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GILLNET SELECTIVITY OF *OMPOK BIMACULATUS* (SILURIDAE) AND *PUNTIUS DORSALIS* (CYPRINIDAE) IN A SMALL-SCALE RIVERINE FISHERY

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Abstract: Gillnet selectivity of two indigenous fish species, *Ompok bimaculatus* and *Puntius dorsalis* was determined in a small-scale fishery at Uruwal Oya, in the Gampaha district. The optimal lengths (L_{opt}) of the two species for different mesh sizes were determined by the Baranov-Holt method. The relationships between L_{opt} and mesh size (M) of gillnet for the two species are described by the following equations:

O. bimaculatus: $L_{opt} = 4.076 + 3.694\ M$ ($r = 0.992$; $p < 0.01$)
P. dorsalis: $L_{opt} = 2.445 + 3.410\ M$ ($r = 0.994$; $p < 0.001$)

The mean sizes of maturity of *O. bimaculatus* (21.6 cm for males and 26.1 cm for females) and *P. dorsalis* (13.4 cm for males and 14.8 cm for females) approximately correspond to L_{opt} in stretched gillnet mesh sizes of 5.8 cm and 3.8 cm respectively according to the above relationships. Therefore there seems to be a need for regulating mesh size of gillnets in this fishery in order to prevent immature *O. bimaculatus* and *P. dorsalis* being caught.

Key words: Baranov-Holt method, Biodiversity, Cyprinidae, Fisheries management, Freshwater fish, Gillnet selectivity, *Ompok bimaculatus*, *Puntius dorsalis*, Riverine fish, Siluridae, Uruwal Oya.

INTRODUCTION

The indigenous freshwater fish of Sri Lanka are almost entirely riverine species.[1] Although the inland fishery of the country is now mainly based on the exotic cichlid species in the multitude of reservoir systems,[2] small-scale fisheries for indigenous species continue in some riverine habitats of the country.[3,4]

Uruwal Oya at Makilangamuwa in the Gampaha district which drains into Negombo estuary (Fig. 1) sustains a small-scale fishery. Major gear is nylon gillnet of the stretched mesh sizes 2.5 cm, 3.8 cm, 4.5 cm, 5.2 cm and 6.4 cm. The lengths and heights of gillnets of all mesh sizes and their filament characteristics (2 ply) are identical. The average daily catch per fisherman is about 9 kg. Because the fishermen use small mesh gillnets for catching indigenous fish species in this riverine habitat, gillnet selectivity studies are extremely important from the conservation point of view.

A few gillnet selectivity studies have been reported in Sri Lanka for the fish fauna of perennial reservoirs[5,6] and for *Amblygaster sirm* (Walbaum) in coastal waters[7,8] However, no gillnet selectivity studies were done for fish species in the riverine habitats of the country. Results of investigations on the gillnet selectivity of two indigenous species *Ompok bimaculatus* (Bloch) and *Puntius dorsalis* (Jerdon) in Uruwal Oya, Gampaha district are reported here.

METHODS AND MATERIALS

In Uruwal Oya at Makilangamuwa area of the Gampaha district (Fig. 1), fishermen set their gillnets for approximately 12 h period from dusk to dawn. *O. bimaculatus* and *P. dorsalis* are the major species caught (Table 1) in the gillnets of mesh sizes 2.5 cm, 3.8 cm, 4.5 cm, 5.2 cm and 6.4 cm.

The total length (TL) and the greatest depth (GD) of *O. bimaculatus* and *P. dorsalis* caught in each of the mesh sizes of gillnets, were measured to the nearest 0.1 cm from July 1994 to March 1995. Samples packed in ice, were also taken to the laboratory and the TL, sex and sexual maturity of individual fish were determined.

