Sri Lanka J. Aquat. Sci. **14** (2009): 15-28

Gillnet selectivity of three flying fish, *Cheilopogon nigricans* (Bennett, 1846), *Cypselurus poecilopterus* (Valenciennes, 1846) and *Cheilopogon suttoni* (Whitle and Colefax, 1938) off the northwestern coast of Sri Lanka

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Abstract

On the northwestern coast of Sri Lanka, off Kandakuliya, there is a seasonal fishery for flying fish resources from October to April every year. In this fishery, major species caught were *Cheilopogon nigricans, Cypselurus poecilopterus* and *Cheilopogon suttoni.* Gillnet selectivity of these three flying fish species was determined using Baranov-Holt method. The optimal lengths (L_{opt}) and probabilities of capture in gillnets of 3.4 cm and 4.5 cm mesh sizes were determined for the three species separately. For this analysis, sampling was conducted from October 2002 to April 2003.

Estimated values of selection range for *Cheilopogon nigricans, Cypselurus poecilopterus, Cheilopogon suttoni* for 3.4 cm mesh size were 18.9-26.8 cm, 16.4-24.3 cm, 18.9-29.7 cm, and for 4.5 cm mesh size were 26.3-33.1 cm, 23.0-30.9 cm, 26.7-37.5 cm respectively. Estimated L_{opt} for 3.4 cm and 4.5 cm mesh sizes respectively were 22.9 cm and 30.3 cm for *Cheilopogon nigricans,* 20.3 cm and 26.9 cm for *Cypselurus poecilopterus* and 24.3 cm and 32.1 cm for *Cheilopogon suttoni*. As these fishes are migratory, when the mesh-wise length frequency data were superimposed on the gillnet selection curves, it was evident that gillnet mesh sizes were effective for catching only a limited range of length classes of all three species studied. In 3.4 cm mesh gillnets, size classes smaller than the optimal length were virtually absent. Also in gillnet catches of 4.5 cm mesh size, size classes bigger than the optimal length were not caught. These indicate that only intermediate size ranges were available in the fishing grounds of all three species. As such, through experience, fishers have identified 3.4 cm and 4.5 cm mesh gillnets as effective fishing gear for catching these species. Hence, strict management options are not an immediately required for managing the flying fish fishery off the northwestern coast of Sri Lanka.

As the catch samples of flying fish species do not represent actual size composition of populations, estimation of growth and mortality parameters using length-based stock assessment methodologies is problematic. As such, for determination of optimal fishing strategies using dynamic pool models, independent estimates of demographic parameters should be used.

Introduction

Small pelagic fish resources are an important source of animal protein for low income people in many developing countries. In Sri Lanka, contribution of the small pelagic fish catches to the total fish production is about 40% (Wijayaratne 2001). Beach seines and gillnets are the most commonly used gear to catch small pelagic fish. Since early 1960's, gillnet has became very popular among coastal fishers as a result of introduction of nylon nets (Dayaratne 1988).

The catch samples from gillnets are not always representative of the population since gillnets are generally selective for specific size classes. Hence, they cannot be directly used in most stock assessment methods. However gillnet with series of mesh sizes were developed as a sampling tool in order to cover the whole spectrum of fish sizes (Vasek et al. 2009). The best condition for studying gillnets size selectivity is to sample a known population. Hence, scientists have used gillnets in combination with beach seines to get a more reliable picture of the sampled fish community (Prchalova et al. 2009). However, such fully controlled experiments are very expensive and questionable in deploying for most of the artisanal fisheries in the developing countries. Attempts were made to quantify gillnet selectivity for *Amblygaster sirm* in coastal waters of Sri Lanka (Dayaratne 1988; Karunasinghe and Wijeyaratne 1991), *Ompok bimaculatus* (Amarasinghe and Pushpalatha 1997), and cichlid species in Sri Lankan reservoirs (Amarasinghe and De Silva 1994) based on commercial gillnet catches. Nevertheless, no gillnet selectivity studies were reported for flying fishes in Sri Lankan coastal waters.

In the present study, an attempt was made to determine the gillnet selectivity patterns, optimal selection lengths and selection ranges of three dominant flying fish species, *Cheilopogon nigricans, Cypselurus poecilopterus, Cheilopogon suttoni* from the commercial landings at Kandakuliya fish landing site in Kalpitiya peninsula, Sri Lanka.

