Research Article

Gill Net Selectivity of Vermiculated Sailfin Catfish *Pterygoplichthys disjunctivus* (Weber 1991; Family Loricariidae) and Coexisting Fish Species in Victoria and Kalawewa Reservoirs in Sri Lanka

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Abstract

*Exotic Pterygoplichthys disjunctivus is an invasive fish and has established naturally recruiting populations in Sri Lankan reservoirs. P. disjunctivus is heavily caught into gill nets with mesh size >8.40 cm which has recommended for the inland fisheries in the country. However, small fish are rarely caught into this fishing gear. Present study was conducted with the objective of studying he efficiency of small meshed gill nets to catch immature stages of P. disjunctivus as a controlling measure of their populations in local water bodies. Similarly, it is important to know the impact of small meshed gill nets on commercial fish stocks and the local fish species living in reservoirs. Gill nets with mesh sizes 1.25, 2.5, 3.75, 5.0, 6.25, 7.5, 8.50 and 10.0 cm (length 20 m & height 2 m each) were used to sample fish species in four hourly intervals in Kalawewa and Victoria reservoirs during a period of 24 hours. Total number of sampling occasions for each reservoir was 24 (6 times per day*4 days) and total exposure time was* 24 hours *(one hour exposure time in one occasion). The total length was measured to the nearest 0.1 cm for each species. The total length measurements were analysed for the selectivity of gillnet. The optimum length for each mesh size for each fish species was calculated. And the gill net selectivity curves were plotted with variables fraction retained versus total length. According to the findings of this study gill nets with smaller mesh sizes cannot be used to catch small specimens of P. disjunctivus. But other endemic and indigenous fish species such as Puntius filamentosus (Dawkinsia singhala), Puntius chola, Puntius dorsalis and Rasbora daniconius have become vulnerable to smaller mesh sizes. These cyprinid fish species occupy littoral areas of reservoirs but these areas are now invaded by P. disjunctivus in the two reservoirs. Study concludes P. disjunctivus cannot be caught differently with other co-existing species with gill nets.*

Keywords: *Coexisting Fish species, Gill net selectivity, P. disjunctivus*

1. Introduction

Knowledge on size selectivity of a fishing gear is of importance in managing fisheries. We can adjust the length range distribution of the fish catch by adjusting the gear selectivity while understanding the sampled population (Clavero and Garcı´a-Berthou, 2005; Miller and Holst, 1997). Gill net is the commonly used fishing gear type in reservoirs (Boy and Crivelli, 1988). It's a low-cost fishing gear and easy to use at different water depths (Hovgard and Lassen, 2000).

According to the present regulation for reservoirs in Sri Lanka, it is mainly based on the commercial exploitation of *Oreochromis* species (*Orechromis mossambicus* and *O. niloticus*). Kumara, *et al.,* (2009) have studied the potential of harvesting minor cyprinid species without damaging the commercial fish stocks in Sri Lanka. Also, Kumara, *et al.*, (2009) have suggested small mesh sized gill nets for harvesting minor cyprinids. Gill net selectivity of *P. disjunctivus* with other endemic and indigenous fish species co-habiting will provide the optimum length and length range according to the mesh size of gill net. It may also reveal whether this fishing gear is efficient in catching *P. disjunctivus*. Currently *P. disjunctivus* are caught into gill nets recommended to catch targeted freshwater food fish *Oreochromis spp*. and major Indian and Chinese carp species. To the authors' best knowledge, no work been done on *Pterygoplichthys* gill net selectivity. The aim of this research was to collect information on selectivity of gill nets on *P. disjunctivus* that could be useful to design a plan to reduce the abundance of this species, as well as in other similar environments. Also, to find out whether different mesh sized gill nets can be used to exploit different sizes of *P. disjunctivus* before it reaches its maturity as well as to gather information whether this species can be caught differently with other co-existing species. Current study may also reveal that the potential of harvesting minor cyprinids in selected depth ranges and avoiding the forage time of the juveniles of commercial fish stocks.

2. Materials and Methods

Present study was conducted in Victoria and Kalawewa resrvoirs. Sampling locations of the reservoirs were given in plate 1 and 2. Gill net selectivity of *P. disjunctivus* was performed for different mesh sizes in Haragama in Victoria reservoir and Kalawewa in Kalawewa reservoir (Figure 1 and 2). Fish sampling was performed twice a month in February, March, August and September in year 2018 in both reservoirs. Gill nets with various mesh sizes were used for the study and the stretched mesh sizes were 1.25, 2.5, 3.75, 5.0, 6.25, 7.5, 8.50 and 10.0 cm, respectively. Four net pieces for each mesh size were used for the present study. Net dimensions were 2 m in height and 20 m in width for each mesh size and the hanging ratio was 0.5. Since *P.disjunctivus* are most abundant along the shallower waters (Nico, *et.al*, (2009), Harlem *et al.*, (2012); Walker, and Humphries, (2013)) gill net were set in shallower areas of 2 m depth of the sampling sites of the two reservoirs. Fish sampling was conducted for 24 hours continuously, for four hourly intervals. Total number of sampling occasions for each reservoir was 24 (6 times per day*4 days) and total exposure time was 24 hours (one-hour exposure time in one occasion). All fish species were identified using standard keys and guides of Munro, (2000), Pethiyagoda, (1991). Page and Robins, 2006. Ambruster and Page, 2006; Nico, *et al.*, 2009 and Bijukumar, *et al.*, 2015 and then grouped accordingly. Gill net selectivity patterns of *P.disjunctivus* and other local species coexisting in the same area were determined from the Baranov and Holt method (Baranov 1914; Holt 1963; Hamley 1975).

The logarithms of catch ratio for two consecutive mesh sizes were found using the following equation (Hamley 1975).

$$\ln C_b / C_a = a + b L \quad (1)$$

where,

C_a = Number of fish caught in the lower meshed gill net for each length class
C_b = Number of fish caught in the higher meshed gill net for each length class
a & b = Constants
L = Length class mid-point

Note that a and b are the intercept and gradient for above linearized catch ratio against length class midpoint plot. Optimum length ($L_{opt\,(1)}$ and $L_{opt\,(2)}$) for adjacent mesh sizes (M_1 and M_2) of gill nets were calculated using a and b values in following equations.

$$L_{opt\,(1)} = -2a.M_1 / [b\,(M_1+M_2)] \quad (2)$$

$$L_{opt\,(2)} = -2a.M_2 / [b\,(M_1+M_2)] \quad (3)$$

where,

$L_{opt\,(1)}$ = Optimum length of lower meshed gill net
$L_{opt\,(2)}$ = Optimum length of higher meshed gill net
M_1 = Mesh size of lower meshed gill net
M_2 = Mesh size of higher meshed gill net
a & b = Intercept and gradient for above linearized catch ratio against length class midpoint plot