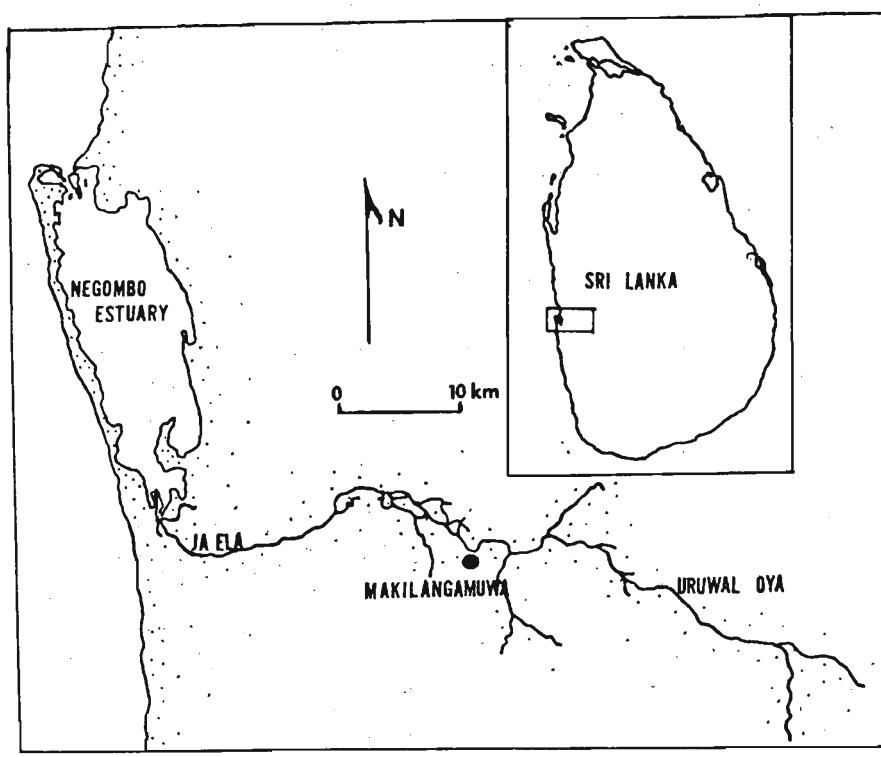

Figure 1: Map of the study site. Inset shows its location in Sri Lanka.

Table 1: Species composition (by numbers) of the catches in the small- scale gillnet fishery in Uruwal Oya, Gampaha district. Total number of fish observed = 3983.

Family/Species	Percentage
Bagridae	
Mystus vittatus (Bloch)	0.6
Cichlidae	
Etroplus suratensis (Bloch)	0.1
Cyprinidae	
Amblypharyngodon melettinus (Valenciennes)	1.4
Esomus danrica (Valenciennes)	0.5
Labeo dussumieri (Valenciennes)	7.0
Puntius chola (Hamilton-Buchanan)	2.2
Puntius dorsalis (Jerdon)	29.3
Puntius filamentosus (Valenciennes)	11.8
Rasbora daniconius (Hamilton-Buchanan)	2.9
Gobiidae	
Glossogobius guiris (Hamilton-Buchanan)	0.6
Heteropneustidae	
Heteropneustes fossilis (Bloch)	1.4
Mastacembelidae	
Mastacembeles armatus (Lacèpéde)	3.2
Ophiocepalidae	
Ophicephalus striatus Bloch	5.3
Siluridae	
Ompok bimaculatus (Bloch)	24.1
Anabantidae	
Anabas testudineus (Bloch)	9.6

Fish of a particular size usually becomes enmeshed in gillnet as a result of its relationship of body depth to the mesh size of net. However, the gillnet selectivity and size distribution of fish caught are conveniently described in terms of length. Therefore, the relationships between TL and GD for each sex of the two species were determined using a linear regression technique. The relationships are highly significant ($p<0.01$) and are as follows:

O. bimaculatus

For males: $GD = 0.343 + 0.197\ TL\ (r = 0.75)$

For females: $GD = 0.653 + 0.173\ TL\ (r = 0.83)$

P. dorsalis

For males: GD = 0.381 + 0.241 TL (r = 0.90)
For females: GD = 0.255 + 0.263 TL (r = 0.91)

The relationships for the two sexes in each species were compared by the Student's t-test and found to have no significant difference at 95% confidence level (For *O. bimaculatus* $t_{obs} = 0.73$ and for *P. dorsalis* $t_{obs} = 1.41$). Therefore, the remaining analyses were performed using combined data for both sexes for the two species. Furthermore as GD is significantly related to TL, selectivity studies were performed using data of TL.

TL measurements of *O. bimaculatus* (830 individuals) and *P. dorsalis* (1325 individuals) caught in gillnets of mesh sizes 2.5 cm, 3.8 cm, 4.5 cm, 5.2 cm and 6.4 cm were analyzed using Baranov-Holt method.[9-11] Owing to the fact that gillnet selectivity studies for individual species in the fisheries of tropical Asia are scanty,[12] step-wise procedure of the analysis is thought to be useful. This method of analysis is based on the assumptions that the mean selection length (optimal length or L_{opt}) is linearly proportional to the mesh size and that the selection curve for fish is symmetrical around the L_{opt} and approximates to shape of a normal distribution.[9] Accordingly, the catch by a gillnet of mesh size M, of fish of length L (C_L) is given by the following equation.[11,13]

$$C_L = F.N_L \exp [-(L-L_{opt})^2/2SD^2]$$

where SD^2 = variance of distribution; N_L = number of fish at length L in the population; F = fishing mortality on fish of length L.

The catches of fish of length L, in two gillnets with slightly different mesh sizes M_1 and M_2 can be expressed by the following equations, assuming that $L_{opt(1)} = dM_1$, $L_{opt(2)} = dM_2$, that SD for the curves of two mesh sizes are the same, and that the nominal fishing effort (hence the fishing mortality, F) with each mesh size is the same.[10, 11, 13]

$$\text{Mesh size } M_1: \ln C_1 = [\ln (F.N_L)][-(L-L_{opt(1)})^2/2SD^2]$$
$$\text{Mesh size } M_2: \ln C_2 = [\ln (F.N_L)][-(L-L_{opt(2)})^2/2SD^2]$$

As such, substituting for $L_{opt(1)}$ and $L_{opt(2)}$, the logarithms of catch ratios in numbers in overlapping selection ranges can be expressed as follows:

$$\ln C_2/C_1 = [d(M_2-M_1)/SD^2]L - [d^2(M_2^2-M_1^2)/2SD^2]$$

The logarithms of catch ratios (in numbers) of overlapping ranges of two gillnets with slightly different mesh sizes are therefore linearly related to length of fish[10,11,13] according to the following form:

$$\ln C_2/C_1 = a + bL$$

where a and b are constants.

