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Gillnet Selectivity and Fishing Pressure on *Sardinella gibbosa* (Bleeker, 1849) off Southeast Coast of India

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Abstract

A study was undertaken on the selectivity of small meshed gillnets and fishing pressure on *Sardinella gibbosa* along Thoothukudi, south east coast of India, with the view to understand the impact of various mesh sizes of gillnets on the fishery of *S. gibbosa*. The selectivity of gill nets was analysed as described by Sparre &Venema (1992) and the fishing pressure on various length groups was analysed using FiSAT. The study revealed a well-defined selectivity by gillnets with 26, 28 and 30 mm mesh sizes. The fishery was found un-affected by growth overfishing on recruitment overfishing as the commercially significant size group was found to be 110 to 160 mm which was higher than the estimated length at first maturity (100 mm). However, during the months from August to November notable landings of juveniles were reported, which was mainly due to the use of gillnets with 26 mm mesh size. The selectivity parameters such as length at first capture (l_b), mean selection length (l_c) and the escapement length (l_d) for the selected gillnets were found to range from 90 to 107 mm, 115 to 135 mm and 145 to 165 mm respectively. The gillnet selection factor for *S. gibbosa* was estimated as 4.50. The study revealed the possibility for further increase in fishing effort for *S. gibbosa* along this coast based on the exploitation ratio (F/Z) of 0.39. The gillnet with 30 mm mesh size was found to be ideal for the commercial exploitation of *S. gibbosa* along this coast.

Keywords: Gillnet selectivity, fishing pressure, *Sardinella gibbosa*, over fishing, optimum mesh size

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Nylon monofilament, which is very popular throughout India for gillnets, is not yet used for capturing *S. gibbosa* along Thoothukudi coast. The fishing is mainly with nylon multi filament gillnet with mesh size ranging from 26-30 mm. Lesser sardines are pelagic shoaling clupeoid fishes which contribute about 3.4% of the total marine fish landings of India about 4.4% of the total marine fish catch of Tamil Nadu (Pillai, 2010) and (Anon, 2011). Of the 15 species of lesser sardines seen in the Indo-Pacific region, 10 are found distributed along south east coast of India including Tamil Nadu coast. *S. gibbosa* is a commercially important species and is captured along Thoothukudi coast largely by gillnets with the mesh size ranging from 26 to 30 mm (Neethiselvan et al., 2001).

Shape of the selection curves of two gillnets with slightly differing mesh size would be the same and the mean selection length would be proportional to the mesh size (Holt, 1957). Olsen (1959) adopted this principle for the estimation of gillnet selectivity factors for herring. Holt (1963) has also suggested bell shaped selection curves (normal curve) for fishes caught by gilling and wedging. Hamley (1975) made an extensive review on gillnet selectivity studies. The review included the studies on factors determining gillnet selectivity curves and the methods of estimation. Gillnet selectivity studies have also been attempted for *Salmo trutta*, (Jensen, 1984), *Perca fluiviatilis* (Linlokken, 1984) and Arctic char and turbot (Jensen, 1986). Jensen (1990) compared the efficiency of two different mesh size (16 and 19.5 mm) for capturing *Perca fluviatilis*, *Lota lota* and salmonids and reported that there was no increase in efficiency with increase in mesh size.

Pierce et al. (1994) reported that gillnets were most effective for retaining Northern pike when fish length/mesh perimeter ratio was between 3.5 and 3.7. Pet et al. (1995) estimated gillnet selectivity for two tilapia, five cyprinids, two catfishes, one goby and half beak in a Sri Lankan reservoir.