Then selection factor (SF) for each meshed gill net was as follows.

$$SF = L_{opt} / M \quad (4)$$

where,

M = mesh size

Analysis is based on the assumption that mean selection length is linearly proportional to the mesh size and the selection curve is symmetrical around the L_{opt} and approximates to the shape of a normal distribution. The variance of distribution (S^2) of the normal distribution was calculated as follows.

$$S^2 = 2a (M_2 - M_1) / b (M_1+M_2) \quad (5)$$

From the square root of S^2 standard deviation (S) was calculated for each mesh size. When there were two estimates each of L_{opt} and SD for a particular species in a given mesh size, mean values were taken. The fraction retained (S_L), i.e. the point of the selection curve for each mesh size was calculated using following equation.

$$S_L = \exp [- (L - L_{opt})^2 / 2 S^2] \quad (6)$$

Then the gill net selection curves for each mesh size for each fish species were plotted. The selection range was calculated (the difference between $L_{25\%}$ and $L_{75\%}$) according to Sparre and Venema 1998.

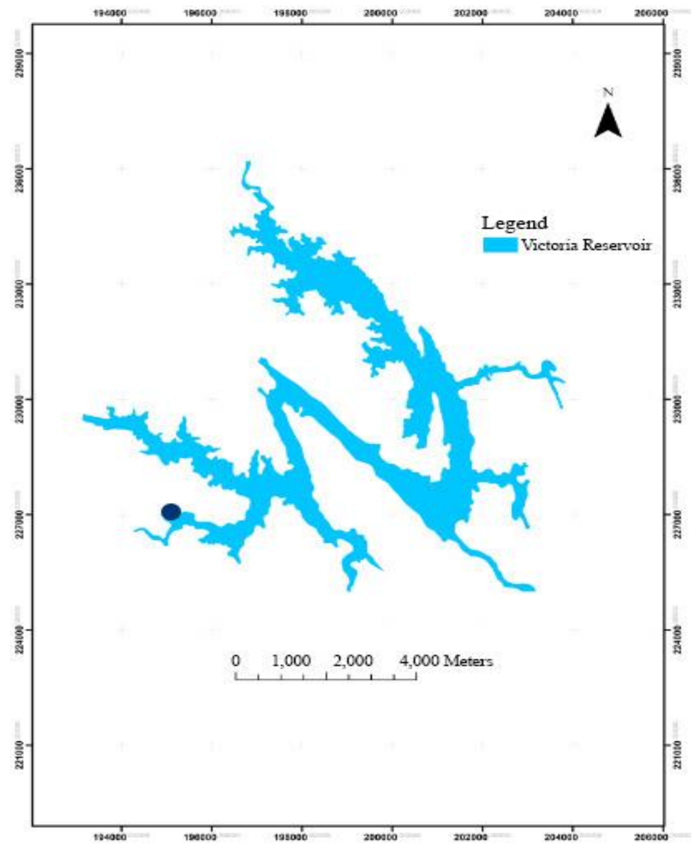


Plate 1: Sampling site in Victoria reservoir

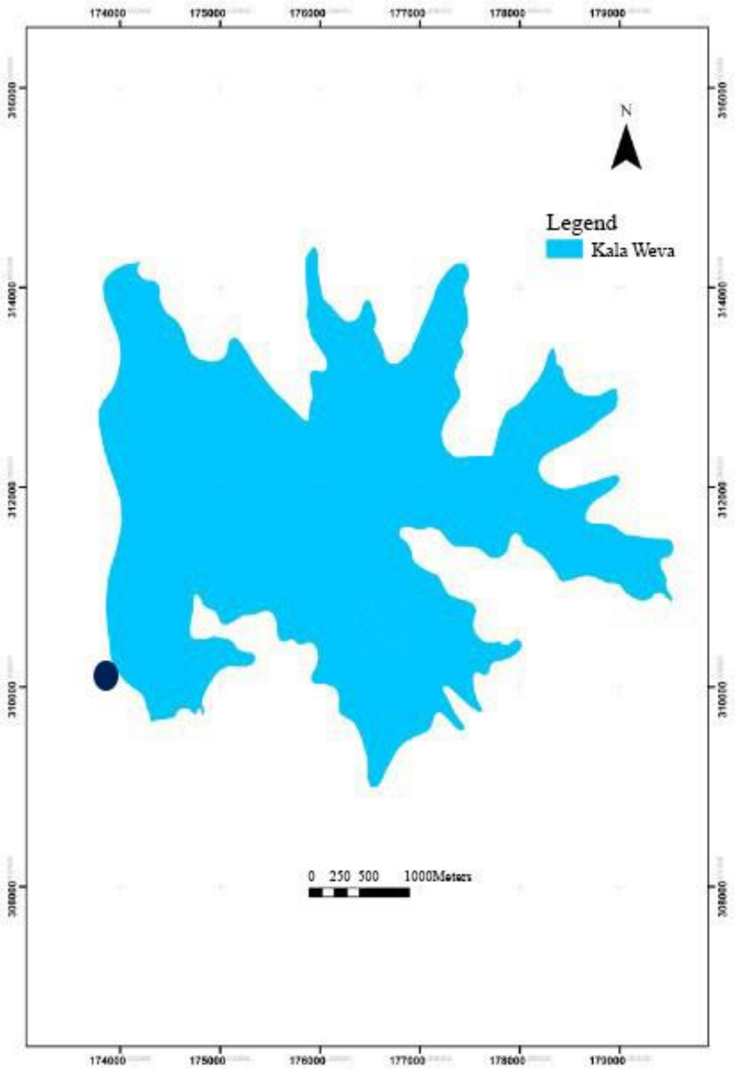


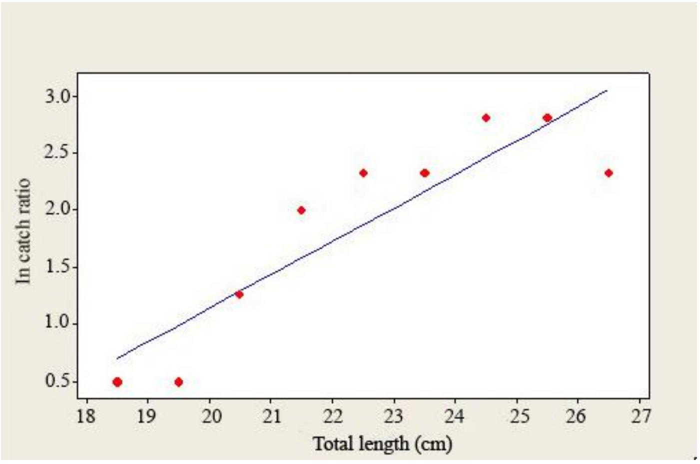
Plate 2: Sampling site in Kalawewa reservoir