In order to adjust length frequencies of the catches of the gillnets of different mesh sizes, they were standardized according to number of fishing trials of each mesh size (Tables 1 and 2). The adjusted length frequencies for the different mesh sizes were expressed as numbers per 100 fishing trials for individual length classes. The regression relationships between the logarithmic catch ratios of overlapping selection ranges of two adjacent mesh sizes ($\ln C_2/C_1$) against mid-points of length classes (L) were obtained for the mesh combinations 2.5 cm/3.8 cm, 3.8 cm/4.5 cm, 4.5 cm/5.2 cm and 5.2 cm/ 6.4 cm. As in the mesh size 6.4 cm, sufficient numbers of *O. bimaculatus* were not caught, the catches of this species in the gillnet of this mesh size were disregarded in the analysis. From the intercept (a) and slope (b) of the regression relationships between $\ln C_2/C_1$ and L, optimal lengths of fish for the mesh sizes were calculated as follows[10]:

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

where $L_{opt(1)}$ and $L_{opt(2)}$ are the optimal lengths of fish corresponding to mesh sizes M_1 and M_2 respectively. The standard deviations (SD) of the selection curves for the both mesh sizes were estimated from the following equation:

$$SD = \{2a(M_1 - M_2)/[b^2(M_1 + M_2)]\}^{0.5}$$

Using $L_{opt(1)}$, $L_{opt(2)}$ and SD estimated, the probabilities of capture for mesh sizes M_1 and M_2 for a given length (L) were calculated by the following equations:

For mesh size M_1: $P_1 = \exp [-(L - L_{opt(1)})^2/2SD^2]$

For mesh size M_2: $P_2 = \exp [-(L - L_{opt(2)})^2/2SD^2]$

where P_1 and P_2 are probabilities of capture for length L for mesh sizes M_1 and M_2 respectively.

The selection factor (SF) was calculated for each mesh size M using its corresponding optimal length (L_{opt}) of fish:

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

Percentage maturity of *O. bimaculatus* and *P. dorsalis* was calculated for males and females separately for each 1 cm length class considering stage III and above as mature fish.[14] From the plots of percentage maturity against length of

fish, mean size of maturity (i.e., length at 50% maturity) (L_m) was estimated for both sexes of the two species. A logistic curve was fitted according to the following equation for each sex of the two species to estimate L_m.[16]

$$P = 100/\{1 + \exp[-r(L - L_m)]\}$$

where P is the percentage maturity at length L and r is a constant. This was performed by transforming the above equation into a straight line as follows:

$$\ln [(1 - 0.01P)/0.01P] = rL_m - rL$$

RESULTS

Length frequency data and adjusted length frequencies (number of fish per 100 fishing trials) of fish caught in gillnets of different mesh sizes are given in Table 2 for *O. bimaculatus* and in Table 3 for *P. dorsalis*.

The plots of logarithm of catch ratio of overlapping length ranges in two adjacent mesh sizes of four combinations of gillnets against length for the two species studied are shown in Fig. 2. The slopes and intercepts of the regression relationships between logarithmic catch ratio and length for various mesh combinations are given in Table 4.

The optimal lengths (L_{opt}) of *O. bimaculatus* and *P. dorsalis* and SD were estimated for each mesh size of gillnets. Since there were two estimates of L_{opt} and two estimates of SD for each of the mesh sizes of 3.8 cm and 4.5 cm for each species and for the mesh size 5.2 cm for *P. dorsalis*, the mean values were taken. The estimated L_{opt}, SD, SF and selection range for *O. bimaculatus* and *P. dorsalis* for various mesh gillnets are given in Table 5. The selection curves of *O. bimaculatus* and *P. dorsalis* for different mesh gillnets are shown in Fig. 3.

The relationships between L_{opt} and mesh size (M) of gillnet for the two species are found to be highly significant and are described by the following equations:

O. bimaculatus: $L_{opt} = 4.076 + 3.694\ M$ ($r = 0.992$; $p < 0.01$)

P. dorsalis: $L_{opt} = 2.445 + 3.410\ M$ ($r = 0.994$; $p < 0.001$)

The plots of percentage maturity of the two species against TL are shown in Fig. 5. The mean sizes of maturity of *O. bimaculatus* (21.6 cm for males and 26.1 cm for females) and *P. dorsalis* (13.4 cm for males and 14.8 cm for females) determined from these plots were related to M using above equations. L_m of female *O. bimaculatus* (26.1 cm) and female *P. dorsalis* (14.8 cm) approximately correspond to stretched gillnet mesh sizes of 5.8 cm and 3.8 cm respectively according to the relationships between L_{opt} and M (Fig. 4).

