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GILLNET SELECTIVITY PARAMETERS FOR COMMERCIALLY IMPORTANT SPECIES, *LABEO ROHITA* IN A TROPICAL RESERVOIR, KERALA, INDIA

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The selectivity of fishing gear characterizes its capacity and efficiency in capturing fish. This knowledge helps in selecting the appropriate mesh size to suit the available fish population. The present study aims to estimate the gillnet selectivity parameters of a commercially important fish species, *Labeo rohita*, from a tropical reservoir in Meenkara, Kerala, India. The study was conducted from September 2019 to February 2020 through experimental fishing using gillnets of different mesh sizes (120, 130, 140, and 150mm) of identical design and dimensions. Selectivity parameters were estimated using Holt's indirect method. The estimated optimum selection length of *L. rohita* for three different mesh sizes (120, 130, and 140mm) was 46.56, 50.44, and 54.32cm, and the common selection factor (SF) was 3.88. The estimated optimum mesh size of 127 mm was found to be ideal for the commercial exploitation of *L. rohita* in the Meenkara reservoir. The gillnet selectivity estimates obtained in the present study will be beneficial to increase the likelihood of capturing targeted size classes as well as better management of the *L. rohita* fishery in Meenkara reservoir.

Key words Exploitation, Gillnet, Mesh size, Reservoir, Selectivity

Introduction

Fishing gear selectivity is critical for stock assessment and fisheries management because gear influences catch composition and target species size (McClanahan and Mangi, 2004). It aids in selecting the appropriate mesh size of the nets for the available fish population (Emmanuel *et al*., 2008). Gillnets are highly selective fishing gear in terms of both fish species caught and fish size retained (Gulland, 1983). Since the mesh size of the gillnet determines the size of fish caught, only a small group of fishes in a specific size range will be captured.

India is the third-largest fish-producing country in the world, with the inland sector (14.73 MMT) contributing 76% of the total fish production (DOF, 2022). The inland fisheries sector provides food and nutritional security, as well as livelihood support and employment, for many people in the country. Reservoir fisheries are one of the foremost contributors to inland fish production in India, even though the average fish production (110 kg/ha/year) from Indian reservoirs is much less compared to the reservoirs of other developed countries (Sharma and Suresh, 2013). Reservoirs are primarily constructed for irrigation and power generation, and fish production from reservoirs is mainly through enhanced capture fisheries and culture-based fisheries. Indian major carps (*Labeo catla*, *L. rohita*, and *Cirrhinus mrigala*) form the mainstay of stocking in reservoirs in India (Sugunan and Suresh, 2022). *L. rohita* is one of the dominant carp species for aquaculture in India, which shares more than 60% of total carp production (Thakur *et al.,* 2023).

Gillnets are the major fishing gear used in Indian reservoirs, like in other parts of the world, as the bottom obstacles, especially tree trunks, limit the use of active gear in reservoirs. Appropriate harvesting size is one of the key parameters for obtaining optimum fish yield from small reservoirs, where fish production is exclusively dependent on culture-based fisheries. For the efficient exploitation of target species, gillnet selectivity plays a greater role. The selectivity of gillnets is influenced by a multitude of factors, including the characteristics of the mesh (such as mesh size, twine size, and type), as well as morphometric features specific to each fish species. The mesh size is a critical aspect impacting the success of gillnets in the capture process (Clarke, 1960; Akongyuure *et al.*, 2017). This is primarily due to the fact that smaller individuals can pass through the mesh unharmed, while larger ones are hindered from traversing through the mesh at either end. Studies on gillnet selectivity are commonly conducted by simultaneously using multiple gillnets with varying mesh sizes. This approach ensures that changes in fish size do not affect the catchability of fish (Kurkilahti and Rask, 1996).

