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Size Selectivity of Square Mesh Cod-end with respect to *Stolephorus commersoni* (Lacepède, 1803) and white fish, *Lactarius lactarius* (Bloch and Schneider, 1801) along East coast of India

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Abstract

Selectivity of trawl cod-ends square mesh with respect to *Stolephorus commersonii* and *Lactarius lactarius* were studied off Visakhapatnam along the east coast of India. Covered cod-end method was applied to assess selectivity parameters. The L_{25}, L_{50}, L_{75} values for 30 mm cod-end of *S. commersonii* were 10.56, 11.17 12.98 cm whereas selection range (SR), selection factor (SF) and selection ratio (Sr) were estimated at 2.42, 3.92 and 0.8 respectively. Estimated L_{25}, L_{50}, L_{75} value for 40 mm trawl cod-end of *L. lactarius* were 13.23, 14.95 and 16.93 cm whereas selection range (SR), selection factor (SF) and selection ratio (Sr) were 3.69, 3.73 and 0.9 respectively. The retention length for the square mesh cod-end found to be superior compared to conventional diamond mesh cod-end.

Keywords: Diamond mesh, selectivity, square mesh, trawl net

Introduction

Selectivity studies help gear technologists to identify the gear elements or the harvesting methods that allow the escapement of unwanted bycatch. Huge quantities of bycatch are generated from trawl nets due to their low selectivity and high efficiency (Kennelly, 1995). Large quantities of juvenile fishes and invertebrates end as discards in trawl fishery along the Indian coast (Gordon, 1991). The total bycatch generated by shrimp trawlers along Vishakhapatnam coast was 40410 t of which 32420 t was discarded and the remaining landed (Rao, 1988). The estimated quantity of commercially important species of finfish and cephalopods in trawl by-catch landed by multi-day commercial shrimp trawlers based at Visakhapatnam Fishing Harbor was on an average, 24,665.88 t per year during 2014 and 2015, of which, juveniles formed 12,757.16 t per year (Pralaya et al., 2021). The poor selectivity in trawl fishery is primarily due to the use of conventional diamond-shaped mesh in cod-ends. As a result, large numbers of juvenile and undersized fishes are caught below their minimum landing size, which in turn, increases the mortality of these species and also decreases their yield per recruit.

The cod-end mesh shape has been identified as an important factor determining the selectivity of a trawl (MacLennan, 1992). The "traditional" diamond-shaped mesh used in the cod-end stretches during the tow, reducing its selectivity when compared to square mesh, that remains open (Robertson & Stewart 1988). Studies have been undertaken to assess the selectivity of different types of meshes in the cod-ends. Selectivity studies along the east coast are limited to a few species with respect to square mesh cod-ends in trawl fishery of the Visakhapatnam coast (Prakash et al., 2008; Rajeswari et al., 2013). Studies have revealed that the introduction of square cod-ends could be a useful management tool for reducing discards along the Indian coast (Boopendranath & Pravin, 2005). However, these results cannot be applied directly for any whole region as trawl selectivity is influenced by other factors like gear design, craft or environment (Wileman et al., 1996).

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Anchovies (Family : Engraulidae), constitute one of the important pelagic resources along the Indian coast (Yohannan & Sivadas, 2003). The anchovies along the Indian coast are called whitebaits. They are marine coastal and schooling fishes, occurring in all seas in the area 60° N to 50° S (Whitehead et al., 1988; Whitehead, 1968). *S. commersoni* is predominant in the trawl catches along the east coast of India (Patadiya et al., 2018). Ten species of whitebaits are present in Indian waters. Five species namely *Encrasicholina devisi, E. punctifer, S. waitei, S. Commersonii* and *S. indicus* are contributing to the fishery in a commercial scale (Luther, 1979). Commercially anchovies have high demand in fresh condition and at the same time there is considerable market for sun-drying and for fishmeal production. Estimated landings of *S. indicus* during 2018-2019 were 105915 t (CMFRI, 2020), which formed 0.66% of total marine landings and 1.69 million metric tonnes of the pelagic finfish landings of India (DoF, 2020). Indian Anchovy is mostly harvested using purse seines, ring seines, gillnets and recently trawls have emerged as an important gear in the anchovy fishery (Yohannan & Sivadas, 2003). They are usually landed in considerable quantities by the small and medium size trawlers operating in coastal waters. Large quantities of immature fishes of both the species are landed by trawlers at Andhra Pradesh, due to the use of diamond mesh cod-ends with 10-20 mm (Jayaprakash, 2005). During trawling, the use of diamond mesh cod ends leads to narrowing at the middle of the cod-end causing the mesh lumen to almost close and hence juvenile fishes are retained in the cod-end (Varghese et al., 1988a; 1988b; Varghese & Kunjipalu, 1996; Pillai et al., 1998; Rajeshwari et al., 2010). Nair et al., 2021 reported the length at first maturity for *S. commersonnii* as 7.1 cm.

