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Determination of Gillnet and Hook Selectivity for *Caranx heberi* Captured off Kanyakumari Coast of India

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Authors' contributions

This work was carried out in collaboration between all authors. Author AB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BM and PP managed the analyses of the study. Author MRB managed the overall analysis of the study. Author KD corrected final MS. All authors read and approved the final manuscript.

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ABSTRACT

Large meshed gillnets having mesh sizes of 13.5 cm, 14 cm, 14.5 cm and 15 cm and Hooks No.5,6,7 and 8 were chosen for determining the selectivity and fishing power of the gears to capture the larger carangid *Caranx heberi* of Kanyakumari coast of India. The catch data were analysed using the software GILLNET (Generalized Including Log-Linear N Estimation Technique) comprised of the methodology of SELECT (Share Each Length Class Total) by fitting various uni-normal models viz., normal scale, normal location, log-normal, gamma and bi-normal model.

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Models were tested using various selectivity parameters like Model Deviance, Dispersion Parameter and residual plots. Bi-normal model was found appropriate for gillnet catch data while normal location for hook catch data despite over dispersion was common in both fits. The mesh size of 13.5 cm and hook No.5 and 6 were found as suitable mesh for capturing larger carangid.

Keywords: Gillnet; hooks; selectivity; SELECT; fishing power; carangid.

1. INTRODUCTION

The larger carangids are most important fishery in the coast of Kanyakumari, Tamil Nadu. They are caught by large meshed gillnets and hooks in these region. However, there is no selectivity studies conducted on this fishery especially in this coast. The selectivity nature of every gear is important for managing the fishery as well as for conservation of resources. Owing to these, It is essential to study the selectivity nature of these two gears despite both the gears are considered as selective in nature. It is also opined that use of larger mesh size may yield more fishing pressure. Species and size of fish caught by a gear is purely determined by the selective characteristics of the gear. Mesh regulation drives the size selection exerted by the gear and the net productivity of the fish stock which escapes from being harvested. Hence, determination of the relative selective of one mesh type to that of another is important in predicting the consequences of changes in mesh regulation [1].

Selectivity of species will be high in static gears like gillnet, long line and trammel net, compared to active gear like trawls and beach seines [2]. In this juncture, it becomes essential to standardize all the gears employed to exploit the larger carangids of the region studied since the selectivity of fishing gear has a direct influence on exploited stock [3]. On account of this, the study is aimed to estimate the selectivity of multifilament gill nets and hooks employed for capturing the larger carangid species along the Kanyakumari coast of South India.

2. MATERIALS AND METHODS

The study was conducted in two phases at different locations. First phase of the study was carried out with the objective of determining the selectivity of gillnet with larger mesh sizes viz., 13.5, 14.0, 14.5 and 15.0 cm during the period from September 2002 to April 2004 in the Kanyakumari coast (08^{o} 01.145′N ;077^{o} 49.137′E and 08^{o} 00.821′N; 077^{o} 45.192′E), Tamil Nadu. It is 13 nautical miles away from the shore with a depth range of 30 to 60 m. The second phase of the experiment was with the objective of determining the selectivity of 'J' shaped flattened tinned round-bent Norwegian mustard hooks (2315 oval) of various sizes, viz., No.5,6,7 and 8 and their respective mean size (shank height multiplied with width) are 1308.69 mm^2, 1061.8 mm^2, 878.9 mm^2 and 681.79 mm^2.

The hook selection study was conducted during the same period of the year 2003 to 2004 at 2.45 nautical mile off the Kanyakumari (08^{o}.02.425'N; 077^{o}.34.590'E) having depth range of 15 to 25 m. The fishing grounds selected for the studies were the ground traditionally being used by the local fishermen for their fishing and characterized with bottom topography of rocks and corals.

The experimental gillnets used in the study were analogous in all respects with the net used by local fishermen having the mesh size of 14 cm. The total length of the net was 2,700 m and it comprised of randomly arranged 36 gangs with chosen mesh size. The length and depth in each gang was 1000 and 80 meshes respectively. The nets made of multifilament nylon twine with RTex value of 737 (13.5, 14 cm) and 786 (14.5, 15) cm were hung to the double lined head rope having diameter of 6 mm and 288 number of Poly Vinyl Chloride (PVC) floats with 100 mm diameter and 20 mm thickness were attached to the head rope. A master float with the size of 280 X 280 X 190 mm (L X B X H) made up of thermocole was attached at both ends of each unit. The hanging ratio of the nets ranged from 0.5 to 0.56. Nets were hauled by the local fishermen in the traditional fishing ground from a FRP boat having Over All Length (OAL) of 8.4 m. After every haul, mesh panels were rearranged randomly to minimize the bias and sampling error. Nets were allowed to drift for 4-6 h from mid-night to dawn.