Materials and Methods

Off Kandakuliya (Figure 1), flying fishes are caught by commercial fisheries using gillnets during the fishing season that commences after the monsoon in October and extends until the end of April of the following year. The fishing crafts leave early in the morning (around 4-5 a.m), set their gillnets approximately for a period of 6 hours and return to the landing site in the late afternoon. The total length

(TL) and the greatest depth (GD) of gilled *Cheilopogon nigricans*, *Cypselurus poecilopterus* and *Cheilopogon suttoni* were measured to the nearest 0.1 cm from October 2002 to April 2003, by making regular weekly visits to the fish landing site in Kandakuliya taking special care to be present at the time when fishers land the boats with the catch. About 40% of the total numbers of boats operated were sampled randomly. These data were recorded for each mesh size separately to estimate the selectivity parameters. The mesh sizes of the net from which the fish samples were obtained were determined by measuring the length of stretched meshes with a cm scale; measurements of stretched mesh sizes from ten randomly chosen regions of the net were averaged.

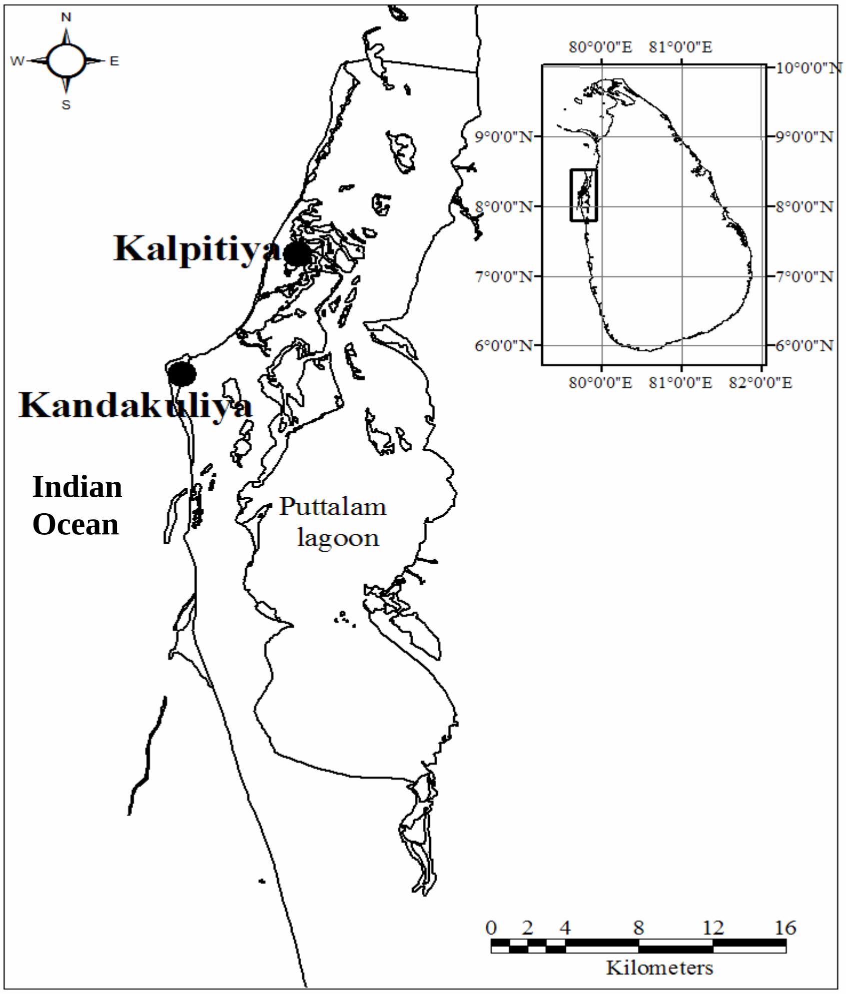

Figure 1. Map of study area (large panel) and its location in Sri Lanka

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 relationship between TL and GD of the each flying fish species was determined using a linear regression technique.

The mesh–wise length frequency data were analyzed using the Baranov–Holt method (Baranov 1914; Holt 1963; Hamley 1975). This method is based on several assumptions (Hamley 1975) viz. in two gill nets of slightly different mesh sizes, length frequency distributions of a fish species caught exhibit same standard deviation; same height of selection curves; and similar fishing mortalities.