Hovgard (1996) observed bimodal selectivity curve for Atlantic cod due to gilling and catching at maxillae. Gilling was about three times as efficient as catching at maxillae and fishing power could be related to the ratio of twine diameter to mesh size. Jensen & Hesthagen (1996) estimated the selectivity of a multi mesh gillnet and series of single gillnet for brown trout. Height of selectivity curves increased exponentially with mesh size in multi mesh nets. Psuty & Borowski (1997) analysed the proportion of fishable length group (35 cm) for the polish bream *Abramis brama* in gillnets and concluded that mesh size of 60 mm and above were ideal for capturing polish bream. In India, gillnet selectivity studies are mainly intended for the optimization of mesh size for the commercial exploitation of marine and fresh water fishes. The effect of different mesh sizes on the fishing efficiency of small meshed gillnets in Kerala coast has been studied by Joseph & Sebastian (1964). Gillnets with mesh size of 51.98 mm and 47.5 mm were found suitable for capturing *Scomberomorus commersoni* at the length group of 525 mm and the most predominant commercial size group of 480 mm respectively (Sreekrishna et al., 1972). The optimum mesh size for the capture of commercially significant size group of *S. commersoni* (850-890 mm) in Cochin coast has been estimated as 76 mm bar length by Sulochanan et al. (1975). Panicker et al. (1978) studied the gillnet selectivity for Hilsa and recommended the webbing made up of 210/2/3 nylon twine with 51 mm bar length for the commercial exploitation of *Hilsa toli*. Webbing made up of 210/2/3 nylon twine having 63 mm bar length was recommended for the capture of *Pampus argenteus*. Optimum size of capture of silver pomfretto avoid the depletion of stock was estimated as 36 cm.

Sathyanarayanappa et al. (1990) optimized the mesh size for the exploitation of *Silago sihama* as at 35 to 40 mm. Mathai (1991) suggested that a net made out of nylon twine (210/1/2) with mesh size of 50 mm is ideal for the exploitation of mackerel in West Bengal Coast. The optimum mesh bar length for the judicious exploitation of commercial size groups of Catla, Mrigal and Rohu in Gandhisagar reservoir have been estimated as 148, 89 and 60 mm respectively (Kartha & Rao, 1991). Thomas & Hridayanathan (2002) suggested to discourage the use of mesh size below 34 mm for gillnets for *S. longiceps* to avoid recruitment over fishing. Jude et al. (2002 a; b; c) determined the optimum mesh size for the commercial exploitation of *Auxis thazard, Thunnus tonngol* and *Euthynnus affinis* in Thoothukkudi coast. Studies on the estimation of gillnet selectivity parameters for lesser sardines in Indian waters is limited. Hence a study was undertaken with the objective of understanding the fishing pressure on different length groups of *S. gibbosa* due to the operation of small meshed gillnet along Thoothukudi coast and to optimize mesh size of the gillnet based on the length at first maturity of *S. gibbosa*.

Materials and Methods

The study was carried out from August 2007 to July 2008 at Therespuram and Inigo Nagar landing centres of Thoothukudi (Lat 8°.76'' N, Long 78°.13'' E). *S. gibbosa* was sampled from small meshed nylon gillnets of three different mesh sizes *viz.*, net 'A' with 26 mm, net 'B' with 28 mm and net 'C' with 30 mm. The general description of the nets from which the fishes were sampled are given in Table 1. The nets were operated from the traditional plank built boats of Thoothukudi origin popularly called as 'Vallams'. Weekly sampling was made on board the vessels. The total length was measured to the nearest mm and weight was taken to the nearest mg.The catch data collected in terms of number and weight during the sampling day was multiplied by the number of boats engaged in fishing on the sampling day to obtain the daily catch. The mean daily catch for a month was worked out by taking the mean total catch estimated during different sampling days of a month. The average daily catch was multiplied by the number of fishing days of a month to obtain the estimated monthly catch. The effort was expressed in terms of boat days and the catch was expressed in terms of kg. The nets were operated between 2 am to 7 am in fishing grounds, 7-10 nautical miles off the coast at depths ranging from 9 to 25 m. The selection curve and selectivity parameters such as the length at first capture l_b (length of fish corresponding to 50% retention on the ascending limb of the selectivity curve), mean selection length (l_c) and escapement length, l_d (length of fish corresponding to 50% retention on the descending limb of the selectivity curve) were estimated as per Sparre & Venema (1992). Selection factor were estimated based on catches from gillnets with three different mesh sizes such as 26 mm, 28 mm and 30 mm. The natural log value of numbers of fish caught in net with mesh size 'A' and net with mesh size 'B' corresponding mid value of each length group was estimated as follows.