Selectivity parameters of gill nets for many freshwater fish species from lakes and reservoirs are reported from different parts of the world (Özekinci *et al.*, 2007; Kumara *et al.*, 2009; Petriki *et al.*, 2014; Tampubolon *et al.*, 2015; Akongyuure *et al.*, 2017; Jorge and Frederic, 2022). In India, the gillnet selectivity studies were mostly conducted for commercially important marine fishes only (Sulochanan *et al.*, 1975; Khan *et al.*, 1989; Jude, 2000; Thomas and Hridayanathan, 2002; Gladston *et al.*, 2017). Such estimates for freshwater fish from inland waterbodies like reservoirs in the country are very limited (Alagaraja, 1977; Khan *et al.*, 1989; Desai and Srivastava, 1990; Kartha and Rao, 1991; Sundaramoorthy *et al.*, 2013). No studies so far have reported the gillnet selectivity of fish species in reservoirs in Kerala, a state located in the southern part of India. The estimation of the optimum mesh size for the freshwater fish in Kerala reservoirs is important because the inland water bodies possess significant production potential yet remain underutilized in many regions of the state. Meenkara, a small reservoir, is one of the highly productive and shallow tropical reservoirs in Kerala, India, that yielded superior results for fish culture (Harikumar and Rajendran, 2007). *Labeo rohita*, *Oreochromis niloticus*, *Oreochromis mossambicus*, *Etroplus suratensis*, *Labeo catla*, etc. are the main species constituting the commercial fishery of this reservoir, and gillnets are the only fishing gear used to capture these species (Pravin *et al.,* 2014; Saranya *et al.,* 2021). Since fish stocking is done annually by the Fisheries Department, sustainable fisheries utilization in the reservoir can be accomplished by using gillnets of suitable mesh size to optimize the catches. Hence, gillnet selectivity parameters for the most abundant and highly demanded fish species in the reservoir, *L. rohita*, have been estimated in the present study.

Materials and methods

Study area

Meenkara, a multipurpose reservoir (Figure 1), is constructed across the river Meenkara, a tributary of the Bharathapuzha River, which is the largest river in Kerala, India. The reservoir was constructed in 1964 as the first stage of the Meenkara-Gayatri irrigation project, mainly used for irrigation. A small part of the storage is also used for drinking water supply in nearby areas.

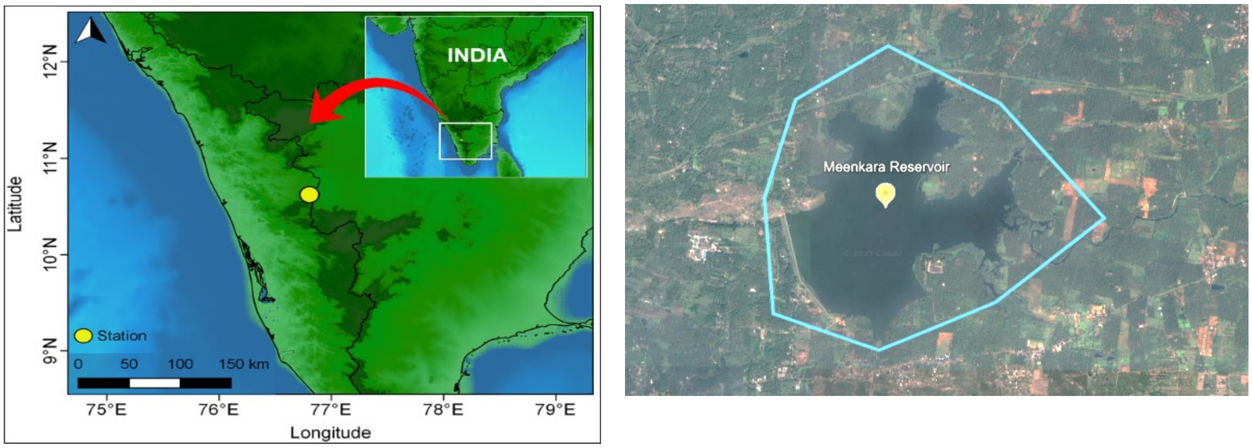

Fig. 1. Map showing Meenkara reservoir, Kerala

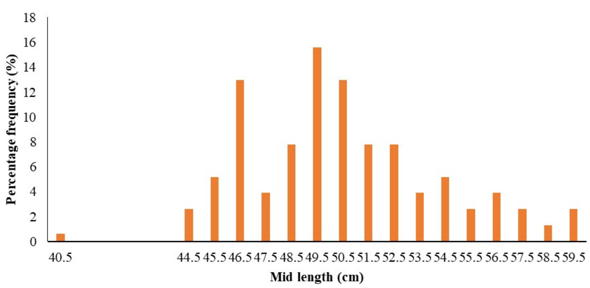

Fig. 2. Percentage length frequency of *L. rohita* captured from all four experimental gillnets