The white fish *Lactarius lactarius* (Bloch & Schneider, 1801) commonly known as false travelly belonging to the Family Lactariidae is widespread in Indo-west Pacific region from East Africa to Southeast Asia, north to Japan, south to Queensland, Australia and Fiji islands (Whitehead, 1968; Luther, 1979). The species is widely distributed in Indian waters forming local fisheries along the Indian coast. They are in high demand in coastal markets (Zacharia & Jayabalan, 2010; Pawase et al., 2015). The white fish is more abundant on the East coast than the West coast of India (Ruben, 1993). The annual production of *L. lactarius* of India during 2019-2020 was 0.19% of the total pelagic fishes landing (DoF, 2020). The fishes of 1 to 3 years of age is represented in the fishery and the length at first maturity is reported as 167.5 mm (Reuben et al., 1993). Studies on the length weight relationship, biology and growth profile, feeding habits has been studied (Rajani Gopal et al., 2018).

The over exploitation of undersized fishes leads to depletion of marine fish populations (Davies et al., 2009). The shape of the cod-end impacts the selectivity of cod-ends. The advantages and superiority of square mesh has been proven by various studies (Robertson, 1986; Robertson et al., 1986; Robertson & Stewart, 1988; Robertson & Ferrow, 1988; Robertson, 1993). In Indian waters, the advantages of square mesh cod-ends were shown by Kunjipalu et al., 1994; Varghese & Kunjipalu, 1996; Raghu Prakash et al., 2013; Rajeswari et al., 2013; Madhu et al., 2016., Madhu, 2021).

Though taxonomy, biology and population dynamics of *S. commersoni and Lactarius lactarius* in Indian waters has been reported (Murty & Vishnudatta, 1976; Zacharia & Jayabalan 2010; Nair et al., 2015) no work has been attempted on the size selectivity parameters of trawl cod-end with respect to these species. The present study was undertaken to study the size selectivity of square mesh cod-ends with respect to *S. commersoni* and *L. lactarius* along the east coast of India off Visakhapatnam in Bay of Bengal.

Materials and Methods

Selectivity experiments were carried out onboard Research Vessel CIFTECH 1 (l15.5 m LOA; 122 hp), off Visakhapatnam coast, using a 30 m demersal trawl fitted with 30 mm and 40 mm square mesh cod-ends. Covered cod-end method was adopted in the current study (Pope et al., 1975; Sparre et al., 1989). Cod-ends were constructed with high density polyethylene (HDPE) netting of 1.5 mm twine size. The square mesh cod-end was covered with a cover made of polyamide netting with 20 mm diamond mesh size and proportionately 1.5 times longer and larger than the cod end to minimise the masking effect of cod end by cover (Lok et al., 1997). Operations were carried out during the day time keeping shooting and hauling procedures identical. Hauls of one hour duration were made at a depth of 30-40 m. Towing speed was about 2.3 to 2.5 kn. The length frequency data were collected for the catch in the cod-end and cover. Proportion of fish of each length entering the net which are retained in the cod-end can be expressed as selectivity. Selection curve for the particular species is obtained when these proportions are plotted against the length.

The logistic model commonly used to describe trawl selection ogive (Sparre et al., 1989) was used in the study 'SL = 1/ 1+ exp(a-b*L)' where 'SL' is the function of the ogive defining for each length 'L', the fraction of fish retained in the cod-end; 'a' and 'b' are constants determined by linear least square estimation or maximum likelihood estimation for each species. The length at 25%, 50% and 75% retentions are represented as L_{50}, L_{25}, L_{75}. selection range (SR) and selection factor (SF) were calculated as L_{50} = (S1/ S2)

L_{25} = (S1 - ln 3)/S2, L_{75} = (S1 + ln 3) / S2, Selection range = $L_{75} - L_{25}$ and Selection factor = L_{50} / Mesh size

Results and Discussion

The details of fishing craft and gear is given in Table 1. The estimated selectivity parameters of *S. commersoni and L. lactarius* with square mesh cod end are given in Table 2. The observed and estimated selection curve along with the length frequencies of *S. commersoni* retained and excluded in the cod-end and cover from 30 mm square mesh cod-end is given in Fig 1.