Similarly, the drift hand lines with experimental hook sizes viz., No. 5, 6, 7 and 8 were used. Of these hooks, No. 7 is conventionally used by the local fishermen. The hand lines were fabricated with help of identified fishermen. Totally four lines with different thickness (2, 1.7 and 0.8 mm) made up of Poly Amide 6.6 (Nylon) monofilament were chosen to attach the hooks. At the end of each hand line, three hooks of similar size were tied using 0.5 mm thick wire. The hooks were randomly changed in every fishing operation throughout the study to avoid interaction between hook sizes and bias during sampling in different strata with different hooks. The length of the first line was 150 m and sinker was not used to allow it to drift in the surface water. The length of the second line was 125 m and had weight of 100 g which was tied at 20 m away from the end of line. Length of third line was 90 m and weights of 300 g and 200 g were attached to this line at a distance of 75 m and 25 m respectively from the end of line. The fourth line was selected with the length of 60 m and weight of 1000 g and 300 g were attached to the line at a distance of 40 m and 15 m respectively. Weights used were mild steel balls or stones. Similarly equivalent quantities of floats were crudely added to place the hooks in the particular strata. Three sets of hand lines were fabricated and operated by the local fishermen for few hours from catamarans as done in gillnet operation.

After operation of both the gears, the catches were sorted out based on mesh and hook size and stored in separate containers. After bringing the catch to the shore, morphometric measurements like Total Length (TL), Fork Length (FL), Gill girth (Gg), Gilled Girth (Gr), Maximum Girth (Gmax), individual weight and total weight of catch were recorded. The measurement of lengths and girths were taken to the nearest cm and mm respectively and weight to the nearest gram.

The selectivity parameters for both mesh and hook were estimated using the software GILLNET (Generalized Including Log-Linear N Estimation Technique) developed by Constat [4]. The software includes Millar's SELECT (Share Each Length Class Total) methodology [5] based on maximized log-likelihood function. The function incorporates five different models under two divisions of uni-normal and bi-normal. The uni-normal function comprises of four models viz., Normal location (where modal length is proportional to mesh sizes but with fixed spread of the curve), Normal scale, Log-normal, and Gamma. They are;

$$r_j(L) = \exp\left(-\frac{(l - k.m_j)^2}{2s^2}\right) \quad (1)$$

$$r_j(L) = \exp\left(-\frac{(l - k_1.m_j)^2}{2{k_2}^2.m_j^2}\right) \quad (2)$$

$$r_j(L) = \frac{m_j}{l.m_1}\exp\left[m - \frac{s^2}{2} - \frac{\left(\log(l) - m - \log\left(\frac{m_j}{m_1}\right)\right)^2}{2s^2}\right] \quad (3)$$

$$r_j(L) = \left(\frac{l}{(k-1).a.m_j}\right)^{k-1} \exp\left(k - 1 - \frac{l}{a.m_j}\right) \quad (4)$$

$$r_j(L) = \exp\left(-\frac{(l - a_1.m_j)^2}{2b_1^2.m_j^2}\right) + \varpi \exp\left(-\frac{(l - a_2 m_j)^2}{2b_2^2}\right) \quad (5)$$

All these functions follow Baranov's principle of geometric similarity [6] except normal location curve. The catch data collected from both gillnet and hooks were fitted twice to the above selectivity functions based on the assumption of equal fishing power and the fishing power proportional to mesh/hook size [7]. Besides, the residual plots of all the functions under both the assumptions were obtained by plotting mesh/hook size against length class for every function. Degrees of freedom (DF) and Model deviances (D) (likelihood ratio) for every function were calculated against the corresponding degrees of freedom

$$\mathrm{D} = \sum_{\mathrm{ij}} \mathrm{res}_{\mathrm{ij}}^2 \quad (6)$$

After estimating all the functions, goodness of fit was evaluated using model deviance (D) [8] and residual plots. The deviance was further evaluated from the residual difference between the proportion of fish of particular length caught and the relative length obtained from the models. The better fit among all the model was decided based on its small deviance value compared to other models. Dispersion parameter (DP) for all the models was calculated to study the kind of dispersion or spread or variance of the selectivity curve. After assessing the fits with above-mentioned statistical tools, the better-fit models obtained were further inspected from the concerned residual plots.

