction of fish retained in the cod-end and S1 and S2 are constants determined by linear least square estimation for each species.

The length classes retention of 25, 50 and 75% are represented as L_{25}, L_{50} and L_{75}, respectively throughout the study. The selection range (SR), selection factor (SF) and selection ratio (Sr) was calculated from cod-ends of diamond and square mesh trawl net. Considering the nominal mesh size, the calculation of SF and SR were done. The calculation of L_{25}, L_{50}, L_{75}, selection range, selection factor and selection ratio were done using the equations:

$L_{50} = (S1/S2)$

$L_{25} = (S1\text{-}ln\ 3) / S2$

$L_{75} = (S1+ ln\ 3) / S2$

Selection range = L_{75}-L_{25}

Selection factor = L_{50}/mesh size

Selection ratio = Selection range / Mesh size

Table 1. Fishing craft and gear details

Craft	
Type of craft	Wooden trawler
LOA (m)	12.6
Engine	Ashok Leyland Marine Diesel
Horse power (HP)	102
Navigation and electronic equipments	Compass, GPS, Echo sounder, VHF
No. of crew member	8-12
Gear	
Type of gear	Trawl
Head rope length (m)	105 m
Cod-end mesh size (mm)	35 both square and diamond
Cover cod-end mesh size (mm)	20 diamond mesh
Otter board (m)	1.5-1.0 (Length x breadth)

Results and discussion

The estimated $L_{25,}$ L_{50}, and L_{75} values of *J. macrorhynus* for 35 mm diamond mesh cod-end were 4.54, 7.04 and 9.54 cm respectively. The selection range (SR), selection factor (SF) and selection ratio (Sr) of 35 mm diamond mesh cod-end were observed as 5.0, 2.01 and 1.42 respectively. The estimated $L_{25,}$ L_{50} and L_{75} values of *J. macrorhynus* for 35 mm square mesh cod-end were 4.83, 7.17 and 9.50 cm respectively while the selection range (SR), selection factor (SF) and selection ratio (Sr) were 4.67, 2.04 and 1.33 respectively.

Selectivity parameters of *J. macrorhynus* for 35 mm diamond and square mesh cod-ends trawl nets are given in Table 2. The retained and escaped length-classes of *J. macrorhynus* and observed and estimated selectivity curve with respect to 35 mm diamond mesh cod-end (M CD) and cover (DM C) are given in Fig. 1 and that for 35 mm and square mesh cod-end (SM CD) and cover (SM C) are given in Fig. 2.

Experimental data of *J. macrorhynus* using 35 mm diamond mesh cod-end indicated that out of 342 individuals retained, 79.2% were retained in cod-end and 20.7% escaped into the cover cod-end and 77.5 and 22.4% of the individuals below the Lm_{50} (length at first maturity) were from main and cover cod-ends respectively. In the main cod-end 7.6% were above Lm_{50}. There was no escapement of species above Lm_{50} through cod-end to cover.

Table 2. Selectivity parameters of 35 mm diamond and square mesh cod-ends of trawl net for *J. macrorhynus*

J. macrorhynus	Diamond mesh cod-end	Square mesh cod-end
S1	3.10	3.37
S2	0.44	0.47
L25	4.54 cm	4.83cm
L50	7.04 cm	7.17cm
L75	9.54cm	9.50cm
Selection range	5.00	4.67
Selection factor	2.01	2.04
Selection ratio	1.42	1.33
Length at first maturity	21.95 cm (Telvekar *et al.,* 2006)	21.95 cm (Telvekar *et al.,* 2006)
Recommended cod-end mesh size	109 mm	107 mm

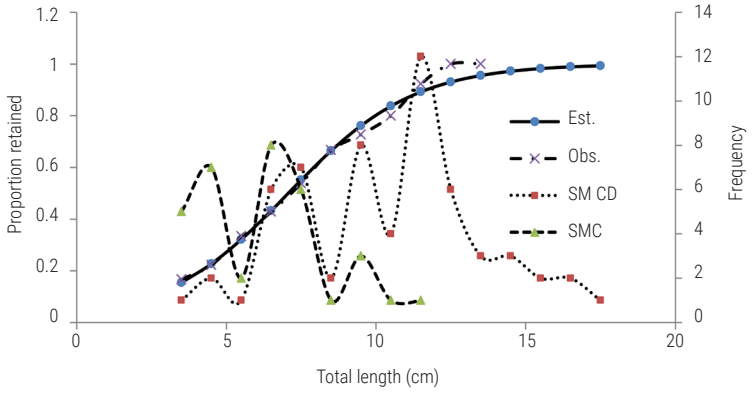

Fig. 1. Selection curve, length frequency distribution, observed and estimation plots of square mesh cod-end of *J. macrorhynus.* Est: Estimated value, Obs: Observed value, SM CD: Square mesh cod-end, SM C: Square mesh cover