3. Results

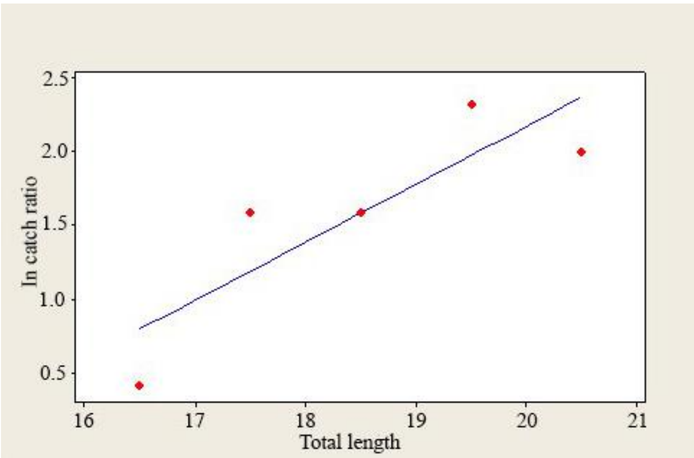
Table 1 shows regression relationships of ln catch ratios (ln C_b / C_a) versus mid points of length classes (cm) of *P. disjunctivus*, *Oreochromis niloticus*, *Puntius filamentosus (Dawkinsia singhala)*, *Puntius dorsalis*, *Puntius chola* and *Rasbora daniconius.* All the relationships were with positive correlations and significant (Table 1). The optimal lengths for each mesh size combination are given in Table 2 in Victoria reservoir. *P. disjunctivus* and *O. niloticus* were vulnerable only to gill nets with mesh sizes 6.25 cm and 8.75 cm. The optimum lengths for *P. disjunctivus* and *O. niloticus* in Victoria reservoir were 13.8 cm / 18.4 cm and 12.0 cm / 16.8 cm, respectively. In Kalawewa reservoir *P. disjunctivus* and *O. niloticus* were not vulnerable only to gill nets with mesh sizes 8.75 cm and 10.0 cm. The optimum lengths for *P. disjunctivus* and *O. niloticus* were 17.3 cm / 19.8 cm and 14.1 cm / 19.8 cm, respectively. Small sized fishes of *P. disjunctivus* and *O. niloticus* were not vulnerable for the gill nets of the two reservoirs.

Figure 1 shows relationships of Ln catch ratios of fish species in the overlapping ranges of gillnets of adjacent mesh sizes (vertical axes) to mid-points of length classes (horizontal axes in cm). The regression equations are given in Table 1.
Victoria

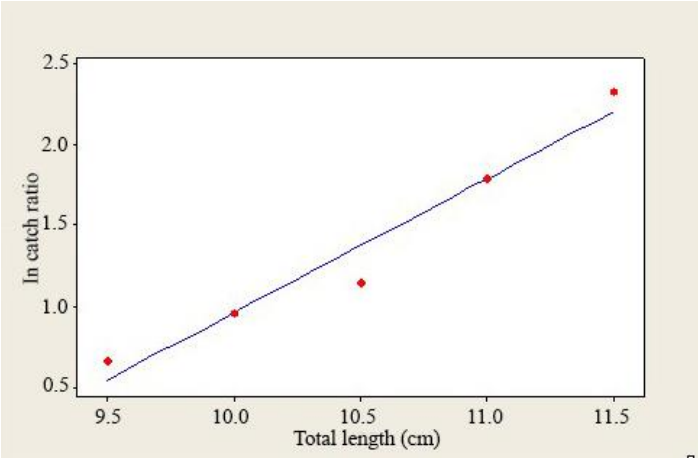
A)



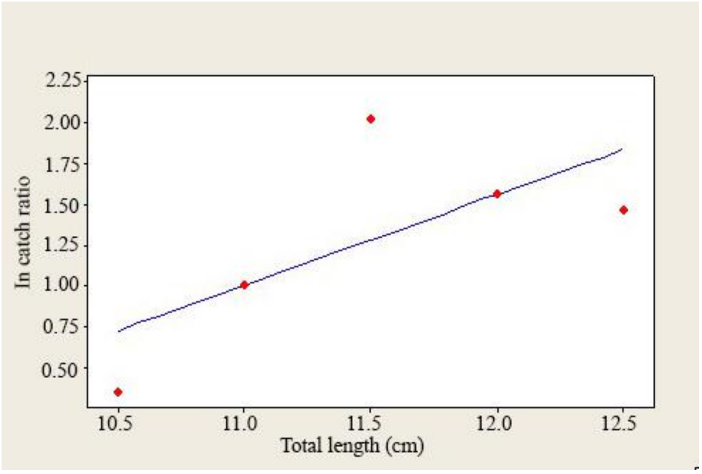
B)



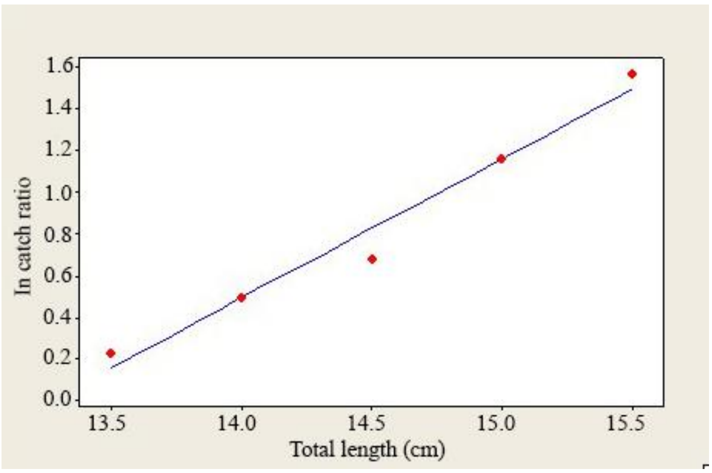
(C) (i)


2.5
2.0
1.5
1.0
0.5
ln catch ratio
9.5
10.0
10.5
11.0
11.5
Total length (cm)