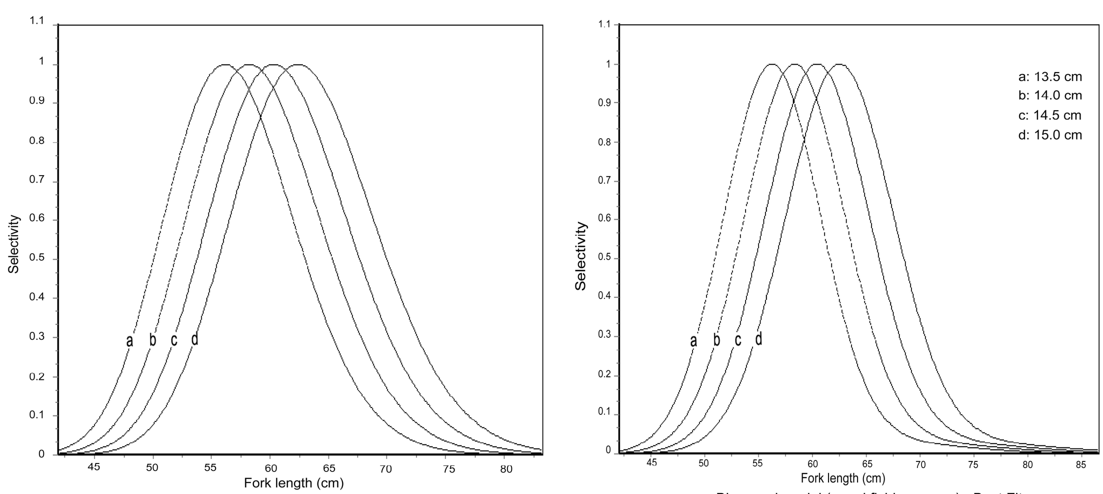
As per suggestion of researchers [9], the better fit model obtained for the catch data of *C. heberi* caught from both gillnet and hook were further approximated to bi-normal model to find out the best fit of the data. After fitting, the tools like Deviance, Degrees of freedom, Dispersion Parameter and residual plots were also determined for the bi-normal model also and validated as done in the uni-normal models to find out the best fit of the selectivity data of the species studied.

3. RESULTS AND DISCUSSION

Over all total catch of *Caranx heberi* obtained from four mesh sizes was 3464 numbers. Of which, 954 specimens were caught from mesh size 13.5 cm, 1143 from 14 cm, 716 from 14.5 cm and 651 from 15 cm while the total catch obtained from four hook sizes was 562 numbers. Of which, 132 specimens were caught from hook size No.5 (1309 mm^2), 125 from No.6 (1062 mm^2), 137 from No.7 (879 mm^2) and 168 from No.8 (682 mm^2). Total degrees of freedom (DF), Standard deviation (SD), model deviance (D), and other selectivity statistics are given in Table 1.

All the selection curves obtained for both gears under uni-normal models were symmetrical in shape without any skewness (Figs. 1 and 3). The better fit of catch data obtained for gillnet and hooks were log-normal model and Normal location model under equal fishing power respectively. It was inferred from the small model deviances of 621.18 and 134.7 drawn for the respective gears under the assumptions of equal fishing power. No significant difference between deviances was found between models (P>0.05) in both gillnet and hooks. Estimated deviance values for the uni-modal models were substantially greater (P<0.01, χ^2 test) than their respective degrees of freedom which was against the general rule of the thumb that the deviance should be less than degrees of freedom [9,10] and justification or rejection of model should never be based on the deviance alone [9].

Estimated dispersion values for the better fit log-normal in gillnet and Normal location in hook were 5.55 and 2.75 respectively under equal fishing power. The dispersion ratio was greater than one in all the cases, thus it could be interpreted as over-dispersion of data in all uni-normal models including better-fit model. Among all residual plots of uni-normal models obtained for mesh and hook selection study, Log-normal and Normal location model fetched good fit for catch data of mesh and hook respectively. However, these plots also did not show best fit due to larger size of residual, the presence of less number of positive residuals, systematic arrangement of residual points in the residual plot instead of random presence, overlapping of residuals one over the other and the residual value was not within the range of '2' [7]. It obviously pointed out that the inferred better fit models for both the gear also did not yield best fit under Poisson distribution [9].