Since the fishing mortality for each mesh sizes was not known, the length frequency data were adjusted for a unit of fishing effort using the following equation and expressed as number of fish for length class L, per 1000 m^2 of gillnet per day (f_{adj}) (Amarasinghe and Pushpalatha 1997).

$$f_{adj} = (\sum_{i=1}^{m} (f_{Li}/A_i * N_i) * 1000)/m \qquad (1)$$

where, f_{Li} – number of fish in length class L caught in N_i net pieces on i^{th} day; A_i – Area of net in m^2; N_i – number of net pieces from which sample has been taken on i^{th} day; and m – number of sampling days.

$$\text{Here } A_i = (N_m * N_D * M^2 * HR^2)/10^4 \qquad (2)$$

where, N_m – number of meshes along horizontal axis of in a net piece; N_D – number of meshes vertical axis in a net piece; M – stretched mesh size of gillnet (cm); HR – hanging ratio of the net (i.e., ratio of hung length to the stretched length of net) (Amarasinghe and Pushpalatha 1997). In the gillnet fishery for flying fish in Kandakuliya area, HR of gillnet was 0.5.

The adjusted length frequency data were analyzed using the method described by Holt (1963) assuming that the selection curves for the gill nets with slightly different mesh sizes could be described by two overlapping normal probability distribution (Hamley 1975; Pauly 1983).

$$C_L = F.\ N_L \exp[-(L-L_{opt})^2/2SD^2] \qquad (3)$$

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 logarithms of catch ratios (in numbers) of overlapping ranges of two gillnets with slightly different mesh sizes are linearly related to length of fish (Hamley 1975; Pauly 1983) according to the following form:

$$\ln[C_B / C_A] = a + b\,L \qquad (4)$$

where C_A and C_B are catches in numbers (i.e. adjusted frequencies) in mesh sizes A and B respectively at the length group with the mid point, L. The intercept (a) and

slope (b) of this regression were used to determine the optimal lengths (L_A and L_B) for each mesh size as follows (Hamley 1975, Pauly 1983):
For mesh size A,

$$L_A = 2a.M_A / [b (M_A+M_B)] \quad (5)$$

For mesh size B,

$$L_B = 2a.M_B / [b (M_A+M_B)] \quad (6)$$

While the standard deviations (SD) of the selection curves for the two mesh sizes (A and B) were estimated from following equation (Pauly 1983).

$$SD = \{2a (M_A-M_B) / [b^2 (M_A+M_B)]\}^{0.5} \quad (7)$$

Probability of capture (P_A and P_B for mesh sizes A and B respectively) for a given length L_i can be calculated by the following equations (Pauly 1983).

$$P_A = \exp [-(L_i - L_A)^2 / 2SD^2] \quad (8)$$

$$P_B = \exp [-(L_i - L_B)^2 / 2SD^2] \quad (9)$$

Results

For all three species of flying fish, relationships between the total length and the greatest body depth were found to be significant at least at 0.001 probability level (Table 1). As such, length data could be used to compute gillnet selectivity patterns. Length frequency data and adjusted length frequencies of fish caught in gillnets of different mesh sizes; 3.4 cm and 4.5 cm (Table 2) show the length ranges of *Cheilopogon nigricans, Cypselurus poecilopterus* and *Cheilopogon suttoni* caught in the fishery.

Table 1. Length-body depth relationships of predominant flying fish species. Y = Total length (cm); X = Body depth (cm); r = Correlation coefficient.

Flying fish species	**Length body depth relationship**	**r**
Cheilopogon nigricans	Y= 9.5249 + 4.16224X	0.87
Cheilopogon suttoni	Y= 22.243 + 1.92138 X	0.71
Cypselurus poecilopterus	Y= 14.5971 + 2.2995 X	0.60
Cypselurus naresii	Y= 23.9816 + 0.4506 X	0.65

Table 2. Length frequency data and adjusted length frequencies (number of fish per 1000 m^2 of net per day) of fish caught in gillnets of different mesh sizes (3.4 cm and 4.5 cm) for *Cheilopogon nigricans*, *Cypselurus poecilopterus* and *Cheilopogon suttoni*