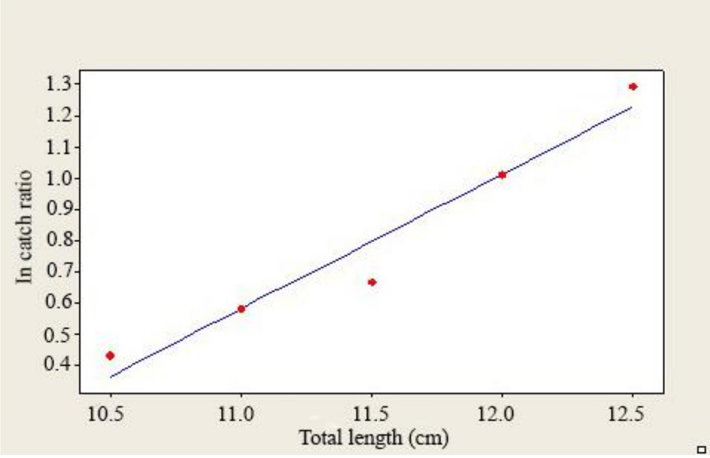
(ii)


2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
ln catch ratio
10.5
11.0
11.5
12.0
12.5
Total length (cm)

(iii)

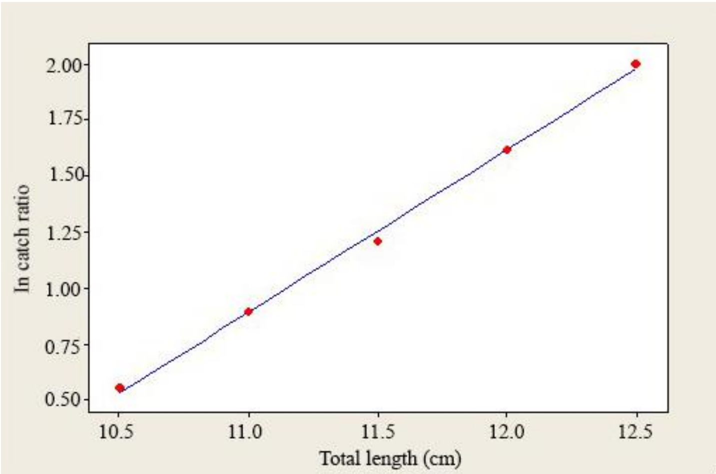

1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ln catch ratio
13.5
14.0
14.5
15.0
15.5
Total length (cm)

(D)

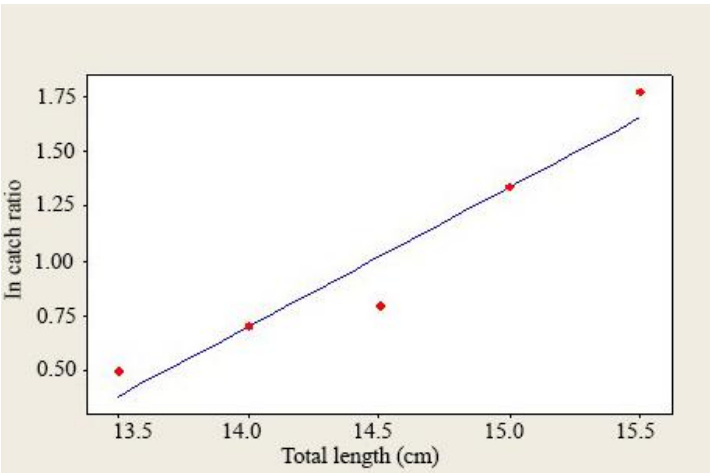

1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
ln catch ratio
10.5
11.0
11.5
12.0
12.5
Total length (cm)

E)

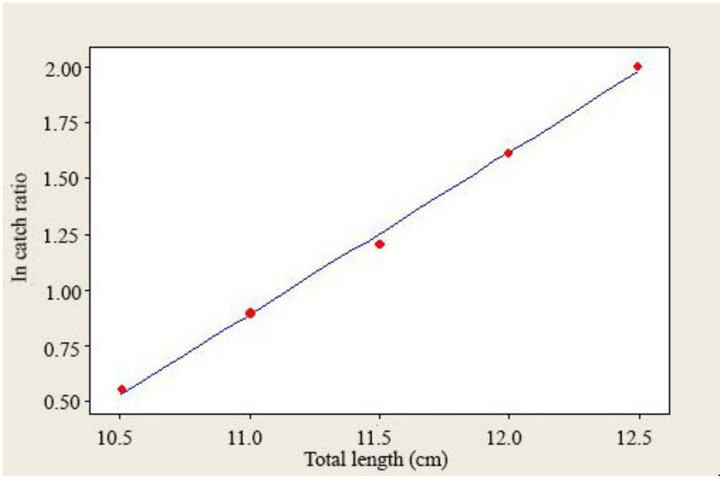
(i)


2.00
1.75
1.50
1.25
1.00
0.75
0.50
ln catch ratio
10.5
11.0
11.5
12.0
12.5
Total length (cm)

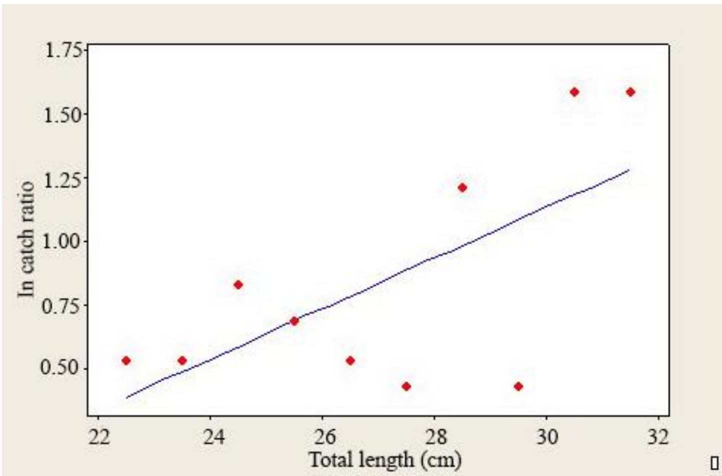
(ii)


1.75
1.50
1.25
1.00
0.75
0.50
ln catch ratio
13.5
14.0
14.5
15.0
15.5
Total length (cm)

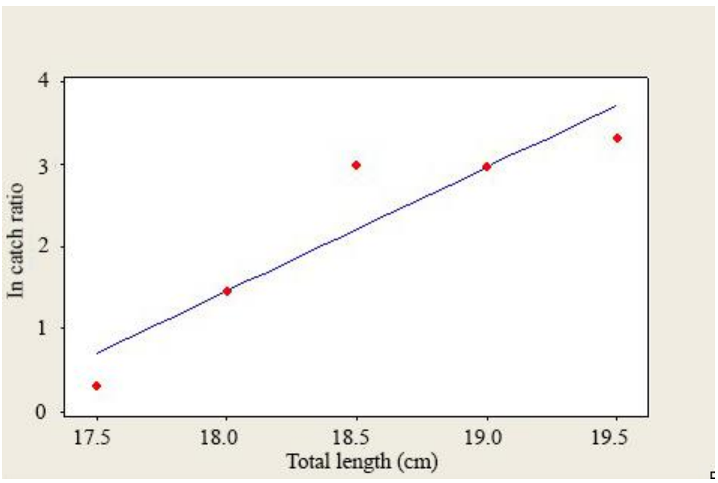
(F)


ln catch ratio
2.00
1.75
1.50
1.25
1.00
0.75
0.50
10.5
11.0
11.5
12.0
12.5
Total length (cm)