Log normal model (equal fishing power) - Better Fit
Caranx heberi

Bi-normal model (equal fishing power) - Best Fit
Caranx heberi

Fig. 1. Selectivity curves of better and best fit model for different mesh sizes

After evaluating the better fit models of log-normal and normal location for the catch data of gillnet and hook through various statistical tools viz., model deviance, DP and residual plots, the goodness of fit, were not found appropriate. Owing to these, the better-fit models of both gears were extended to bi-normal model. Estimated bi-modal selectivity curves and their parameters for both gears under the assumption of equal fishing power and fishing power proportional to mesh or hook size are presented in Table 1 and Figs. 2 and 3.

In the case of mesh selection study, the better fit uni-normal model could be extended into bi-normal model and deviance value also reduced to 546.64 from 621.18 under the assumption of equal fishing power. Considerable reduction in model deviance obtained from bi-normal model and significant improvement in the plot of deviance residuals revealed the best fit of the catch data [10]. The dispersion parameter for the bi-normal model obtained for the mesh selection was 5.55 which exposed over dispersion of the model. It may be due to shoaling nature of carangid species as reported by other researchers [7] and a common problem with larger fish. It reinforces the fact that gillnets catch data follows normal distribution with bell shaped selectivity curve [5].

However, in hook selectivity study, the selectivity data did not converge into bi-normal model. Non-convergence of hook selectivity data into bi-normal model may be due to single mode of capture or over-parameterization or lack of quantity of data. Hence, it could be concluded that uni-modal normal location would be best fit for the catch data of *C. heberi* obtained from hooks.

Modal length of fish caught from better and best mesh and hook size are given in Table 2. Respective estimated modal length and selection range of the best fit model for the catch data of mesh were 56.2 to 62.5 cm and 4.49 to 4.99 and hook were 41.7 - 80 cm and 14.41 - 14.9 respectively under equal fishing power. The modal length increased with meshes as well as hook size which in turn determines the fishing power of the hook. Modal lengths obtained through better and best fit models for both gears were almost equal and higher than other models. Researchers [2] found that modal lengths worked out based on SELECT method differed from the estimation of modal length obtained by other researchers [11] using Holt model. Variation in the modal length between the models in the present study also may be attributed to the differences within models and availability of wider size range of species in the sea [12]. It may be common in the case of overlapping of catch distribution since model follows principle of proportionality of Baranov [2]. However, the selection ranges varied between models tested and yielded wider selection range in uni-modal model than bi-modal models. The narrow selection range might be due to constant random entangling which same time leads into better fit [13].

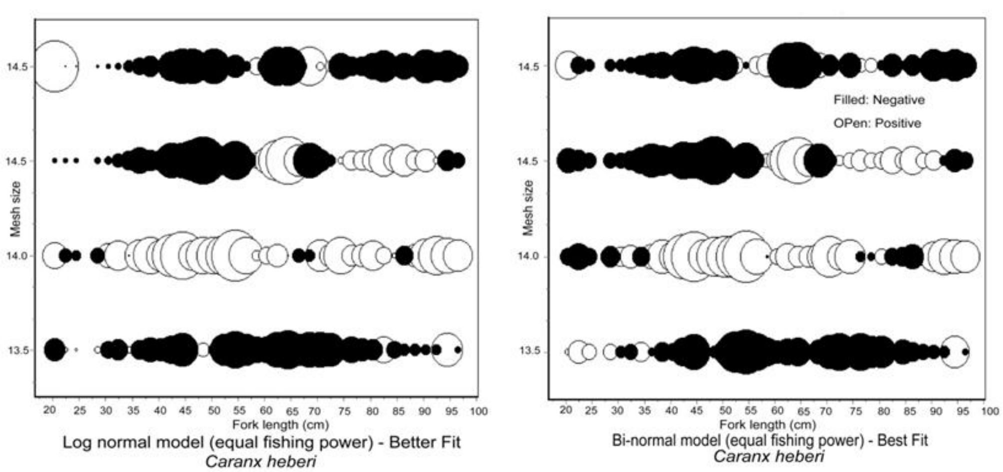


Fig. 2. Residual plots of selectivity curves of better and best fit models for different mesh sizes