Table 2: Length frequencies (I) and adjusted length frequencies for 100 fishing trials (II) of *O. bimaculatus* caught in five different mesh sizes of gillnets in Uruwal Oya. Number of fishing trials for gillnets of five mesh sizes: 2.5 cm - 39; 3.8 cm - 32; 4.5 cm - 26; 5.2 cm - 23; 6.4 cm - 31. Note that the frequencies marked with asterisks were not used in the regression analyses because most of these fishes were entangled (not gilled) in the gillnets. Also fishes caught in 6.4 cm mesh gillnets were disregarded in the analysis (see text).

Length class (Mid length) (cm)	Mesh size (cm) 2.5		3.8		4.5		5.2		6.4	
	I	II	I	II	I	II	I	II	I	II
10-11 (10.5)	3	7.7								
11-12 (11.5)	5	12.8								
12-13 (12.5)	6	15.4								
13-14 (13.5)	9	23.1	7*	21.9*						
14-15 (14.5)	15	38.5	15*	46.9*						
15-16 (15.5)	24	61.5	21*	65.6*						
16-17 (16.5)	35	89.7	31	96.9	10	38.5				
17-18 (17.5)	27	69.2	34	106.3	13	50.0	7	30.4		
18-19 (18.5)	19	48.7	43	134.4	17	65.4	10	45.5		
19-20 (19.5)	10	25.6	39	121.9	21	80.8	13	56.5		
20-21 (20.5)	4	10.3	20	62.5	23	88.5	15	65.2		
21-22 (21.5)	2	5.1	14	43.8	28	107.7	19	82.6		
22-23 (22.5)			12	37.5	21	80.8	19	82.6		
23-24 (23.5)			9*	28.1*	14	53.8	21	91.3		
24-25 (24.5)			9*	28.1*	12	46.2	18	78.3		
25-26 (25.5)			6*	18.8*	10	38.5	16	69.6		
26-27 (26.5)			4*	12.5*	6	23.1	15	65.2		
27-28 (27.5)			2*	6.3*	3	11.5	11	47.8		
28-29 (28.5)					2	7.7	8	34.9		
29-30 (29.5)					1	3.8	5	21.7	2	6.5
30-31 (30.5)					1	3.8	9	39.1	5	16.1
31-32 (31.5)							3	13.0	7	22.6
32-33 (32.5)							3	13.0	6	19.4
33-34 (33.5)							1	4.3	4	12.9
34-35 (34.5)									4	12.9
35-36 (35.5)									1	3.2
36-37 (36.5)									1	3.2