$Y = Ln\ (CA/CB)$

Where, CA = Fish caught in small meshed net A

CB = Fish caught in large meshed net B

Linear regression analysis was made against the mid value of each of the length group as follows

$Ln\ (CB/CA) = a_1 + b_1L$

Where, a_1 = intercept for BA combination

b_1 = slope value for BA combination

$Ln\ (CC/CB) = a_2 + b_2L$

Where, a_2 = intercept for CB combination

b_2= slope value for CB combination

L = mid length of a length group

CA, CB and CC refers to catch in number in net with the mesh size A, B and C corresponding to the mid value of length group, L.

The common selection factor (SF) for three-mesh combination *viz*., A, B and C was derived using the equation.

$$SF = \frac{-2 \times [(A + B) \times a_1/b_1] + [(B + C) \times a_2/b_2]}{(A+B)^2 + (B+C)^2}$$

The common standard deviation(s) for three-mesh combination A, B and C was derived using the equation.

$$S = \frac{1}{3-1}\ x-2 \times a_1 \times (B-A) + \frac{-2 \times a_2 \times (C-B)}{b^2_1 \times (A + B)} \qquad b^2_2 \times (B+C)$$

The mean selection length (L_c) of each net was estimated from the common selection factor (SF) as follow

$L_{ci} = SF \times mi$

Where, 'L_{ci}' refers to mean selection length of different nets.

'mi' refers to different mesh size.

The fraction of fish retained in the gill net (SL) was estimated by the following relation.

$$SL = \exp\left[\frac{-(L - L_c)^2}{2 \times s^2}\right]$$

Where, L_c = Mean selection length

L = Mid length of the size group / length group

S = Standard deviation for the three mesh combination.

To estimate length at first maturity (l_m), 50 specimens for each species covering both sexes with wide length range were observed and was estimated based on the method of Venkataramanujam & Ramanathan (1994).

Table 1. Description of the selected gillnets

Sl. No.	Parameters	Gillnets A, B & C*
1	Webbing material	Nylon
2	Twine specifications	210D/1/2
3	No. of meshes in length	1500
4	No. of meshes in height	400
5	Mesh size*	A-26 mm, B-28 mm & C-30 mm
6	Horizontal hanging co-efficient	0.5
7	Vertical hanging co-efficient	0.86
8	No. of floats	10
9	Specifications of float	PVC Cylindrical 55 mm x 50 mm
10	No. of sinkers	5
11	Specifications of sinker	Stone - 250 g for A & B and 300 g for C
12	Specifications of Selvedge	5 meshes of 75 mm polyethylene

The commercially significant size group of *S. gibbosa* in the fishery was worked out as a percentage of total catch from the pooled catch data of nets with the mesh size varying from 26 to 30 mm. Optimum length of capture was fixed based on the significant contribution to the total catch and the length at first maturity. The fishes with length exceeding the length at first maturity were treated as fishable length group. The extent of fishing pressure on different length groups of *S. gibbosa* was estimated by virtual population analysis using FiSAT (Gayanilo & Pauly, 1997). The length frequency data, sample weight, 'a' and 'b' values of length weight relationship equation and catch-effort data were used as input information for the estimation of fishing pressure. The total instantaneous mortality co-efficient 'Z' was estimated from the catch curve and the natural mortality co-efficient 'M' was estimated using Pauly's equation available with FiSAT. The fishing mortality co-efficient 'F' was derived by subtracting M from Z. The exploitation ratio (F/Z) was used to assess the present level of exploitation.