(Area of the circle is proportional to square of the residual)

Table 1. SELECT model parameter estimates for gillnet and hook selectivity for *Caranx heberi*

Gear	Model		Degrees of freedom	Equal fishing power			Fishing power á mesh/hook size		
				Parameters	SD	Model deviance	Parameters	SD	Model deviance
Gillnet	Normal location	Fixed spread (k,s)	112	4.2107, 5.7289	0.0201, 0.1002	639.13	4.2491, 5.7526	0.0204, 0.1013	637.58
	Normal scale	Spread α mj (k1,k2)	112	4.2843, 0.3971	0.0199, 0.0067	775.93	4.3214, 0.3951	0.0199, 0.0067	777.73
	Lognormal	Spread α mj (m,s)	112	4.0376, 0.0980	0.0050, 0.0016	**621.18**	4.0472, 0.0980	0.0051, 0.0016	621.18
	Gamma	Spread α mj (k,a)	112	0.0386, 109.844	0.0013, 3.5476	637.76	0.0386, 110.844	0.0013, 3.5658	637.76
	Bimodal	Spread α mj (a1,b1)	109	4.1657, 0.3323	0.0169, 0.0061	**546.64**	4.1923,0.3311	0.0171, 0.0061	547.11
		(a2,b2)		4.9949, 0.5162	0.1199, 0.0340	546.64	5.0502, 0.5122	0.1159, 0.0338	547.11
		w		0.0274	0.0081	546.64	0.0330	0.0092	547.11
Hand line	Normal location	Fixed spread (k,s)	49	6.1149, 14.4052	0.0822, 0.6474	**134.7**	6.4680, 14.8971	0.0888, 0.6984	149.52`
	Normal scale	Spread α mj (k1,k2)	49	6.7328, 1.5791	0.0922, 0.0734	150.14	7.0942, 1.5318	0.0920, 0.0661	151.34
	Lognormal	Spread α mj (m,s)	49	3.8284, 0.2443	0.0155, 0.0108	135.58	3.8881, 0.2443	0.0170, 0.0108	135.58
	Gamma	Spread α mj (k,a)	49	0.3798, 18.0569	0.0341, 1.4901	137.55	0.3798, 19.0569	0.0335, 1.5124	137.55
	Bimodal	Spread α mj (a1,b1)	46	5.5276, 0.8313	0.2597, 0.2947	**134.74**	7.094, 1.532	-	151.33
		(a2,b2)		7.4180, 1.4817	0.7278, 0.3190	134.74	-	-	151.33
		w		1.3824	1.253	134.74	-	-	151.33

Table 2. Modal length and spread of gillnets and hook selectivity curves of various models for *Caranx heberi*

Model	Mesh size (cm)/ Hook Size															
	13.5				14				14.5				15			
	Modal length (cm)		Spread		Modal length (cm)		Spread		Modal length (cm)		Spread		Modal length (cm)		Spread	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Normal location	56.8	57.4	5.73	5.75	59	59.5	5.73	5.75	61.1	61.6	5.73	5.75	63.2	63.7	5.73	5.75
Normal scale	57.8	58.3	5.36	5.33	60	60.5	5.56	5.53	62.1	62.7	5.76	5.73	64.3	64.8	5.96	5.93
Lognormal	56.1	56.7	5.6	5.65	58.2	58.8	5.8	5.86	60.3	60.9	6.01	6.07	62.4	63	6.22	6.28
Gamma	56.7	57.2	5.43	5.46	58.8	59.3	5.64	5.66	60.9	61.5	5.84	5.86	63	63.6	6.04	6.07
Bimodal	56.2	56.6	4.49	4.47	58.3	58.7	4.65	4.64	60.4	60.8	4.82	4.8	**62.5**	62.9	4.99	4.97
	No. 8				No. 7				No. 6				No. 5			
Normal location	41.7	44.1	14.41	14.9	53.7	56.9	14.41	14.9	64.9	68.7	14.41	14.9	**80**	84.7	14.41	14.9
Normal scale	45.9	48.4	10.77	10.45	59.2	62.4	13.88	12.46	71.5	75.3	16.77	16.27	88.1	92.9	20.67	20.05
Lognormal	43.3	46	11.75	12.47	55.8	59.3	15.14	16.08	67.5	71.6	48.3	19.42	83.2	88.3	22.55	23.94
Gamma	44.2	46.8	10.7	11.01	56.9	60.3	13.79	14.19	68.8	72.8	16.66	17.14	84.8	81.8	20.53	21.13
Bimodal	37.7	48.4	5.67	10.45	48.6	62.4	7.31	13.46	58.7	75.3	8.83	16.27	72.4	92.9	10.88	20.05