		Cheilopogon nigricans				***Cypselurus poecilopterus***				***Cheilopogon suttoni***			
		4.5cm		**3.4cm**		**4.5cm**		**3.4cm**		**4.5cm**		**3.4cm**	
Length Class (cm)	**Mid point (cm)**	**Total F**	**F_{adj}**	**Total F**	**F_{adj}**	**Total F**	**F_{adj}**	**Total F**	**F_{adj}**	**Total F**	**F_{adj}**	**Total F**	**F_{adj}**
19.0-19.5	19.25	0		0									
19.5-20.0	19.75	0		1	2.99								
20.0-20.5	20.25	0		1	2.99			1	4.19				
20.5-21.0	20.75	0		6	23.97	1	2.39	0					
21.0-21.5	21.25	0		5	19.72	0	0	2	8.74				
21.5-22.0	21.75	1	2.39	11	41.34	2	4.79	4	16.78				
22.0-22.5	22.25	2	4.79	7	26.96	8	17.11	12	53.47				
22.5-23.0	22.75	2	4.79	15	58.46	4	9.57	10	42.64				
23.0-23.5	23.25	2	4.79	9	32.95	8	17.11	12	51.03			2	1.19
23.5-24.0	23.75	6	12.31	16	59.77	7	16.76	8	36.01			0	0
24.0-24.5	24.25	13	30.44	26	95.02	12	23.61	9	40.89			0	0
24.5-25.0	24.75	10	21.21	21	79.89	12	23.61	10	42.64			0	0
25.0-25.5	25.25	23	50.28	15	58.46	15	30.44	17	75.49			1	0.59
25.5-26.0	25.75	24	51.99	19	78.09	13	24.85	2	8.74	1	0.42	1	0.59
26.0-26.5	26.25	38	84.83	17	62.21	13	24.85	4	16.78	1	0.42	1	0.59
26.5-27.0	26.75	33	71.49	13	50.13	6	12.08	1	4.19	0	0	0	0
27.0-27.5	27.25	43	89.27	10	38.54	1	2.39	0	0	1	0.42	1	0.59
27.5-28.0	27.75	59	126.21	10	38.54	1	2.39	1	4.19	0	0	0	0
28.0-28.5	28.25	70	146.39	8	25.46	0	0	0	0	1	0.42	0	0

Table 2 continued on page 21

Table 2 continued from page 20

Length Class (cm)	Mid point (cm)	*Cheilopogon nigricans* 4.5cm Total F	F_{adj}	*Cheilopogon nigricans* 3.4cm Total F	F_{adj}	*Cypselurus poecilopterus* 4.5cm Total F	F_{adj}	*Cypselurus poecilopterus* 3.4cm Total F	F_{adj}	*Cheilopogon suttoni* 4.5cm Total F	F_{adj}	*Cheilopogon suttoni* 3.4cm Total F	F_{adj}
28.5-29.0	28.75	49	102.27	5	19.72	0	0	0	0	5	2.48	0	0
29.0-29.5	29.25	31	64.65	4	12.48	0	0	0	0	7	3.81	3	1.79
29.5-30.0	29.75	19	38.51	4	12.48	0	0	1	4.19	4	2.09	4	2.39
30.0-30.5	30.25	17	36.59	2	5.99	0	0	0	0	5	2.64	3	1.79
30.5-31.0	30.75	18	37.62	1	2.99	0	0	0	0	13	6.89	4	2.36
31.0-31.5	31.25	7	13.34	0	0	0	0	0	0	4	2.09	3	1.79
31.5-32.0	31.75	6	12.31	1	2.99	0	0	0	0	16	8.05	7	4.49
32.0-32.5	32.25	2	4.79	1	2.99	0	0	0	0	21	10.75	25	15.2
32.5-33.0	32.75	0	0	0	0	1	2.39	0	0	28	13.95	7	4.49
33.0-33.5	33.25	1	2.39	2	5.99	0		1	4.19	34	16.97	8	5.39
33.5-34.0	33.75	0	0	2	5.99	0		0	0	27	14.41	3	1.79
34.0-34.5	34.25	0	0	0	0	0		1	4.19	23	11.67	6	3.54
34.5-35.0	34.75	0	0	0	0	0		0		24	12.31	2	1.19
35.0-35.5	35.25	0	0			0		0		30	15.11	8	4.84
35.5-36.0	35.75	1	1.71			0				10	5.11	1	0.59
36.0-36.5	36.25	1	1.71			1				14	7.24	6	3.54
36.5-37.0	36.75	0	0			0				4	2.09	0	0
37.0-37.5	37.25	1	1.71			0				6	3.09	3	1.79
37.5-38.0	37.75	1	1.71							3	1.59	2	1.19
38.0-38.5	38.25	1	1.71							3	1.59	2	1.19
38.5-39.0	38.75	0	0							0	0	0	0
39.0-39.5	39.25	1	1.71							2	1.09	0	
39.5-40.0	39.75	0	0							0	0	0	