Results and Discussion

Sardinella gibbosa was recorded throughout the year with the peak season from September to March (Fig. 1). Similar observations have been made by Bennet et al. (1986) and Neethiselvan et al. (2001) along Thoothukudi coast. The fishery was mainly constituted by the fishes with length ranging from 100 to 160 mm. The smallest specimen recorded during the study was 40 mm and the biggest being 180 mm. All length groups showed year around representation in the fishery except during the month of April, where there was a definite peak by a particular length. The length group, 100 to 160 mm though showed its dominance from September to March, contribution of juveniles (40 to 80 mm) in the catches was notable during the months of August to November. Bennet et al. (1986) observed notable contribution of juveniles of *S. gibbosa* in the gillnet catches of Thoothukudi coast from August to October. Similar observation could be made in the present study also. Strict mesh size regulation is required to avoid the use of gillnets with the mesh size of 26 mm during the period from August to November to avoid the capture of juveniles. The representation of smaller length groups of *S. gibbosa* in the fishery throughout the year indicates its continuous breeding behaviour along Thoothukudi coast. The monthly average estimated catch and effort of *Sardinella gibbosa* for the period from August 2007 to July 2008 is given in Table 2. The peak fishing season of *S. gibbosa* was found to be from October to March (Table 2), during which the length group 100-160 mm notably contributed to the fishery (Fig. 1).The use of gillnets with 30 mm mesh size and above may be encouraged during the period from February to July, as bigger fishes contribute significantly to the fishery during this season. Rao (1981) observed the dominance of bigger fishes of *S. gibbosa* in the earlier part of fishing

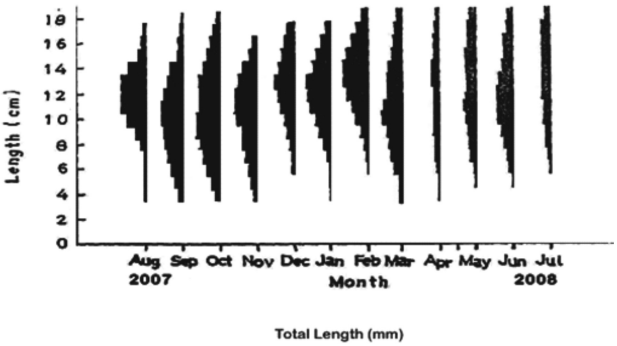

Fig. 1. Seasonal length frequency distribution of *Sardinella gibbosa* in small meshed gillnets along Thoothukudi coast

Table 2. Monthly average catch and effort of *Sardinella gibbosa* for the period from August 2007 to July 2008

Sl. No.	Months	Total no. of boats operated	Boat days	Landings/ boat (Nos)	Total weight landed/ boat (kg)	Estimated total landings (Nos)	Estimated total landings in weight (kg)
1	August	180	3240	880	20	2851200	64800
2	September	200	4400	1100	52	4840000	110000
3	October	240	5520	2200	50	12144000	276000
4	November	260	6240	2860	65	17846400	405600
5	December	280	6720	3300	75	22176000	504000
6	January	300	6600	3520	80	26400000	6,00000
7	February	280	6720	2860	65	19219200	436800
8	March	250	5750	2200	50	12650000	287500
9	April	200	3600	1540	35	5544000	126000
10	May	150	2250	1100	25	2475000	56250
11	June	150	2400	880	20	2112000	48000
12	July	160	2880	792	18	2138400	48600
Total			56320	Total		130396200	2963550

season and smaller length group during the later part of fishing season along Waltair coast of Andhra Pradesh (Lat 17°.96'' N and Long 83°.31'' E). However, a reverse phenomenon was observed in the present study in Thoothukudi coast revealing the differences in the fishing pattern of *S. gibbosa* between Thoothukudi and Waltair coasts.

The length group, 121-130 mm *S. gibbosa* dominated the catch to the tune of 23.30% in net 'A'. However, in net 'B', the length group, 131-140 mm was found dominated to the extent of 21.34%. In the case of net 'C', the length group, 141- 150 mm dominated as much as 22.92% of the catch (Table 3). It was evident that 12.62% of the catch from net 'A' was found to be immature fishes. The operation of net 'A' (26 mm) would lead to growth overfishing and was found to capture the maturing fishes (91-110 mm) to the extent of 19.22%, which may lead to recruitment over fishing. The present finding is in accordance with earlier observation by Neethiselvan et al. (2001), who stressed to discourage the use of gillnets with the mesh size of 26 mm and below along Thoothukudi coast in order to prevent growth overfishing of *S. gibbosa.*

The net 'B' with 28 mm mesh size, captured only 1.86% of juveniles, which is negligible and can be ignored. Mature fishes with a length ranging from 91-110 mm were captured only to the tune of 15.03%. Therefore the operation of net 'B' with 28 mm mesh size did not pose any threat both to juveniles and mature fishes. In the net 'C' with 30 mm mesh size was concerned, there was no impact on juveniles and maturing groups (Table 3). Therefore, it is evident that gillnet with 30 mm mesh size ideal for capturing *S. gibbosa* as the operation of this net did not pose either growth over fishing or recruitment over fishing.