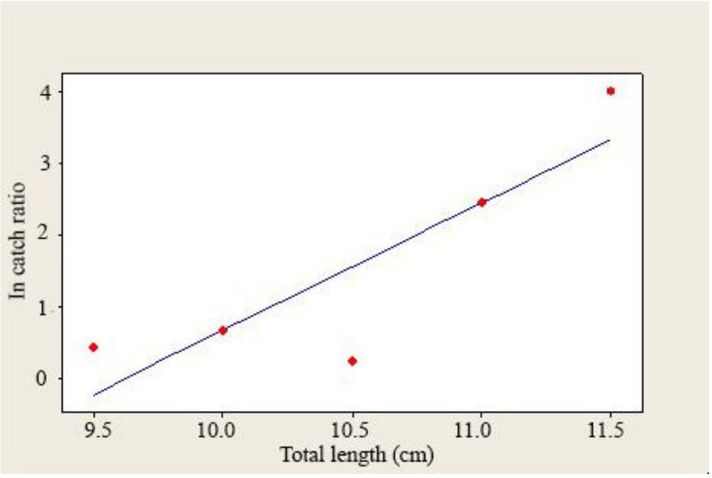
(G)


ln catch ratio
1.75
1.50
1.25
1.00
0.75
0.50
22
24
26
28
30
32
Total length (cm)

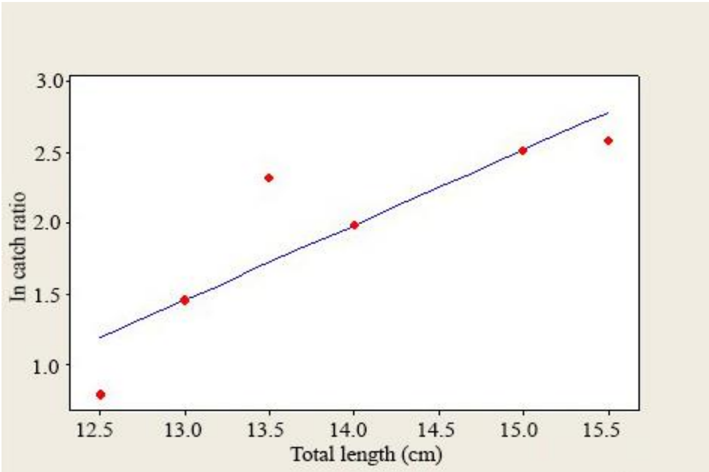
(H)


ln catch ratio
4
3
2
1
0
17.5
18.0
18.5
19.0
19.5
Total length (cm)

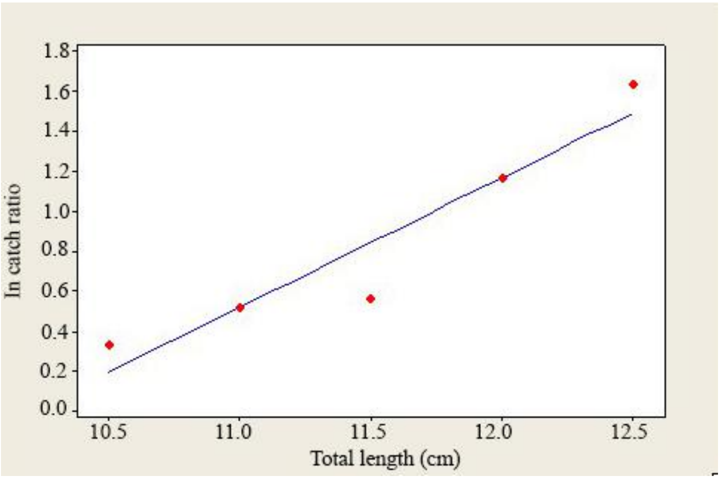
(I) (i)


ln catch ratio
Total length (cm)
9.5
10.0
10.5
11.0
11.5
0
1
2
3
4

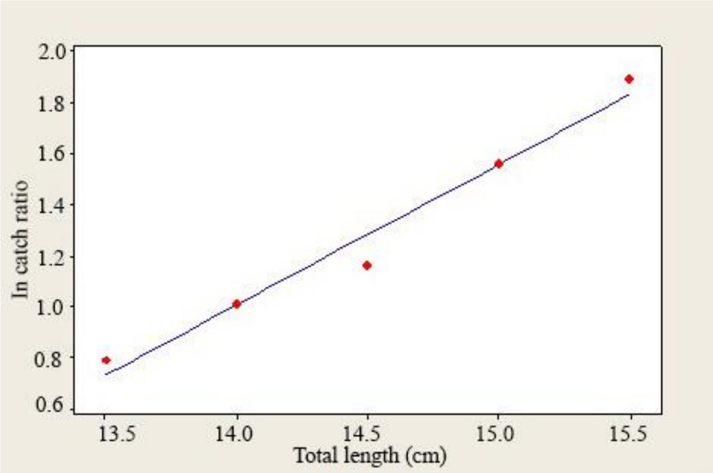
(ii)


ln catch ratio
Total length (cm)
12.5
13.0
13.5
14.0
14.5
15.0
15.5
1.0
1.5
2.0
2.5
3.0

(L) (i)


ln catch ratio
Total length (cm)
10.5
11.0
11.5
12.0
12.5
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

(ii)



(J)