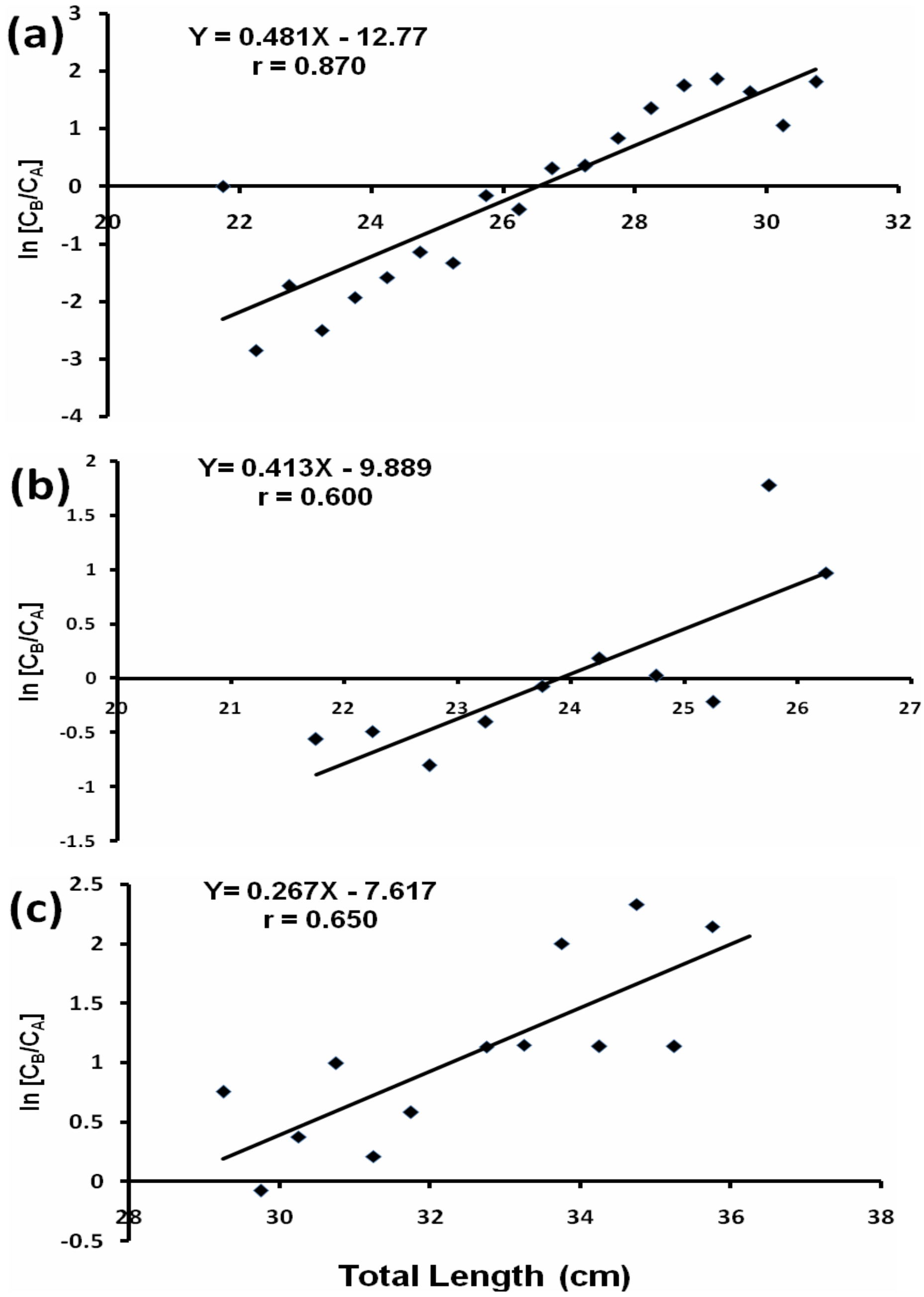

Figure 2. Relationships of ln catch ratio to total length of (a) *Cheilopogon nigricans,* (b) *Cypselurus poecilopterus* and (c) *Cheilopogon suttoni*. C_A and C_B are catches in numbers (i.e. adjusted frequencies) in mesh sizes A (3.4cm) and B (4.5cm) respectively. r = Correlation coefficient.

Scatter logarithmic plots of catch ratios of two mesh sizes against corresponding mid point of length classes show linear relationship as in Figure 2. As such, the assumption that the selection curve for fish is symmetrical around the L_{opt} approximating a shape of normal distribution is valid.