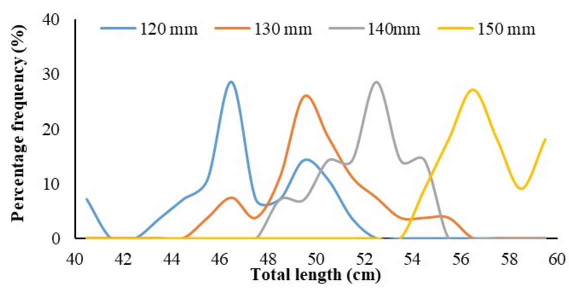

Fig. 3. Percentage length frequency of *L. rohita* obtained from gillnets of different mesh sizes

The land use pattern consists of a mixture of agriculture land, crop land, waste land, water bodies, wet land, *etc*. (KERI, 2014). The dam is located at a latitude of 10°38' N and a longitude of 76° 48' E. The reservoir area is 2.59km^2, with a catchment area of 90.65 km^2.

Experimental fishing

The experimental fishing was conducted from September 2019 to February 2020 using multi-meshed gillnets of identical design and dimensions. The hanging coefficient and design of the nets were similar to the nets used by fishermen in the reservoir. Polyamide monofilament gillnets of 0.23mm diameter with mesh sizes 120, 130, 140, and 150mm were used. Each gillnet unit had a length of 35m and a depth of 30m. The hanging coefficient of all four gillnets was 0.3. The four gillnets were connected horizontally from the smaller mesh size (120mm) to the large mesh size (150mm), and experimental fishing was conducted in randomly selected regions of the reservoir. The nets were set during the evening at 6 p.m. and hauled on the next morning at 6 a.m., with a soaking time of 12 hours.

Catches of *L. rohita* obtained from different mesh sizes were sorted, counted, and weighed. Total length (cm) with an accuracy of 0.1cm and weight (g) to the nearest 0.01g were measured using a measuring scale and a digital balance, respectively.

Selectivity analysis

Selectivity was estimated according to Holt (1963) method

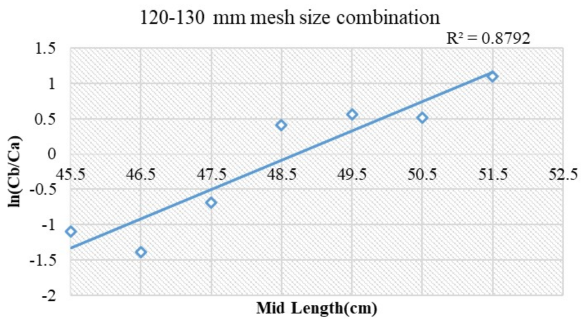

Fig. 4. The plot of the logarithm of catch ratios (Y) of overlapping length classes in two adjacent mesh size combinations (120 & 130 mm; 130 &140 mm) of gillnets against mid-length (X) of fishes

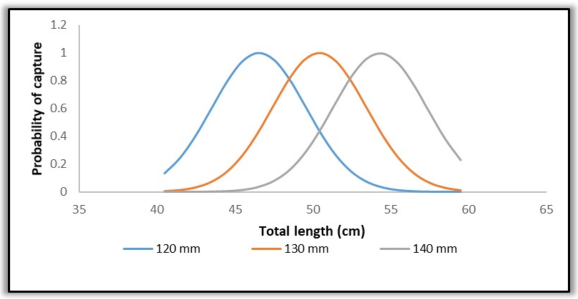

Fig. 5. Selectivity curves of *L. rohita* obtained in gillnets of different mesh sizes

The procedure involves

Step 1: Catch ratios were calculated as the proportion between the numbers of fish of each length class caught in gill nets of different mesh sizes. Only the length groups where the frequencies overlapped were considered. Here, three mesh sizes are used: m_1, m_2, and m_3.

$$Cb/Ca = \frac{\text{Catch in numbers in gillnet with larger mesh size } (m_2)}{\text{Catch in number in gillnet with smaller mesh size } (m_1)}$$

Similarly Cc/Cb also calculated where Cc represents catch in numbers in gillnet of mesh size m_3 which is larger than m_2.