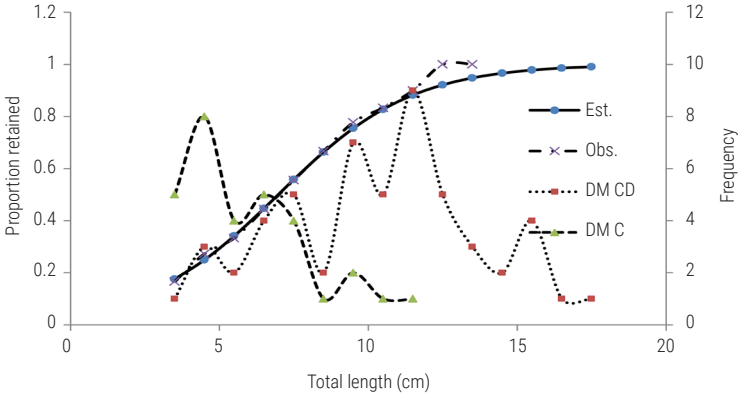

Fig. 2. Selection curve, length frequency distribution, observed and estimation plots of diamond mesh cod-end of *J .macrorhynus.* Est: Estimated value, Obs: Observed value, DM CD: Diamond mesh cod-end, DM C: Diamond mesh cover

In 35 mm square mesh out of the total 362 individuals retained, 67.9% was retained in cod-end and 32.3% escaped into cover. Out of the total number of individuals below Lm_{50} retained, 62.9 and 37.0% were in the cod-end and cover, respectively. In the cod-end, 12.7% were above Lm_{50}. No escapement of matured *J. macrorhynus* was observed from main cod-end through cover cod-end.

The estimated L_{25}, L_{50} and L_{75} of *P. bindus* for 35 mm diamond mesh cod-end were 2.30, 5.63, and 8.96 cm respectively while selection ranges, selection factor and selection ratio were 6.65, 1.60 and 1.90 respectively. The L_{25}, L_{50} and L_{75} values of *P. bindus* for 35 mm square mesh cod-end were 3.85, 7.53 and 11.21cm respectively with selection range, selection factor and selection ratio estimated as 7.36, 2.15 and 2.10 respectively. Estimated L_{25}, L_{50}, L_{75} values were relatively higher for square compared to diamond mesh cod-ends (Table 3). The retained and escaped length-frequency, observed and estimated selection curve for diamond and square mesh cod-ends and cover are given in Fig. 3 and 4.

Data of *P. bindus* for 35 mm diamond mesh cod-end showed that out of 321 individuals retained, 59.8 and 40.1% were retained in cod-end and cover respectively. Out of the individuals below Lm_{50}, 38.0 and 61.9% were from cod-end and cover respectively while of those above Lm_{50}, 98.2 and 1.72% were from cod-end and cover respectively.

Investigation on 35 mm square mesh cod-end revealed that out of 598 individuals of *P. bindus* captured, 53.8% were retained in the cod-end and 46.1% were retained in cover. Out of total number of individuals below Lm_{50}, 32.5% were in the cod-end and 67.5% in the cover; of the individuals above Lm_{50}, 87.1 and 12.8% were from cod-end and cover respectively.

Table 3. Selectivity parameters of 35 mm diamond and square mesh cod-end of trawl net for *P. bindus*

P. bindus	Diamond mesh cod-end	Square mesh cod-end
S1	1.86	2.11
S2	0.33	0.28
L_{50}	5.63	7.53 cm
L_{25}	2.30	3.85 cm
L_{75}	8.96	11.21 cm
Selection range	6.66	7.36
Selection factor	1.60	2.15
Selection ratio	1.90	2.10
Length at first maturity	8.7 cm (Balan, 1963)	8.7 cm (Balan, 1963)
Recommend cod-end mesh size	54 mm	40 mm

Mean selection length (MSL) is the length at which 50% of fishes escape through the webbing of meshes.