Estimated optimal lengths (L_{opt}) and selection ranges were found to be slightly different among *Cheilopogon nigricans, Cypselurus poecilopterus* and *Cheilopogon suttoni* for each mesh size of gillnets (Table 3). Similarly estimated selectivity curves also varied among three species (Figures 3, 4 and 5).

Table 3. The estimated optimal lengths (cm), standard deviation (SD in cm) and selection ranges (in cm) for *Cheilopogon nigricans, Cypselurus poecilopterus, Cheilopogon suttoni* for two different mesh sizes (3.4 cm and 4.5 cm).

Species	**Optimum length**			**Selection range**	
	3.4 cm	**4.5 cm**	**SD**	**3.4 cm**	**4.5 cm**
Cheilopogon nigricans	22.7	29.5	3.92	18.78- 26.62	25.58 – 33.42
Cypselurus poecilopterus	20.4	27.3	3.96	16.44 -24.36	23.34 – 31.26
Cheilopogon suttoni	23.6	31.2	5.39	18.21 -28.99	25.81 – 36.59

Discussion

During the present study, it was observed that the fishery was entirely dependent on gillnets of two mesh sizes; 3.4 cm and 4.5 cm stretched mesh sizes. Selection ranges of the three flying fish species (*Cheilopogon nigricans, Cypselurus poecilopterus* and *Cheilopogon suttoni*; (Table 4) and their mesh-wise length frequency distributions (Figures 3, 4 and 5) indicate that smaller size classes and larger size classes of flying fish are virtually absent in the catches of 3.4 cm mesh and 4.5 cm mesh gillnets respectively. According to Jinadasa (1991), flying fish shows spawning migration along the Indian and Sri Lankan coasts during a particular time of the year. Through, the age determination of a spawning population of flying fish sampled from 1969 to 1972, Jinadasa (1991) has shown that they belonged to 1+ age class. Based on growth parameters, Jinadasa (1991) has further shown that there were no survivors from the population of previous year. These findings confirm that in each year a fresh stock of spawning fish approach Sri Lanka. As such, it is obvious that spawning stock consists of a particular sized fish. Presence of a certain size range of flying fish in the fishing ground may be attributed to spawning aggregation. Studies on reproductive biology of these species might be useful to confirm this phenomenon. Due to the presence of a certain size range of flying fishes in the fishing area, use of smaller (< 3.4 cm) or larger mesh (> 4.5 cm) gill net may not have any significant effect on the flying fish stocks.

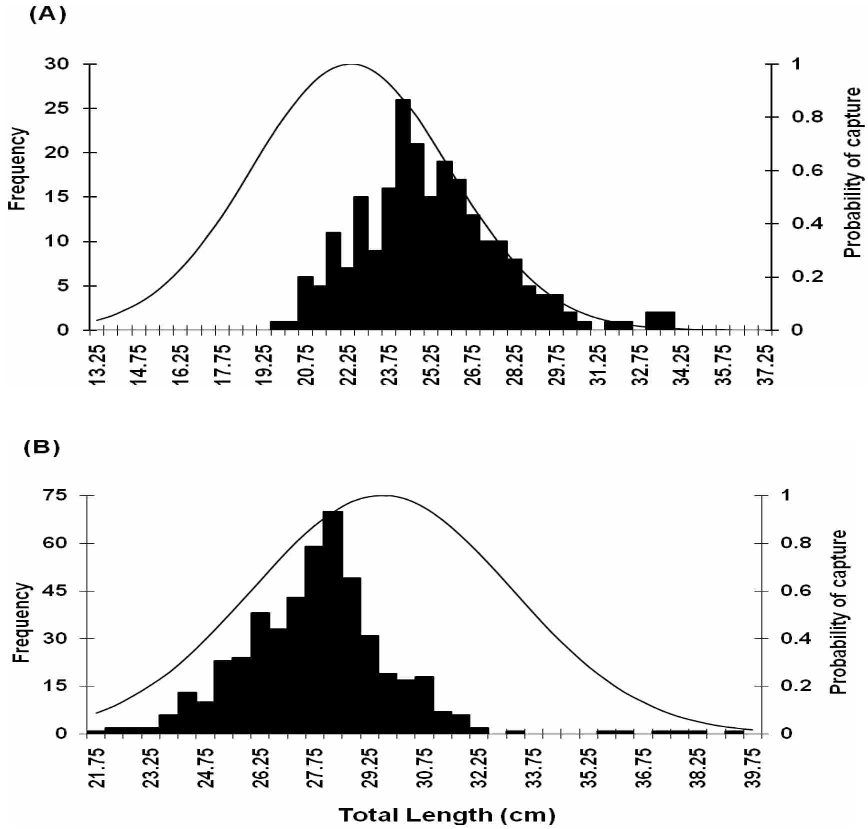

Figure 3. Selection curves of *Cheilopogon nigricans* for (A) 3.4cm and (B) 4.5cm mesh sizes. Histogram indicates percentage length frequency distribution.