The selectivity parameters such as length at first capture (l_b), mean selection length (l_c) and escapement length (l_d) estimated for different nets can be derived from Fig. 2. In the present study, the length

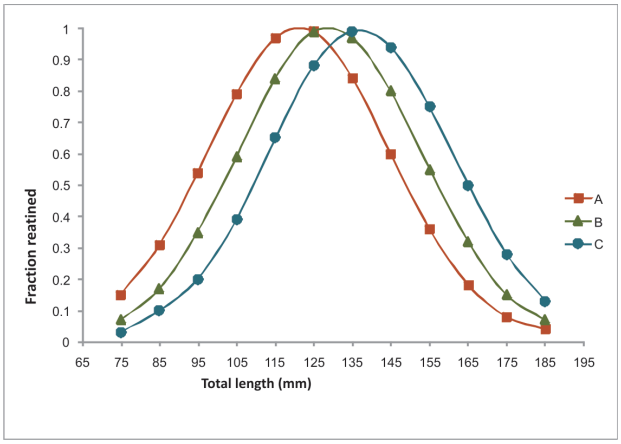

Fig. 2. Selection curves of Net 'A', Net 'B' and Net 'C' with respect to *Sardinella gibbosa*

Table 3. Percentage of length frequency of *Sardinella gibbosa* caught in Net 'A', Net 'B' and Net 'C'

Length (mm)	Percentage of Length frequency			Total catch in numbers (percentage)
	A	B	C	
71-80	2.52	-	-	0.85
81-90	3.50	1.86	-	1.83
91-100	6.60	5.75	2.29	4.95
101-110	12.62	9.28	6.04	9.39
111-120	18.25	11.32	11.25	13.62
121-130	23.30	17.52	15.21	18.84
131-140	16.50	21.34	17.71	18.58
141-150	3.74	18.37	22.92	16.56
151-160	5.83	10.58	15.21	10.43
161-170	2.14	3.34	5.21	3.52
171-180	-	0.93	2.08	0.92
181-190	-	0.93	2.08	0.65

Table 4. Enmeshing pattern of various size groups of *Sardinella gibbosa*

Size range (mm)	% enmeshing in Gillnet A			% enmeshing in in Gillnet B			% enmeshing in Gillnet C		
	S*	G*	W*	S*	G*	W*	S*	G*	W*
111-115	-	65	35	-	75	25	-	80	20
116-120	-	68	32	-	82	18	-	86	14
121-125	-	70	30	-	94	6	-	96	4
126-130	-	86	14	-	100	-	-	97	3
131-135	-	96	4	2	98	-	-	99	1
136-140	8	92	-	4	96	-	8	92	-
141-145	14	86	-	7	93	-	21	79	-
146-150	18	82	-	10	90	-	28	72	
151-155	25	75	-	15	85	-	30	70	-
156-160	30	70	-	30	70	-	32	68	-

S*- Snagged, G*- Gilled, W*- Wedged

at first capture varied between 90 to 107 mm for different nets. Mean selection length for a particular mesh size refers to the length of fish, which are retained 100% in a gill net. The l_c increased with the increase in mesh size and ranged between 115 to 135 mm.The value of l_d refers to the length at which 50% of fishes return back due to the over size of fish exceeding the mesh size and remaining 50% are retained. The l_d value of *S. gibbosa* ranged from 145 to 165mm (Fig. 2). The mean selection factor estimated for *S. gibbosa* was 4.50.

The mean commercially significant size in the fishery i.e, 135 mm was found to be captured at 96% by gilling in net 'A' (Table 4) and the remaining 4% was captured by wedging. This group to the extent of 98% by net 'B' by gilling and the remaining 2% was captured by wedging (Table 4). In the case of net 'C', the mean commercially significant size in the fishery (135 mm) was captured 99% by gilling and the remaining 1% was captured by wedging (Table 4). Small meshed gillnets of 26, 28 and 30 mm were found to be the ideal gear for the capture of *S. gibbosa* as they showed clear cut selectivity over different size ranges and entangling was not reported in all the three type of nets.