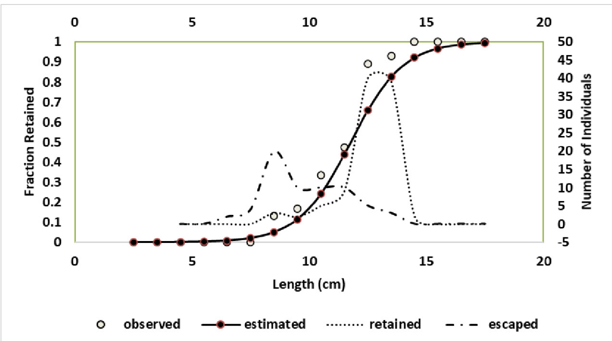

Fig. 1. The observed and estimated selection curve along with the length frequencies of *Stolephorus commersoni* retained and excluded in the cod end and cover from 30 mm square mesh cod-end

The escapement data of *L. lactarius* using 40 mm square mesh cod-end revealed that out of the total of 107 individuals that entered the trawl, 55 individuals escaped into the cover cod-end and 52 individuals were retained in the cod-end, with a total escapement of 51%. Out of the total number

Table 1. Details of fishing vessel and gear

Vessel	
Type of craft	Steel trawler
LOA	15.5
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
Cod-end mesh size (mm)	30 and 40 mm square
Cover cod-end mesh size (mm)	20 diamond mesh
Otter board (m)	1.5-1.0 (Length x breadth)

of *L. lactarius* individuals retained in the cod-end, 48 and 90% were below the L_{fm} (length at first maturity) of 16.75 cm from cod-end and cover cod-end respectively. Of the total catch 70% of the individuals were below the L--$_{fm}$ and 30% were above the L_{fm}. The optimum mesh size derived for *L. lactarius* from the size at first maturity and the selection factor from the present study was 45.2 mm for square mesh cod-end. The smooth sigmoid curves were obtained for *S.commersoni and L. lactarius*, which is a characteristic of most mobile gears like trawls (Wileman et al., 1996). As size increases, the percentage of fish retained also increases until escapement is zero and all fish is retained.

Proportion of fish of each length entering the net which are retained in the cod-end can be expressed as selectivity. The mean selection length L_{50} at which 50% of the fish is retained by the cod-end by equating the areas on the selection curve was estimated as 11.8 cm. The L_{25}, and L_{75} values for *S. commersoni* with 30 mm square mesh cod-end was 9.34 cm, and 11.81 cm respectively. Selection factor, selection range and selection ratio for *S. commersoni* were estimated as 3.92 and 2.42, 0.8 respectively. This is the first report of selectivity of 30 mm cod-end mesh for *S.commersoni*. Kunjipalu et al., 2001 reported lower L_{50} of 8.8 cm for *Stolephorus* sp. for 20 mm square mesh along Cochin coast of India.

Table 2. Details of selectivity parameters for *Stolephorus commersoni and Lactarius lactarius* in respect of square mesh cod-end

Parameters	Species	
Selectivity Parameters	*Stolephorus commersoni*	*Lactarius lactarius*
Mesh size	30 mm	40 mm
S1	10.6	8.9
S2	0.9	0.6
L_{50}	11.77 cm	14.95 cm
L_{25}	10.56 cm	13.23 cm
L_{75}	12.98 cm	16.93cm
Selection range (SR)	2.42	3.69
Selection factor (SF)	3.92	3.73
Selection ratio (SR)	0.8	0.9
Length at first maturity- female (FL, mm)	7.1 cm (Nair et al., 2021)	16.75 cm (Ruben et al. 1993)
Calculated Optimum cod-end mesh size (mm)	18.1 mm	45.2 mm

Results of this study cannot be directly compared as the present study pertains to a single species while Kunjipalu et al., 2001 elucidates the selectivity parameters for *Stolephorus* species. However, the selectivity parameters were in general agreement to the fact that selectivity parameters are higher in the present study due to the increased square mesh size. The length/size at first maturity (L_{Fm}) of *S. commersoni* was reported as 7.1 cm and 7.2 for for male and female respectively (Nair et al., 2021). The escapement data of *S. commersoni* using 30 mm square mesh cod-end revealed that out of total 165 individuals 65 individuals escaped into the cover-cod end recording an escapement percentage of 39% of the total number. Out of the total number of *S. commersoni* individuals retained in the cod end, 96% were above the L_m of 7.1 cm. The optimum mesh size derived from L_m and the selection factor from the present study was 18.1 for square mesh cod-end. As selectivity parameters are influenced by a lot of other parameters, recommendations for a multispecies trawl fishery can be undertaken only after considering other factors that influence selectivity.