Selectivity of some pelagic fish species such as *Clupea pallasi*, *Coregonus clupeiformes*, *Dorosoma cepedianum*, *Morone saxatilis*, *Rutilus rutilus* and *Stizostedion vitreum* whose swimming speed increases with size, has been observed to increase with mesh size (Hamley 1980; Borgstrom 1989). Therefore, it appears that selectivity by passive gear such as gillnets depends not only on the geometry of the nets and fish as Baranov (1914) has suggested, but also on other factors such as individual swimming speed (Borgstrom1989), behavioural patterns and visibility and stretchability of the net (Hamley 1975). On the other hand, it is interesting to note that some species like *Amblygaster sirm* showed the same catch efficiencies for different mesh sizes (Regier and Robson 1966). The apparent non-compatibility of the length frequency distributions and probability of capture of the catch samples in 3.4 cm and 4.5 cm mesh gillnets might be due to the absence of smaller and larger size class in the fishing area. The selection curves for the three species of flying fish can however, be estimated using Baranov-Holt method, provided that there are overlapping ranges of length classes in two mesh sizes.

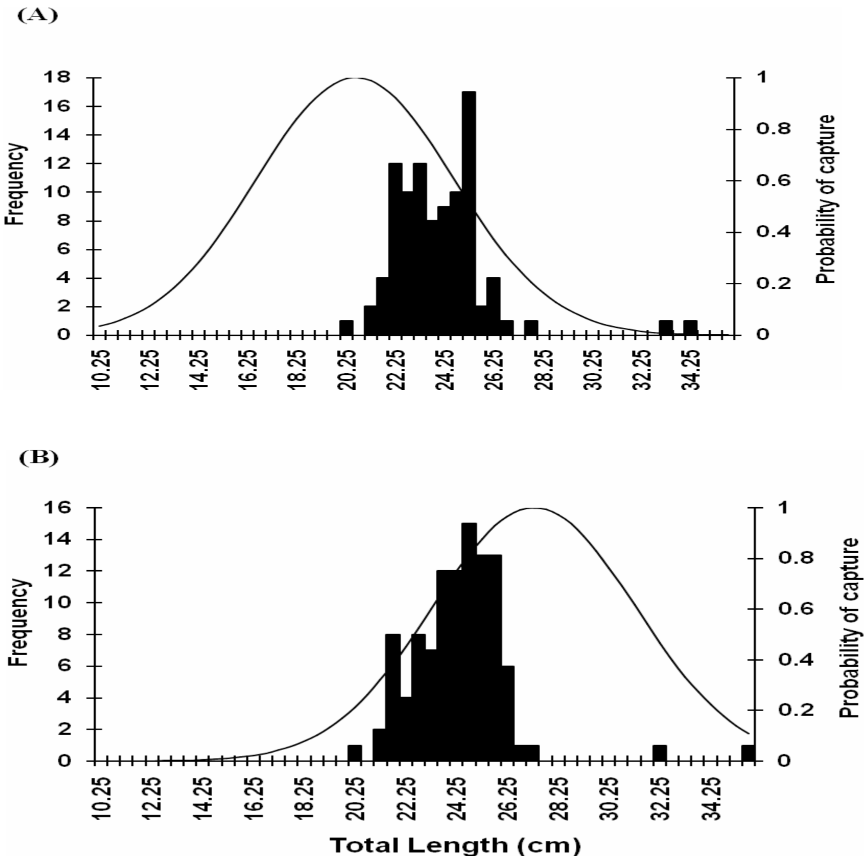

Figure 4. Selection curves of *Cypselurus poecilopterus* for (A) 3.4cm and (B) 4.5cm mesh sizes. Histogram indicates percentage length frequency distribution

Estimated optimum lengths corresponding to different species are found to be different. *Cheilopogon suttoni* shows the maximum optimum lengths for both mesh sizes while *Cypselurus poecilopterus* shows the lowest. This must be attributed to the body shape of the *Cypselurus poecilopterus,* which is characterized by higher body depth compared to *Cheilopogon suttoni.*