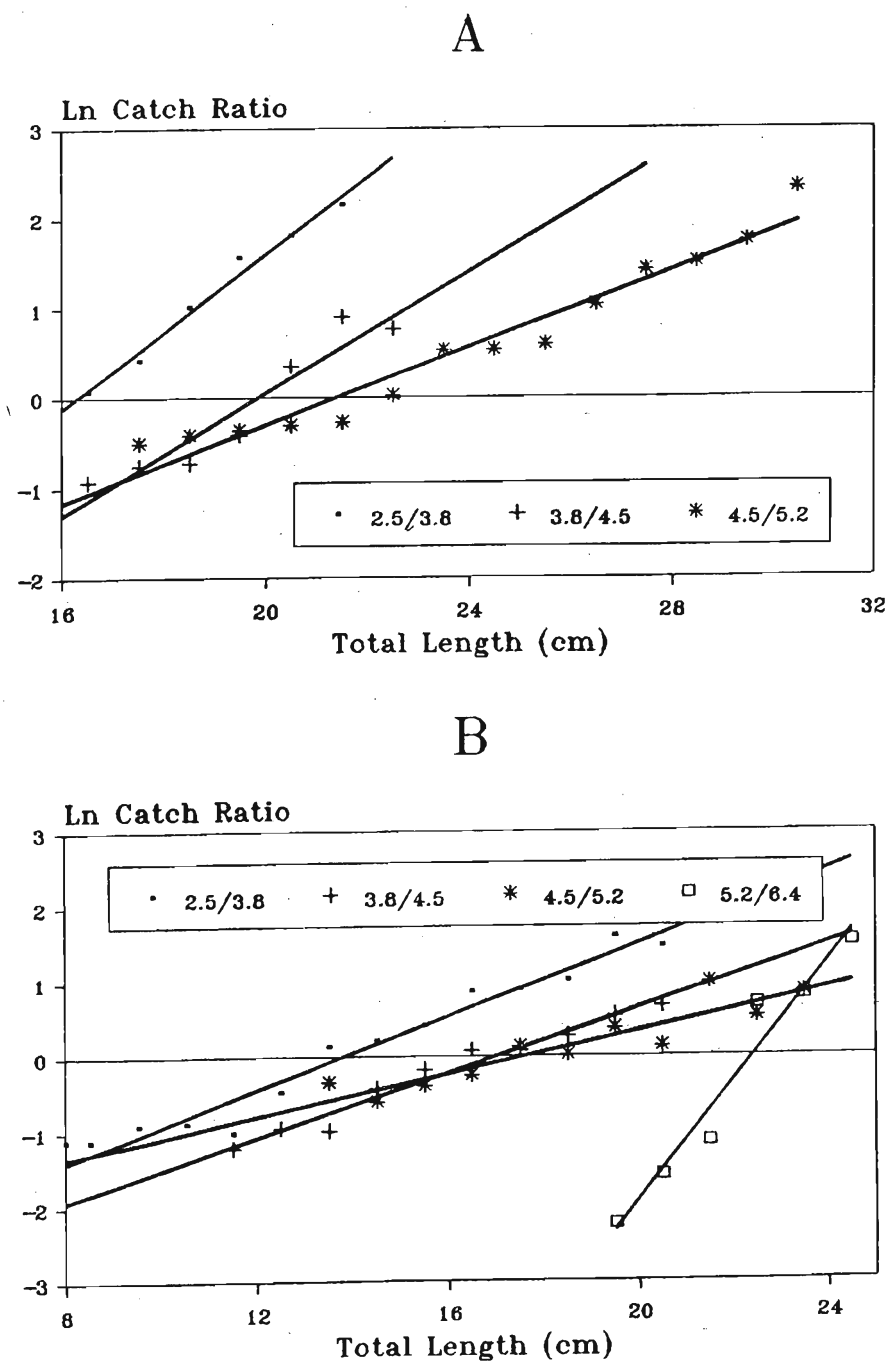

Figure 2: The plots of logarithm of catch ratio of overlapping length ranges in two adjacent mesh sizes of four combinations of gillnets against length of fish. A - *O. bimaculatus*; B - *P. dorsalis*.