a: Equal Fishing Power, b: Fishing power α mesh/hook size

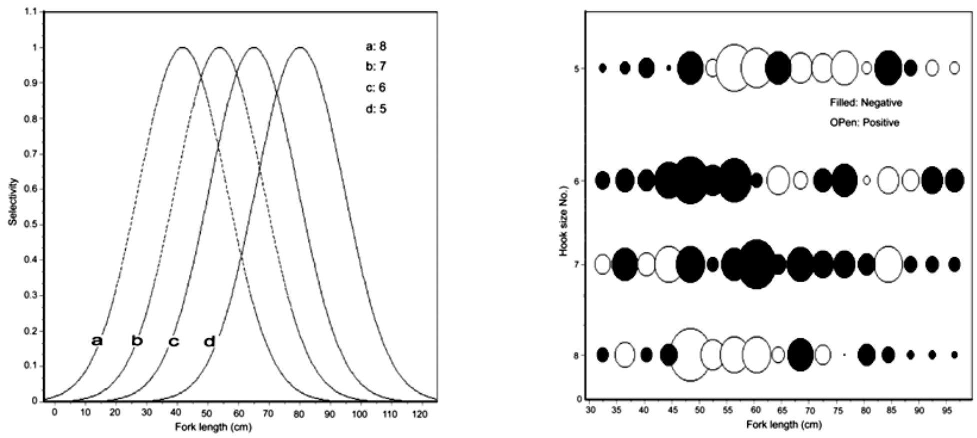


Fig. 3. Hook selective curve and residual plot of normal location (equal fishing power) of *Caranx heberi*

(Area of the circle is proportional to square of the residual)

Residual plots of log-normal and bi-modal function of mesh selection and normal location of hook selection under the assumption of equal fishing power were presented in Figs. 2 and 3. In general, fishing power of any gear differs with size of net as well as mesh. The increase in the mesh sizes increases the net size since the length of the net is proportional to mesh size though there are same numbers of meshes in each unit. Thus, estimation of fishing power is also considered as important since it influences and improves the fit of selectivity data as well [14]. Plots obtained for gillnet explained that the mesh sizes of 13.5, 14, and 14.5 cm were greater than modeled which were revealed from predominant presence of more number of positive residuals. Residual plots of both uni-modal log-normal and bi-modal were almost similar despite number of positive residuals present was lower in 14 cm and higher in 15 cm than log-normal fit. There was no great difference shown with log-normal model in terms of size of groups caught except in the mesh size 15 cm. Residual plots of both bi-modal and log-normal model could not be distinguished though there was drastic reduction observed in the deviance of bi-modal than log-normal fit.

In the case of hook selection study, residual plots of best fit model i.e., normal location revealed that the fishing powers of hook No.5, 6, and 8 were greater than hook size No.7. Similarly, fishing power of the above hooks was similar between normal location and gamma model. Fishing power of hook No. 5 and 6 was same in normal location model by capturing larger size of fish. The performance of the mesh (13.5 cm) and hooks (No.5 & 6) may be due to abundance of the larger size of fishes in the environment and single mode of capture. Residual plot showed the effect of fishing power between different mesh and hook sizes. Fishing power of different mesh or hook sizes are important since catch rates vary between adjacent mesh or hook sizes to a greater extend as stated by the researchers [13]. (1999). However, other researchers [15] expressed that assessing the equal fishing power directly at maximum selectivity was difficult.

4. CONCLUSIONS

Comparison of the selective effects of different gears is complex particularly between selective gears. Further, the mean size of fish caught from one gear to another gear varies due to various biological factors such as availability, abundance, age, sex, and size, or environmental factors such as fishing ground, depth, etc. Selection curves of gillnets and hooks of the present study are assumed as bell shaped multi-normal and uni-normal in nature respectively. In this study, hook selectivity data fit appropriately with uni-normal model despite it is complex in nature in general. It is also opined that fit may depend on models applied though it is normally influenced by biological behavior and capturing methods. This study revealed that gillnet yielded obvious size selection range than hooks in capturing larger carangid, *C. heberi* of the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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