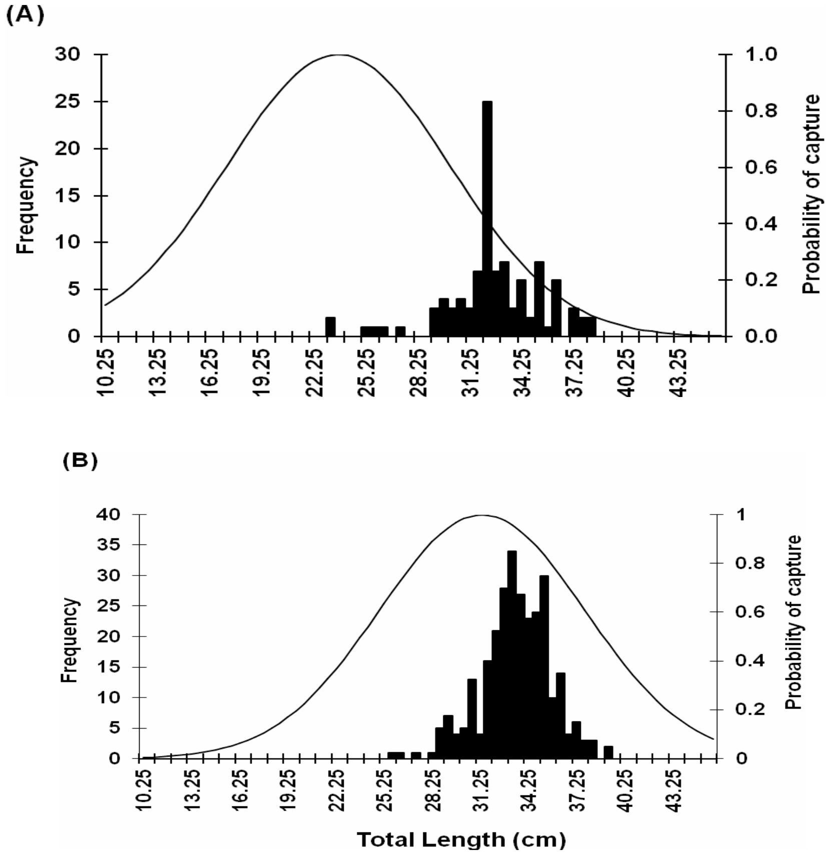

Figure 5. Selection curves of *Cheilopogon suttoni* for (A) 3.4cm and (B) 4.5cm mesh sizes. Histogram indicates percentage length frequency distribution.

Presence study revealed that the gillnet selection curve does not exactly correspond to the size distribution of flying fish in each mesh size. Probabilities of capture are often used to correct length frequency distribution for the influence of gear selection (Sparre and Venema 1998). Due to the absence of smaller and larger flying fish in the fishing area, care should be taken in correcting the length frequency data for gear selection. From present analysis it is evident that in 3.4 cm mesh gill nets, size classes smaller than optimal length and in 4.5 cm mesh gill nets, size classes greater than optimal lengths can be overestimated when correcting for gillnet selection.Furthermore, length frequency data obtained from the gillnet catches of flying fish species provide two disadvantages in quantifying mortality parameters. Firstly, size distributions of flying fish caught in gillnets do not represent population size structure due to the gillnet selectivity. Secondly, being highly migratory stocks (Jinadasa 1991), larger size group of the landings of flying fish may be absent in the fishing area. As such, the slope of the length converted catch curve of a given flying fish stock represents total mortality plus the proportion of emigration of the fish stock. Consequently length frequency data collected from a restricted fishing area for a seasonal fishery such as flying fish are not sufficient to estimate total mortality. The data should cover the entire range of distribution of the fish stock.

Due to the absence of fish of the size outside the presently exploited size ranges, it is very unlikely that fishers change mesh sizes of gill nets to catch flying fish of smaller or larger size classes. This study therefore reveals that strict management options such as limitation of mesh size, close season, close areas, limitation of fishing community are not immediately required for managing the flying fish fishery off the northwestern coast of Sri Lanka.

Acknowledgements

The author is grateful to Professor U.S. Amarasinghe, Department of Zoology, University of Kalaniya for his guidance throughout the study and help in preparing this manuscript. Scholarship awarded to the author by the Asian Development Bank, Science and Technology Personnel Developmental Project is also gratefully acknowledged.

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