Step 2: Natural log values of these catch ratios per length class were regressed to mid-length of each class group as a linear function as described in Sparre and Venema (1992):

$$\ln (Cb/Ca) = a_1 + b_1 L$$

Where L is the mid length of each length class; a_1 and b_1 are the intercept and slope of the model. Similarly linear regression with ln (Cc/Cb) against mid-length of each class groups was also made with a_2 and b_2 as intercept and slope respectively.

$$\ln (Cc/Cb) = a_2 + b_2 L$$

Step 3: The selection factor (Sf) for each mesh size was calculated using the equation

$$Sf = (-2a / [b (m_1+m_2)])$$

The common selection factor (SF) for the three-mesh combination is calculated as follows (Sparre and Venema, 1998)

$$SF = \frac{-2x\,[(m_1+m_2)\,x(a_1/b_1)] + [(m_2+m_3)x(a_2/b_2)]}{(m_1+m_2)^2 + (m_2+m_3)^2}$$

Step 5: The standard deviation (Sd) of each probability function was calculated as follows:

$$Sd = \sqrt{\frac{-2a\,(m_2-m_1)}{b^2(m_1+m_2)}} = \sqrt{SF * \left(\frac{m_2-m_1}{b}\right)}$$

The common standard deviation (SD) was calculated as the mean value of the individual estimates for each consecutive pair of mesh sizes.

Step 6: The optimum selection lengths (Lm) for each mesh size were calculated from the following equations:

$$Lm = (SF) \times m$$

Step 7: Using the values for Lm and SD, the probability (P) of capture for a given length L in a gillnet having a mesh size m was calculated using the formula by Pauly (1984).

$$P = \exp [- (L - Lm)^2 / 2SD^2]$$

For all the three meshes (m_1, m_2 and m_3) probability of capture was calculated. Selectivity curves were drawn using the probability of capture against each length class.

Step 8: The recommended/ optimum mesh size (m) is calculated from the mid-length of the commercially significant length group of the respective species in cm (L_{opt}) and the estimated common selection factor (SF).

$$m = L_{opt} / SF$$

Table 1. Mid-length of length classes, corresponding catch ratios, and natural logarithm of catch ratios of *L. rohita* caught in different mesh size combinations. Ca, Cb, Cc, and Cd represent catches in gillnets of 120, 130, 140, and 150 mm mesh sizes, respectively

Mid-length (cm) (X)	Ca	Cb	Cc	Cd	Cb/Ca	ln(Cb/Ca)	Cc/Cb	ln(Cc/Cb)	Cd/Cc	ln(Cd/Cc)
43.5	4									
44.5	8									
45.5	12	4			0.33	-1.0986				
46.5	32	8			0.25	-1.3863				
47.5	8	4			0.50	-0.6933				
48.5	8	12	4		1.50	0.4055	0.3333	-1.0986		
49.5	16	28	4		1.75	0.5596	0.1429	-1.9459		
50.5	12	20	8		1.66	0.5108	0.4000	-0.9163		
51.5	4	12	8		3	1.0986	0.6667	-0.4055		
52.5		8	16				2	0.6931		
53.5		4	8				2	0.6931		
54.5		4	8	4			2	0.6931	0.5	-0.6932
55.5				8						
56.5				12						
57.5				8						
58.5				4						
59.5				8						

Table 2. Intercepts (a), slopes (b), regression coefficients (r^2), and standard deviation (Sd) of the regression relationship between the natural logarithm of catch ratios (Y) and the midpoint of length class (X) of *L. rohita*

Mesh combination (mm)	Intercept (a)	Slope (b)	Regression coefficient (r^2)
120-130	-20.246	0.416	0.879
130-140	-22.886	0.438	0.803

Table 3. The estimated values of Lm and Sf for different mesh sizes

Mesh size (mm)	Optimum selection length (L_m)	Selection factor(Sf)	Standard deviation
120	46.56	3.90	3.06
130	50.44	3.89	3.02
140	54.32	3.87	2.98

Result and discussion

Labeo rohita was found to be the second most abundant fish species in the Meenkara reservoir (Saranya *et al.*, 2021). The selectivity parameters for *L. rohita* were estimated using the length frequency data of fish caught in 120, 130, 140, and 150 mm gillnets. The length frequency distribution of *L. rohita* caught from all four gillnets is given in Figure 2. The total length of *L. rohita* ranged from 40 to 60 cm captured from all the mesh sizes. The modal lengths estimated were 46.5 cm, 49.5 cm, 52.5 cm, and 56.5 cm for the mesh sizes 120, 130, 140, and 150mm, respectively (Figure 3). Modal lengths showed an increasing trend with an increase in mesh size, which agrees with the results of Baranov (1948) Carol and Garcia-Berthou (2007). Many authors have pointed out that this phenomenon is attributed to the intra-specific selectivity characteristic of gillnets (Santos *et al.*, 1995; Sbrana *et al.*, 2007; Hosseini *et al.*, 2017).

Mid-lengths of *L. rohita* caught in gillnets of different mesh sizes and corresponding natural logarithms of catch ratios are depicted in Table 1.