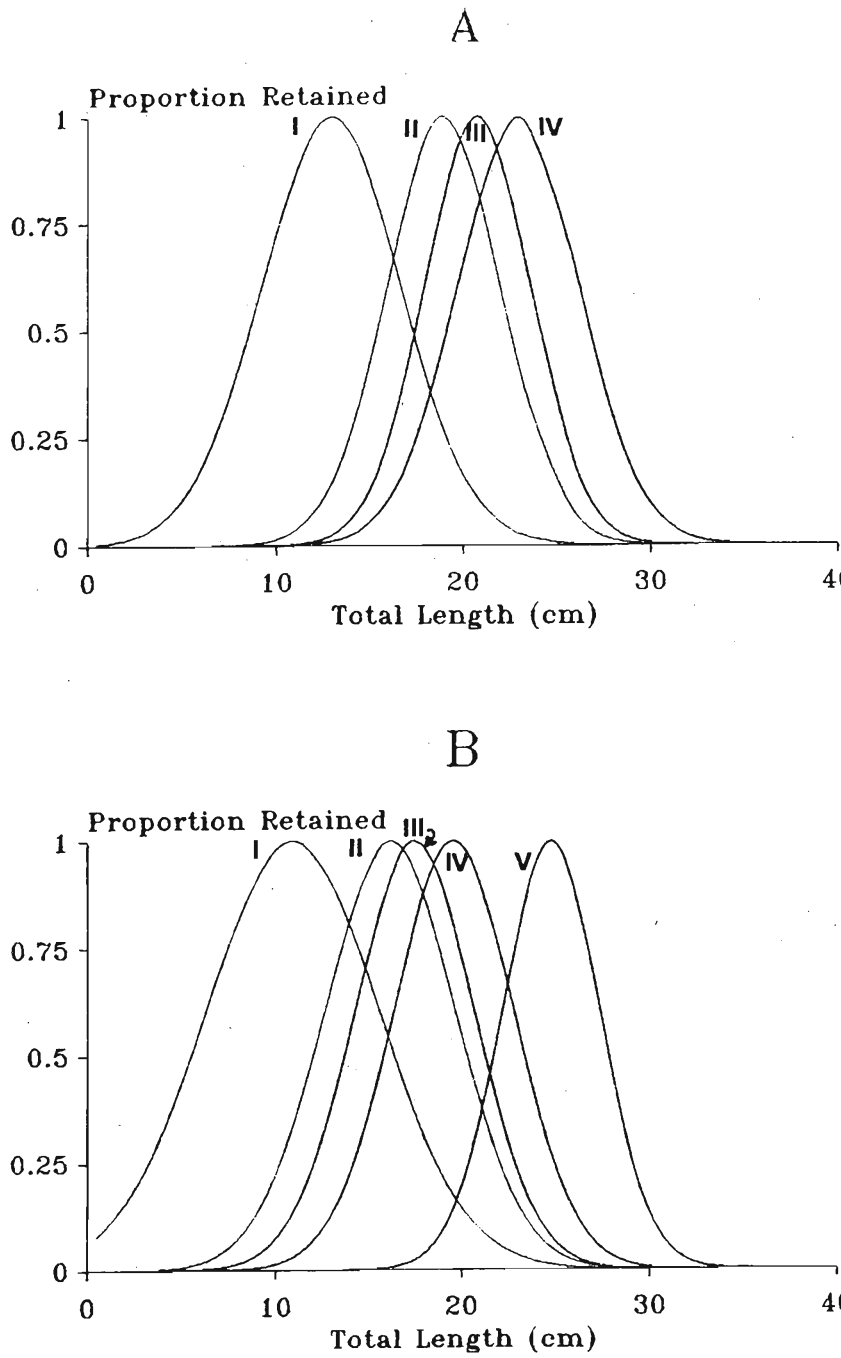

Figure 3: **The selection curves of *O. bimaculatus* (A) and *P. dorsalis* (B) for different mesh gillnets. I - 2.5 cm; II - 3.8 cm; III - 4.5 cm; IV - 5.2 cm; V - 6.4 cm.**

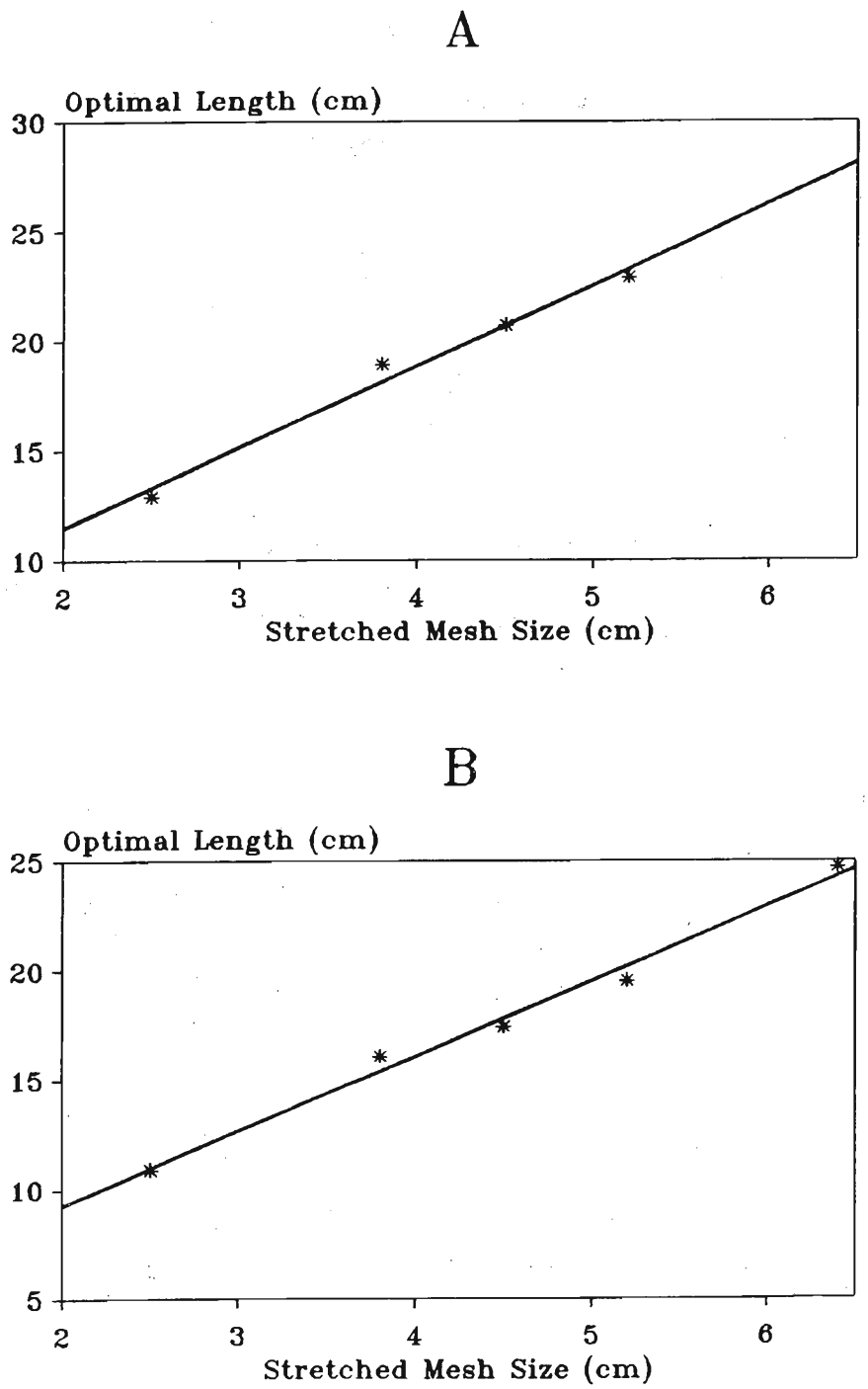

Figure 4: The relationships between the optimal length and mesh size of gillnets of two fish species in Uruwal Oya. A - *O. bimaculatus*; B - *P. dorsalis*.