The L_{25}, L_{50}, L_{75} values for *L. lactarius* was 13.23, 14.95 and 16.93 cm, respectively. The estimated selection factor and selection range for 40 mm square mesh cod-end were 3.93 and 0.9 respectively. The L_{50} for *L. Lactarius* with 20 mm square mesh reported by Kunjipalu et al. (2001) off Kochi was 6.9 cm. The higher L_{50} vales in the present study for *L. Lactarius* can be attributed to increased mesh size but other factors like differences in gear and vessel configuration and data collection methods also need to be considered. There are no other studies on the selectivity of this species to cod-ends. However selectivity characteristics of square mesh cod-end with respect to *Caranx para, Dussumieria acuta, Metapenaeus dobsoni, Thryssa purava, Nemipterus japonicus, Saurida tumbil, Metapenaeus dobsoni, Parapenaopsis stylifera, Thryssa dussumeri, Leiognathus bindus* and *Upeneus vittatus* have been reported from

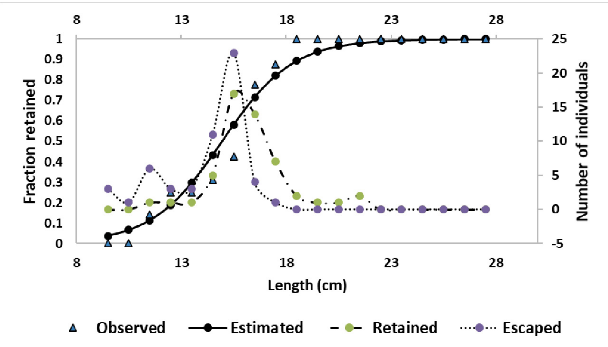

Fig. 2. The observed and estimated selection curve along with the length frequencies of *Lactarius lacatrius* retained and excluded in the cod-end and cover from 40 mm square mesh cod-end

Indian waters (Varghese et al., 1988a; Kunjipalu et al., 1994; Varghese et al., 1996; Kunjipalu and Varghese, 1994; Kunjipalu et al., 2001; Prakash et al., 2008; Rajeswari, 2013; Madhu et al., 2016., Madhu., 2021). Selectivity studies using square mesh cod-ends have shown that square shaped meshes are relatively selective for many species than diamond meshes (Robertson, 1983; Robertson & Stewart, 1988; Walsh et al., 1992; Boopendranath & Pravin, 2005; Prakash et al., 2008; Boopendranath et al., 2012; Madhu et al., 2016). The main reason for relative increase in selectivity parameters is because square mesh remains open during towing, whereas diamond meshes tend to distort due to longitudinal and transverse tension on mesh bars depending on catch size, current and other factors.

The body shape of target species plays a vital role on the effect of mesh size and cod-end selectivity. Hence the square mesh cod-ends have been reported to have better selectivity than diamond shaped ones of similar mesh size for round fishes like haddock and whiting (Roberston & Stewart, 1988) and Hake (Stergiou et al., 1994). The other factors that affect the cod-end selectivity of trawls are the size of the mesh openings of the cod end and the probability that the fishes come across these openings (MacLennan, 1992; Wileman et al., 1996). Selection parameters are also affected by twine diameter, speed of tow, seasonal changes, cod-end weight, cod- end circumference (Broadhurst et al., 1997). Though studies of the selectivity analysis indicate that the square meshes are more selective in certain species and unselective for certain species like annular sea bream (Tosunoðlu et al., 2003b; Özbilgin et al., 2005) in the Aegean Sea. This is mostly attributed to body shape where studies have shown that that square-meshes were found to be less selective for deep-bodied and flat fish (Guijarro & Massuti, 2006; Sala et al., 2008).

More studies are needed to study the biological and economic costs of bycatch, and the benefits and costs of prospective gear solutions. Long term management measures include technical measures like increasing mesh size. With the adoption of such management practices considerable short-term economic losses are anticipated. Short-term effects are to be addressed to realise the long-term gains. The ecological and the socio-economic impacts of need to be addressed before changes are made (Petri, 2005). Operational factors such as speed of tow, cod-end catch, season, time of haul, twine thickness, tow duration influence selectivity in trawls also need to be taken into consideration (Dahm et al., 2002). Even though these parameters were assumed as constant since this is the first study of the two species with respect to 30 and 40 mm square mesh cod end, this will form a baseline document for further studies integrating parameters that could influence selection. Further studies using different sizes and shapes along with experimental designs to assess factors affecting selection need to be carried out to emulate a suitable strategy for recommending a suitable mesh size for trawls operated along East coast of India. Recommendations of mesh sizes should be considered only after obtaining information of the survival of the escaped fishes. Further studies using different sizes and shapes along with experimental designs to assess factors affecting selection need to be carried to emulate a suitable strategy for recommending a suitable mesh size for trawls operated along east coast of India.

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