Mesh size = Mean selection length /Selection factor

To estimate the optimum cod-end mesh size to permit the fish which has attained maturity to escape, the mean selection length is substituted with length at first maturity (Lm_{50})

Optimum mesh size = Lm_{50}/Selection factor

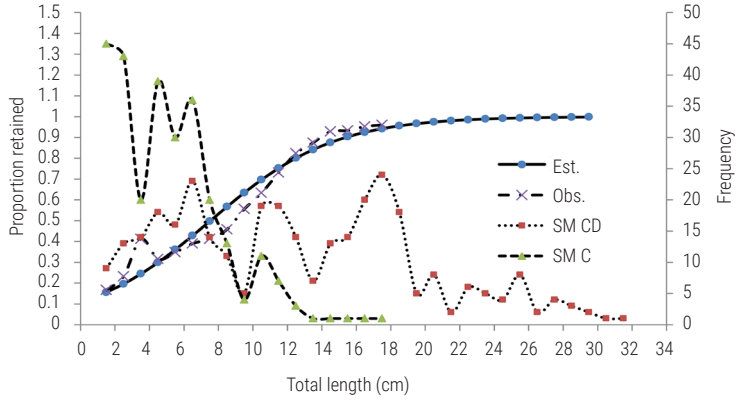

Fig. 3. Selection curve, length frequency distribution, observed and estimation plots of square mesh cod-end of *P. bindus*. Est: Estimated value, Obs: Observed value, SM CD: Square mesh cod-end, SM C: Square mesh cover

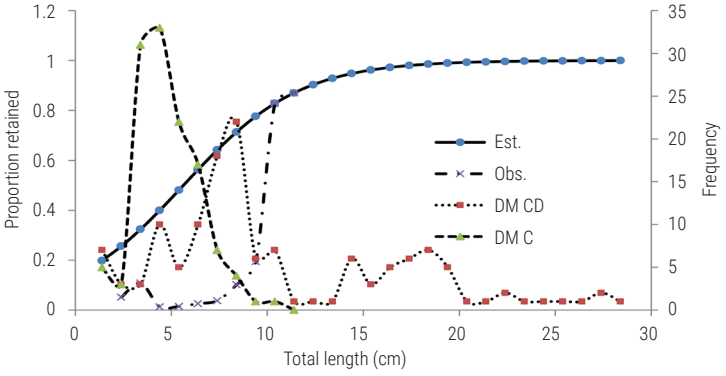

Fig. 4. Selection curve, length frequency distribution, observed and estimation plots of diamond mesh cod-end of *P. bindus*. Est: Estimated value, Obs: Observed value, DM CD: Diamond mesh cod-end, DM C: Diamond mesh cover

Selectivity of 35 mm square is higher than 35 diamond mesh cod-end. The calculated optimum mesh size for diamond and square mesh was 109 and 107 mm for *J. macrorhynus* respectively for selective fishing to maintain sustainable fisheries. The determined optimum mesh size of diamond and square mesh cod-ends for *P. bindus* was 54 mm and 40 mm for judicious exploitation.

Earlier investigations have reported that square mesh has greater escapement of immature fishes over diamond mesh cod-end for *Johnius* spp. which may be due to tapering of cod-end when tension is applied to net (Liu *et al*., 1985; Kunjipalu *et al*., 1994; Varghese *et al*., 1996; Kunjipalu *et al*., 2001). Kunjipalu *et al.* (2001) estimated L_{50}, L_{25}, L_{75} values for *Johnius* spp. as 10.21, 9.21 and 11.22 cm for 40 mm square mesh cod-end off Kochi. Slightly lower values were observed in the present study which might be due to the smaller mesh size deployed. Kunjipalu *et al*. (1994) recorded slightly higher values of L_{50}, L_{25}, L_{75} for 30 mm diamond (9.92, 7.63, 12.12 cm) and square (9.75, 8.26, 11.53 cm) mesh cod-ends which revealed higher L_{50} in diamond shape cod-end for the genus *Johnius* spp. off Kerala along the west coast of India. L_{50}, L_{25}, L_{75} (11.10, 10.70, 11.60 cm) values of *J. borneensis* for 40 mm diamond mesh cod-end reported from north-west Australian waters by Liu *et al.* (1985) was higher compared to the present study. Selectivity estimated for 20 mm diamond and square mesh cod-ends by Vargheese *et al.* (1996) for *Johnius* spp. were comparatively lower due to smaller mesh size used.