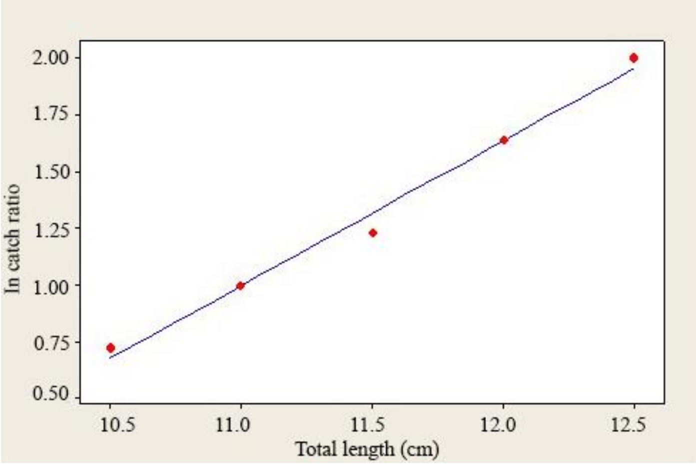


Figure 1: The relationships of ln catch ratios of fish species in the overlapping ranges of gillnets of adjacent mesh sizes vs to mid-points of length classes. Victoria reservoir -(A) P. disjunctivus (6.25/8.75 cm) ;(B) O. niloticus (6.25/8.75 cm); C) Puntius filamentosus (Dawkinsia singhala) (i) (1.25/2.5 cm), (ii). (2.5/3.75 cm), (iii). (2.5/3.75 cm); (D) Puntius dorsalis (3.75/5.0 cm); (E) Puntius chola (i) (2.5/3.75 cm); (ii). (3.75/5.0 cm); (F) Rasbora daniconius (2.5/3.75 cm); Kalawewa reservoir -(G) P. disjunctivus (8.75/10.0 cm) ;(H) O. niloticus (6.25/8.75 cm) ;(I) Puntius filamentosus (Dawkinsia singhala); (i). (2.5/3.75 cm); (ii). (3.75/5.0 cm); (J) Puntius chola (i) (2.5/3.75 cm), (ii) (3.75/5.0 cm); (K) Rasbora daniconius (2.5/3.75 cm)

The regression equations are given in Table 1.

Table 1: Regression relationships of ln C_b / C_a versus mid length (cm) of *P. disjunctivus, Oreochromis niloticus, Puntius filamentosus (Dawkinsia singhala), Puntius dorsalis, Puntius chola* and *Rasbora daniconius.*

Species Victoria reservoir	Mesh size combination	Regression relationship	Correlation coefficient	p	Figure no.
P. disjunctivus	6.25/8.75	y = 0.2937x - 4.7371	0.795	<0.01	A
O. niloticus	6.25/8.75	y = 0.3904x - 5.6415	0.732	<0.10	B
P. filamentosus (Dawkinsia singhala)	1.25/2.5	y = 0.8305x - 7.3458	0.944	<0.01	Ci
	2.5/3.75	y = 0.5543x - 5.0937	0.426	<0.10	Cii
	3.75/5.0	y = 0.6685x - 8.8676	0.967	<0.01	Ciii
P. dorsalis	3.75/5.0	y = 0.911x - 11.78	0.995	<0.01	D
P. chola	2.5/3.75	y = 0.4309x - 4.1588	0.936	<0.01	Ei
	3.75/5.0	y = 0.6356x - 8.1953	0.911	<0.01	Eii
R. daniconius	2.5/3.75	y = 0.7211x - 7.0377	0.996	<0.01	F
Kalawewa reservoir					
P. disjunctivus	8.75/10.0	y = 0.0994x - 1.8511	0.429	<0.01	A
O. niloticus	6.25/8.75	y = 1.5104x - 25.736	0.828	<0.10	B
P. filamentosus (Dawkinsia singhala)	2.5/3.75	y = 1.7847x - 17.184	0.709	<0.10	Ci
	3.75/5.0	y = 0.5309x - 5.4447	0.702	<0.10	Cii
P. chola	2.5/3.75	y = 0.6488x - 6.6182	0.878	<0.05	Di
	3.75/5.0	y = 0.5502x - 6.6952	0.964	<0.01	Dii
R. daniconius	2.5/3.75	y = 0.6395x - 6.0376	0.985	<0.01	E

Table 2 shows the estimated optimal lengths of the fish species for each mesh size of gillnets in Victoria reservoir.

Table 2: Estimated optimal lengths of the fish species for each mesh size of gillnets in Victoria reservoir.

Species	Mesh size (cm)	Optimum length (cm)	SF	SD	Selection range
P. disjunctivus	6.25	13.8	2.2	12.3	10.8-21.1
	8.75	18.4	2.1	13.1	15.9-23.4
O. niloticus	6.25	12.0	1.9	6.5	9.0-15.0
	8.75	16.8	1.9	9.3	13.8-19.8
P. filamentosus (Dawkinsia singhala)	1.25	5.8	4.6	12.7	4.3-8.8
	2.5	7.3	2.9	14.2	4.3-10.3
	3.75	11.3	3.0	7.0	9.3-13.3
	5.0	15.1	3.0	6.4	13.1-17.5
P. dorsalis	3.75	8.1	2.1	4.4	6.1-10.1
	5.0	10.8	2.1	4.7	9.8-11.8
P. chola	2.5	7.7	3.0	8.8	5.7-9.7
	3.75	11.5	3.0	8.0	8.5-14.5
	5.0	14.7	2.9	6.8	11.7-17.7
R. daniconius	2.5	7.8	3.1	5.7	5.8-9.8
	3.75	11.7	3.1	5.8	9.7-13.7

Table 3 shows the estimated optimal lengths of the fish species for each mesh size of gillnets in Kalawewa reservoir.

Table 3: The estimated optimal lengths of the fish species for each mesh size of gillnets in Kalawewa reservoir.

Species	Mesh size (cm)	Optimum length (cm)	SF	SD	Selection range
P. disjunctivus	8.75	17.3	1.9	3.2	16.3-20.3
	10.0	19.8	1.9	3.7	18.8-21.8
O. niloticus	6.25	14.1	2.2	6.4	11.1-16.1
	8.75	19.8	2.2	6.7	17.8-21.8
P. filamentosus (Dawkinsia singhala)	2.5	7.7	3.0	3.8	6.7-8.7
	3.75	11.9	3.1	5.6	9.9-13.9
	5.0	16.4	3.2	7.1	13.4-19.4
P. dorsalis	3.75	8.1	2.1	4.4	6.1-10.1
	5.0	10.8	2.1	4.7	8.8-12.8
P. chola	2.5	8.1	3.2	7.4	6.1-10.1
	3.75	11.3	3.0	7.2	9.3-13.3
	5.0	13.9	2.7	7.6	10.9-16.9
R. daniconius	2.5	8.1	3.2	4.4	7.1-9.1
	3.75	10.8	2.8	4.7	9.8-11.8

Figure 2 shows the gill net selection curves for fish species in Victoria reservoir (a). *P. disjunctivus* (b). *O. niloticus* (c). *P. filamentosus (Dawkinsia singhala)* (d). *P. dorsalis* (e). *P. chola* (f). *R. daniconius.*Vertical axes – Probabilities of capture; Horizontal axes – Total length in cm. Mesh sizes (in cm) corresponding to individual selection curves are also indicated here.

Figure 2 shows the gill net selection curves for fish species in Kalawewa reservoir.