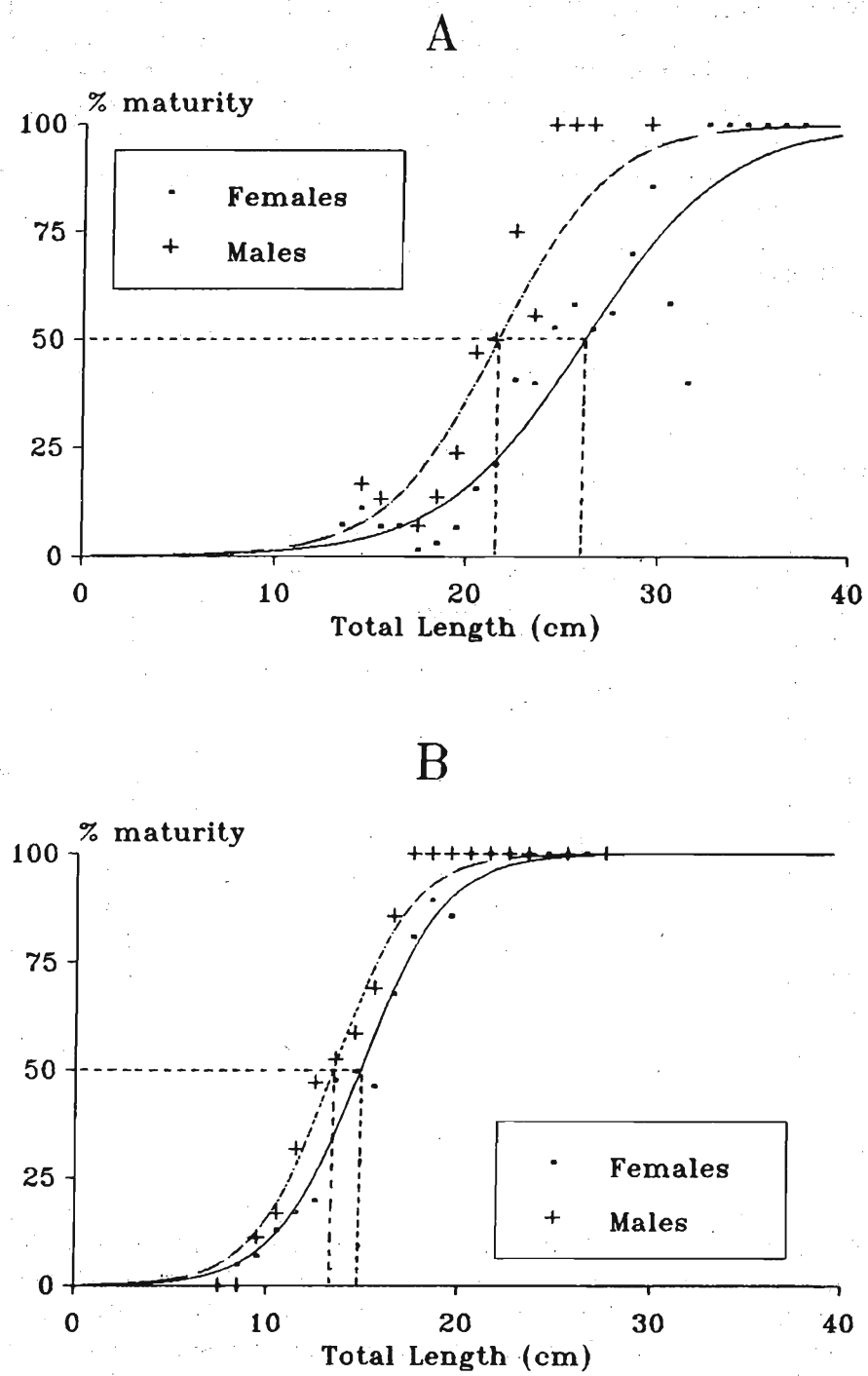

Figure 5: **The plots of percentage maturity against length of (A) *O. bimaculatus* and (B) *P. dorsalis* in Uruwal Oya. Broken lines -males; Solid lines - females.**

Table 3: Length frequencies (I) and adjusted length frequencies for 100 fishing trials (II) of *P. dorsalis* caught in five different mesh sizes of gillnets in Uruwal Oya. Number of fishing trials for gillnets of five mesh sizes: 2.5 cm - 39; 3.8 cm - 32; 4.5 cm -26; 5.2 cm - 23; 6.4 cm - 31. Note that the frequencies marked with asterisks were not used in the regression analyses because most of these fishes were entangled (not gilled) in the gillnets.