The natural logarithm of catch ratios of overlapping length ranges obtained in each combination of gillnets was plotted against the fish's mid-length (Figure 4). The intercepts (a), slopes (b), and coefficients of determination (r^2) of these regression relationships are shown in Table 2. Enough individuals of *L. rohita* were not obtained in a 150-mm gillnet for calculating catch ratios (Y) of overlapping length classes with adjacent mesh sizes (140mm), so it is not considered in selectivity analysis. Even though a range of mesh sizes were used in the study, fewer fish belonging to overlapping length classes were caught in the larger mesh size combination (150 and 140mm). These variations may be indicative of the small size structure of the fish populations in the studied reservoir (Petriki *et al.*, 2014).

The optimum selection length (Lm) and selection factor (Sf) were estimated for both mesh sizes in each mesh combination (Table 3). The optimum selection length obtained is 46.56cm, 50.44cm, and 54.32cm for *L. rohita* in 120, 130, and 140mm gillnets, respectively. The estimated optimum selection length shows a gradual increase with an increase in mesh size. According to Sparre and Venema (1998), the optimum selection length (Lm) is proportional to the mesh size. Similar observations were made by researchers in other selectivity studies around the world (Amarasinghe and Pushpalatha, 1997; Ozekinci *et al.,* 2007; Akongyuure *et al.,* 2017; Faye *et al.,* 2018).

The estimated common selection factor (SF) and common standard deviation (SD) for *L. rohita* were 3.98 and 3.02, respectively. According to Andreev (1962), the selection factor varies between 5 and 10, which is comparatively higher than the present study. Lower range values between 2.59 and 2.89 were reported by Oginni *et al.* (2007) for mono filament gill net operation for Sarotherodon galilaeus in Iwo reservoir. The variations in selection factors are influenced by various factors, including body proportions, sexual maturity, the timing and depth of net deployment, fish swimming speed, and individual behaviors (Dayaratne, 1988; Borgstrom, 1989; Ozekinci *et al.*, 2007). In fusiform fish, characterized by a thin and elongated body shape, this value is high; however, it decreases as the body thickens (stubby form) (Hovgard and Lassen, 2000; Altinagac *et al.*, 2009).

The maximum probable length of fish obtained in each mesh size also increased with the increase in mesh size, as shown in the estimated selection curve (Figure 5). The uniformity in the peak height of the selectivity curve was evident across the four different mesh sizes, a pattern similar to findings in other selectivity studies (Ogutu-Ohwayo *et al.*, 1998; Ozekincie *et al.*, 2007; Hailu, 2014; Jayasinghe *et al.*, 2017; Braimah, 2020). A total length of 46.5cm showed the maximum probability of capture in a 120-mm gillnet for *L. rohita*. In a 130-mm gillnet, the maximum probable length of capture was 50.5 cm; in a 140-mm gillnet, it was 54.5 cm.

In a small reservoir like Meenkara, fish production is entirely dependent on stocking. The stocked fish are caught when they reach a suitable market size. Gillnets of mesh sizes above 100 mm are permitted to operate in this reservoir. The commercially significant length group in the *L. rohita* fishery was found to be between 46 and 47cm, with a mid-length of 49.5cm. considering the optimum length of capture as 46.5cm, the optimum mesh size has been estimated for *L. rohita* as 127mm. The value is almost similar to the estimation by Kartha and Rao (1991) for the judicious exploitation of *L. rohita* in the Gandhisagar reservoir, which was found to be 120mm mesh size. Variation in values might be explained by the characteristics of the nets, differences in the study area, and seasonal variations.

Conclusion

In a country like India, where reservoirs contribute significantly to the country's inland fish production at its minimal level of exploitation, the importance of selectivity studies or the optimization of mesh size for the most used fishing gear, like gillnet, is significant. Knowledge of selectivity is crucial for the effective management of reservoir fisheries, as culture-based capture fisheries are practiced in various reservoirs in India. Presently, there is very little information on gillnet selectivity for *L. rohita* from South Indian reservoirs. Since *L. rohita* catches form a dominant fishery in Meenkara reservoir, Kerala, the gillnet selectivity estimates obtained in the present study will be beneficial to increase the likelihood of capturing targeted size classes from this small reservoir as well as for the maintenance of a sustainable population. The baseline data from the study will be useful to develop a more accurate assessment of the population size and to maintain sustainable and profitable outcomes from the reservoir.

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