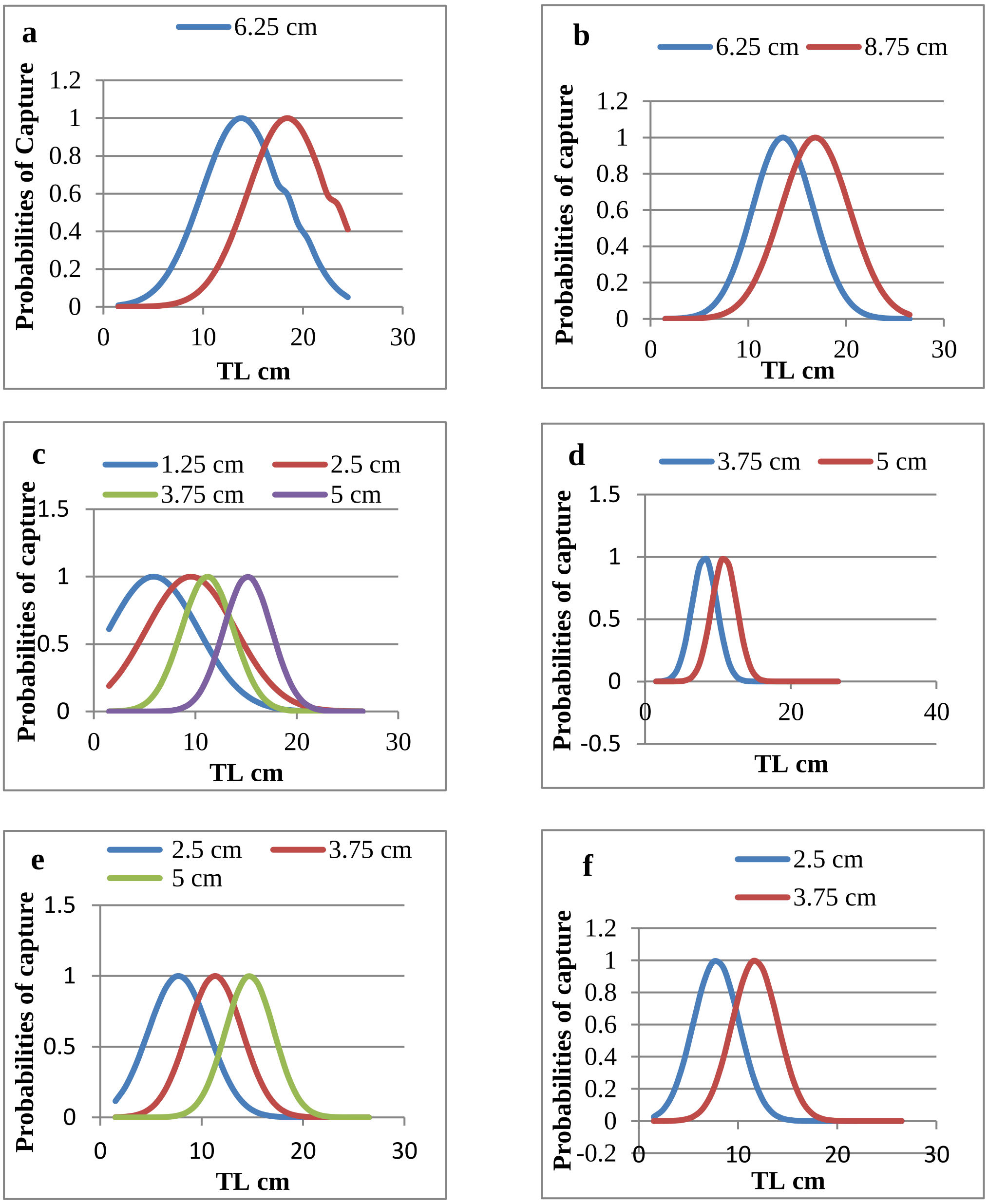


Figure 2: The gill net selection curves for fish species in Victoria reservoir (a). *P. disjunctivus* (b). *O. niloticus* (c). *P. filamentosus (Dawkinsia singhala)* (d). *P. dorsalis* (e). *P. chola* (f). *R. daniconius* .Vertical axes – Probabilities of capture; Horizontal axes – Total length in cm. Mesh sizes (in cm) corresponding to individual selection curves are also indicated here.

Figure 3 shows the gill net selection curves for fish species in Kalawewa reservoir.

(a). *P. disjunctivus* (b). *O. niloticus* (c). *P. filamentosus (Dawkinsia singhala)* (d). *P. chola* and (e). *R. daniconius* Vertical axes – Probabilities of capture; Horizontal axes – Total length in cm. Mesh sizes (in cm) corresponding to individual selection curves are also indicated here.