The length at first maturity (l_m) of a fish helps to decide the fishable length group (Santos et al., 1998) as fishing of juveniles leads to growth overfishing and that of matured fishes before spawning leads to recruitment overfishing. In the present study, the $l_m$was estimated as 100 mm (Fig. 3). However, Sekharan, (1955) estimated the l_m of *S. gibbosa* as 92 mm in Mandapam coast. The l_m of *S. gibbosa* has been found to range from 111-120 mm in Waltair coast by Ganapati & Rao (1957). Luther (1994) estimated the l_m of *S. gibbosa* as 142 mm in Vishakhapatnam coast which reveals that *S. gibbosa* attains maturity relatively at lower length group in Thoothukudi coast than in Vishakhapatnam coast. Length frequency distribution of *S. gibbosa* in the commercial fishery is given in Table 3. The commercially significant length group in the fishery was found to be 110 to 160 mm and the mean length of capture of commercially significant length group 135 mm was well above the l_m. It may be concluded that gillnet with 30 mm mesh size would be ideal for the commercial exploitation of *S. gibbosa* along Thoothukudi coast.

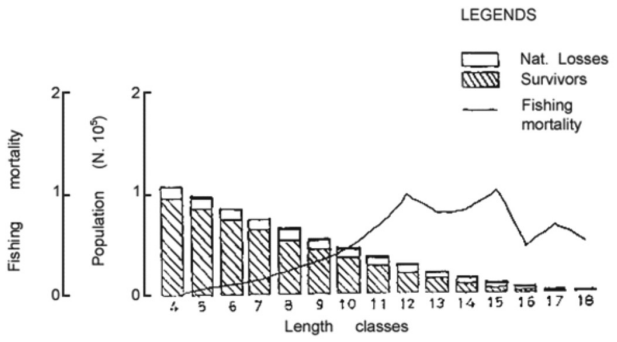

Fig. 3. Length structured virtual population analysis of *Sardinella gibbosa*

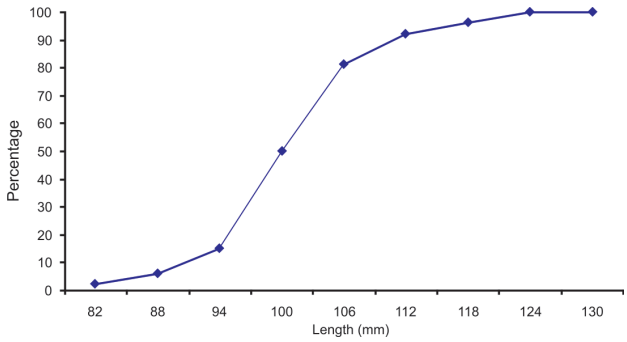

Fig. 4. Determination of Length at first maturity of *Sardinella gibbosa*

Virtual population analysis helps to find out the extent of fishing pressure on different age groups of a fish population besides loss due to natural mortality (Richard et al., 1996). Peak fishing pressure on length group, 120-150 mm of the population of *S. gibbosa* was clearly evident. Natural mortality was found to be higher in the smaller length group and decreased gradually as the animal grows up to 100 mm and after that the mortality was mainly due to fishing (Fig. 3). It was evident that the 'M' was relatively higher up to 100 mm indicating susceptibility of young fishes to natural causes like environmental variations and predation. Peak fishing pressure of 120 and 150 mm may not pose any serious threat to the fishery, as the length at first maturity of *S. gibbosa* is 100 mm (Fig. 4).

It may be concluded that fishery of *S. gibbosa* suffers mainly due to growth over fishing due to the operation of gillnet with 26 mm mesh size particularly from August to November. The total instantaneous mortality (Z), fishing mortality (F) and natural mortality (M) were 4.50, 1.41 and 3.09 respectively. The exploitation ratio (F/Z) estimated for *S. gibbosa* in Thoothukudi coast in the present study was found to be 0.31, which indicates further scope for the exploitation of *S. gibbosa* along this coast.

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