Length class (Mid length) (cm)	Mesh size (cm) 2.5		3.8		4.5		5.2		6.4	
	I	II	I	II	I	II	I	II	I	II
7-8 (7.5)	11	28.2								
8-9 (8.5)	52	133.3	14	43.8						
9-10 (9.5)	61	156.4	20	62.5						
10-11 (10.5)	80	205.1	27	84.4						
11-12 (11.5)	97	248.7	29	90.6	7	26.9				
12-13 (12.5)	74	189.7	38	118.8	12	46.2				
13-14 (13.5)	56	143.6	53	165.6	16	61.5	10	43.5		
14-15 (14.5)	50	128.2	51	159.4	27	103.8	13	56.5		
15-16 (15.5)	38	97.4	47	146.9	32	123.1	19	82.6		
16-17 (16.5)	17	43.6	33	103.1	29	111.5	20	87.0	3*	9.7*
17-18 (17.5)	12	30.8	24	75.0	21	80.8	21	91.3	7*	22.6*
18-19 (18.5)	8	20.5	18	56.3	19	73.1	17	73.9	9*	29.0*
19-20 (19.5)	2	5.1	8	25.0	11	42.3	14	60.9	2	6.5
20-21 (20.5)	2	5.1	7	21.9	11	42.3	11	47.8	3	9.7
21-22 (21.5)			6*	18.8*	3	11.5	7	30.4	3	9.7
22-23 (22.5)			7*	21.9*	2	7.7	3	13.0	8	25.8
23-24 (23.5)			3*	9.4*	1	3.8	2	8.7	6	19.4
24-25 (24.5)							1	4.3	6	19.4
25-26 (25.5)									3	9.7
26-27 (26.5)									1	3.2

DISCUSSION

Most riverine fish species spend a part of their life cycles in riverine habitats.[15] In Sri Lanka, indigenous freshwater fish is reported to move to riverine habitats when they mature.[4] Therefore scientific management of small-scale fisheries in riverine habitats is needed for conservation of freshwater fish biodiversity in the country. Control of size of fish landed is one effective management option in the inland fishery of Sri Lanka.[2] Since the mesh size of gillnet is related to the size of fish, length at first capture in a fishery can be adjusted by changing mesh size of gillnet. This is of particular importance in the Sri Lankan context because gillnet is the major fishing gear in the inland waters of the country.[2]

Table 4: The intercepts (a), slopes (b) and correlation coefficients (r) of the regression relationships between logarithmic catch ratios (ln C_2/C_1) and length (L) for various mesh combinations for the two fish species. All relationships are significant at least at 0.1% level.

Mesh combination	*O. bimaculatus*			*P. dorsalis*		
	a	b	r	a	b	r
2.5/3.8	-6.9880	0.4295	0.992	-3.3314	0.2427	0.979
3.8/4.5	-6.6932	0.3374	0.949	-3.6261	0.2132	0.982
4.5/5.2	-4.5840	0.2145	0.974	-2.4843	0.1409	0.914
5.2/6.4	-	-	-	-17.7659	0.7925	0.974

Table 5: The estimated optimal lengths (L_{opt} in cm), Standard Deviations (SD in cm), Selection Factors (SF) and Selection Ranges (in cm) for *O. bimaculatus* and *P. dorsalis* for various mesh gillnets.

Mesh size	*O. bimaculatus*				*P. dorsalis*			
	L_{opt}	SD	SF	Selection range	L_{opt}	SD	SF	Selection range
2.5	12.9	3.7	5.165	9.2-16.6	10.9	4.0	4.384	6.3-15.5
3.8	18.9	3.0	4.973	15.9-21.9	16.1	3.5	4.241	12.6-19.6
4.5	20.7	2.8	4.593	17.9-23.5	17.4	3.2	3.867	14.2-20.6
5.2	22.9	3.2	4.406	19.7-21.1	19.5	3.2	3.750	16.3-22.7
6.4	-	-	-	-	24.7	2.6	3.865	22.1-27.3

The present analysis indicates that with gillnets of stretched mesh sizes smaller than 5.8 cm for *O. bimaculatus* and 3.8 cm for *P. dorsalis*, there is a potential for immature individuals being caught because these mesh sizes correspond to the L_m of the two species. It must be noted that not in all fisheries L_m can be considered as the minimum permissible size at first capture. For example, the fisheries for many clupeid species such as *Alosa pseudoharengus* in north-west Atlantic area are based on the spawning populations.[16] However, the two fish species of the present study, living in lotic freshwater habitats where environmental conditions are less stable than in marine habitats, cannot be expected to be able to withstand heavy juvenile mortality rates. As such, excessive use of gillnets of mesh sizes smaller than 5.8 cm and 3.8 cm might be detrimental to *O. bimaculatus* and *P. dorsalis* respectively which are the two dominant species in Uruwal Oya (Table 1).

Hitherto, there have been no fishery regulations imposed on the capture of indigenous and endemic fish in riverine habitats of Sri Lanka. However, there seems to be a need for regulating the landing size of *O. bimaculatus* and *P. dorsalis* in this riverine habitat due to the reason that according to information gathered from the inhabitants in the area, nearly 500 people are said to be fishing in the river during the rainy season (May-June). The peak spawning of the indigenous riverine fish occurs during the rainy seasons[17] so that intensive fishing of juvenile fish in the river during peak spawning is deleterious to their biodiversity. Wijeyaratne[18] mentioned that use of small meshed gillnets without proper monitoring may pose a severe threat to freshwater fish biodiversity in Sri Lanka through depletion of fish stocks below a critical level where recovery is impossible. Hopefully the present study will provide baseline information for planning management strategies for riverine fisheries of Sri Lanka.

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