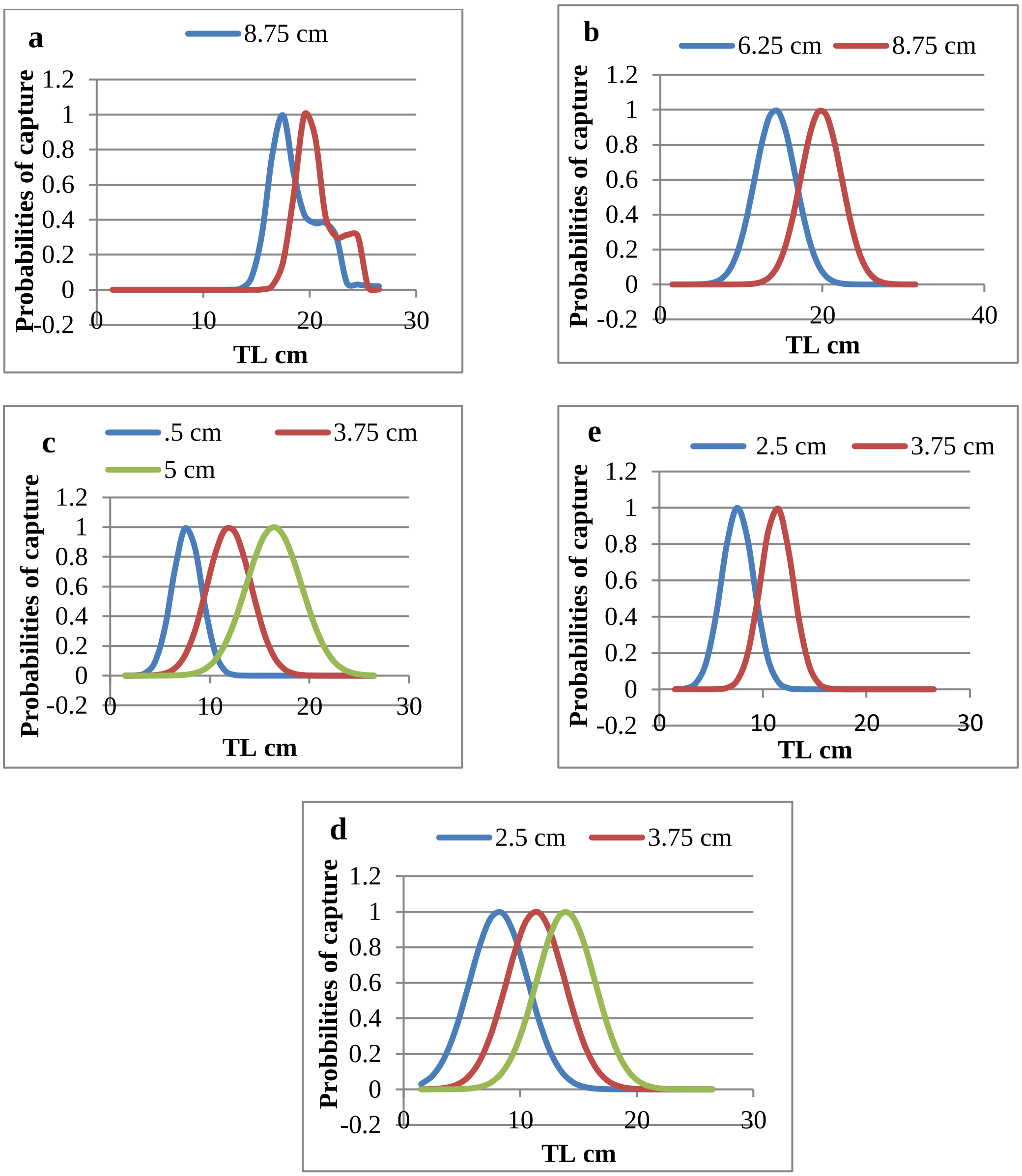


Figure 3: The gill net selection curves for fish species in Kalawewa reservoir.
(a). *P. disjunctivus* (b). *O. niloticus* (c). *P. filamentosus (Dawkinsia singhala)* (d). *P. chola* and (e). *R. daniconius* Vertical axes – Probabilities of capture; Horizontal axes – Total length in cm. Mesh sizes (in cm) corresponding to individual selection curves are also indicated here.

4. Discussion

The gill net selectivity in this study shows that by increasing the mesh size the optimum length also increases, for a particular species. There are slight differences in the optimum lengths for the two reservoirs for same species due to gear encounter variations even though the gear dimensions were same. *P. disjunctivus, O. niloticus, P. filamentosus (Dawkinsia singhala), P. dorsalis, P. chola* and *R. daniconius* were gilled in sufficient numbers in the fishing occasions throughout 24 hours during the gill net selectivity studies. *E. suratensis, G. guiris, M. vittatus, H. fossilis* and *M. armetus* were not caught in sufficient numbers so those were excluded from analysis of gill net selectivity. The optimum lengths of cyprinids in the current study (Tables 2 and 3) are in consistent with those of Kumara, *et al.,* (2009). Also, for smaller mesh sizes juvenile *O. niloticus* were not caught because of their distribution differences in the reservoir (Kumara, *et al.,* 2009). There is a possibility that juveniles of *P. disjunctivus* also dwell in the same habitat as juveniles of *O. niloticus* because smaller *P. disjunctivus* were very rare in the catch of smaller meshed gill nets. There is another possibility that this stage of *P. disjunctivus* were in littoral area in association with nesting burrows, for the protection from predation.

Gill net with same mesh size, colour, length, depth and hanging ratio, the selectivity for different locations may change due to fish encounter with the gill net and retention of the fish caught Hamely (1975). And gill net selectivity depends on other abiotic factors such as fish morphology, behaviour and fish distribution (Craig *et al.*, 1985; Gray *et al.,* 2005). Also, fish caught in a given size of mesh typically differ in length by no more than 20% of the optimum length (i.e., the length most efficiently retained by the mesh: Hamely (1975, 1980) causing gill nets to be strongly size selective. So, the gill net selectivity estimations can be used for this purpose i.e. using the proper meshed net the yield can be increased. This may help in controlling the population size of *P. disjunctivus*. However sufficient studies should be there on gill net selectivity seasonally. Gill nets are highly selective for those species captured mainly by gilling (i.e. captured behind the gill cover) or wedged (being held by a mesh around their maximum body girth). Due to the selective nature of gill nets, mesh size can be controlled to restrict the size of fish captured, and either selection or retention curves can be used to calculate an optimal mesh size. The retention is supposed to increase with size up to a length of maximum catch and decrease thereafter and consequently the range of size at catch of a target species can be controlled with a careful choice of the mesh size. However, in addition to mesh size a number of technical characteristics related to gear construction (hanging ratio) and twine specifications (material, thickness, colour etc.) have a significant influence on the catch size distribution (Fonseca, *et al.*,2005). Similarly, biological characteristics also influence retention by size. For a number of species, the existence of well-developed teeth, protruding maxillaries, or body projections (spines) together with higher swimming activity, can result in a significant proportion of fish being entangled (Fonseca, *et al.*, 2005). Furthermore, managers would like to predict what effect any proposed change in mesh regulations might have on the size composition of the catch (Motlagh, *et al.,* 2011). For these reasons, gill net selectivity has often been estimated using a variety of methods for different fish species (e.g. reviews). Knowledge of selectivity is needed in managing a commercial gillnet fishery as the proper mesh size aids in obtaining the maximum yield. In recent years, new methods have been developed. The gill net selectivity studies will help to decide whether gillnet is a suitable fishing practice to exploit sucker mouth armored sail fin catfishes and the suitable mesh size to catch this species optimally. This fish harvest can be used not only for fish value added products from its meat and roe, but also extractions of various chemicals such as collagen from flesh, skin and scales. Loricariids have been consumed by humans in their native geographical area of spreading (Mendoza Alfaro, *et al.*, 2009) has expounded Loricariids fish flour to feed Tilapias to obtain good growth rates. For commercialization purposes, the percentage the protein contained in the meat was calculated 19% of the weight so the meat can be used in formulating animal diets.

5. Conclusion and Suggestions

Small sized *P. disjunctivus* were not vulnerable to small meshed gill nets but cyprinid fish species. So, *P. disjunctivus* cannot be caught differently with other co-existing species with gill nets. Hence gill net is not a suitable fishing practice to harvest all sizes of this species through massive exploitation for controlling / eradication measures. It is suggested that a suitable fishing method should be identified for effective controlling / eradication of *P. disjunctivus* in Sri Lankan water bodies. Current study also revealed that the potential of harvesting minor cyprinids in selected depth ranges and avoiding the forage time of the juveniles of commercial fish stocks as concluded previously by Kumara, *et al.,* (2009) and Amarasinghe (1985). Further investigations on selectivity of the fishes of current study using best fit selectivity models will be carried out.

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