Kunjipalu *et al.* (1994) recorded L_{50}, L_{25}, L_{75} for *Leiognathus* spp. for 30 mm diamond and square cod-ends as 6.66, 5.67, 8.00 and 6.41, 5.39, 6.41 cm off Kochi. Vargheese *et al.* (1996) observed L_{50}, L_{25}, L_{75} as 4.74, 2.93, 6.79 cm and 5.36, 2.65, 8.00 cm for 20 mm diamond and square mesh cod-ends for *Leiognathus* spp. off Kochi. Kunjipalu *et al.* (2001) estimated L_{50}, L_{25}, L_{75} for 40 mm square mesh cod-end of *Leiognathus* spp. as 7.80, 7.47 and 8.13 respectively. Raghu Prakash *et al.* (2008) estimated L_{25}, L_{50}, L_{75} values for *P. bindus* as 5.52, 7.7 and 9.88 cm respectively for 40 mm square mesh cod-end along east coat of India. The L_{25} value recorded in the present study was lower as compared to an investigation carried out by Silvestre (1986) from Samar Sea, Philippines. Selection range in the present study was much higher in square and diamond mesh cod-end compared to a study carried out by Kunjipalu *et al*. (1994). Due to limited selectivity studies for *J. macrorhynus,* direct comparison cannot be made with the present study. This is the first investigation on selectivity of *J. macrorhynus* for 35 mm diamond and square mesh cod-ends from east coast of India. Considering the overall selectivity parameters, a square mesh showed more selectivity than diamond mesh cod-end for *P. bindus*.

This is the first report of selectivity study carried out on *J. macrorhynus* and *P. bindus* for 35 mm diamond and square mesh cod-ends along the Indian coast and thus this study forms a crucial baseline data for further selectivity studies. The L_{25} and L_{50}, values were relatively higher in square mesh over diamond mesh cod-ends. However, L_{75} was slightly higher for diamond mesh cod-end. Selection range and selection ratio were slightly higher in diamond shape mesh cod-end while selection factor is higher for square mesh cod-end for *J. macrorhynus* (Table 2).

Some studies reveal that a diamond mesh lumen tends to close when towing and prevent the fish from escaping out of the cod-end (Robertson, 1983; Robertson and Stewart, 1988; Isaksen *et al.,* 1990; Walsh *et al*., 1992; Varghese *et al*., 1996; Stergio *et al*., 1997; Tosunoglu, 2007; Boopendranath *et al.,* 2012).

Many authors have reported that square shaped cod-end was better in selectivity over conventional diamond meshes (Robertson, 1983; Robertson and Stewart, 1988; Casey *et al.,* 1992; Walsh *et al.,* 1992; Ju-Hee Lee *et al.,* 1994; Kunjupalu *et al.,* 1994; Lowry *et al.,* 1995; Vargheese *et al.,* 1996; Graham and Kynoch, 2001; Kunjupalu *et al.,* 2001; Campos *et al.,* 2002; Broadhurst *et al.,* 2004; Boopendranath and Pravin, 2005; Bahamon *et al.,* 2006; Guijjarro and Massuti, 2006; Bullough *et al.,* 2007; Raghu Prakash *et al*., 2008, 2009; Sistiaga *et al.,* 2009; Madhu *et al.,* 2011; Boopendranath *et al.,* 2012; Rajeswari *et al.,* 2013; Madhu, 2021). Pillai *et al.* (1996) observed that smaller size groups of *Nemipterus* sp., *Decapterus* sp., *Priacanthus* sp. and *Saurida* sp. had higher percentage of escapement in 40 and 50 mm square mesh cod-ends. The cod-end is a part where fishes accumulate and therefore becomes bulbous in shape (Robertson and Stewart, 1988; Reeves *et al.,* 1992). The target species body shape is also reported to influence the cod-end selectivity (McCracken, 1963; Rajeswari *et al.,* 2013). Factors such as body shape, maximum girth, stiffness of twine, swimming ability and species reaction to gear panels affect the escapement through the cod-end meshes (Thompson and Ben-Yami, 1984; Fryer, 1991; Campos and Fonseca, 2003; Campos *et al.,* 2003). Selection factors such as body shape, including slender and broad bodied fis are used for comparison of selective properties (Brandt,1963; McCracken, 1963; McLennan, 1992).

Modified mesh shape and size are generally used as a management tool (Millar and Fryer, 1999), since it provides an easier way to change the existing fishing gear system (Ragonese *et al.*, 2002). There is global interest for improving size and species selectivity to reduce unwanted catch and mortality from commercial trawl gears (Boopendranath and Pravin, 2005). In the current investigation, square mesh cod-end showed better selectivity over conventional diamond mesh cod-end for 35 mm trawl net for *J. macrorhynus and P. bindus*.

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