Asian Fisheries Science **15**(2002): 215-228
ISSN: 0116-6514
https://doi.org/10.33997/j.afs.2002.15.3.003

Asian Fisheries Society, Manila, Philippines

Aspects of the Biology and Fishery of Malabar Sprat, *Ehirava fluviatilis* (Osteichthyes: Clupeidae) in Bolgoda Lake, Sri Lanka

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Abstract

A seasonal fishery from December to May each year exists for a small-sized clupeid, *Ehirava fluviatilis* in an estuary on the West coast of Sri Lanka. Two kinds of lift nets are used for catching this species. The theoretical weight of 50 mm fish, as calculated from length-weight relationship that was used as an index of body condition (942 mg) is considerably higher than that of a reservoir population (540 mg). In contrast to feeding habits reported from the reservoir population in which rotifers were the major food items, *E. fluviatilis* in the estuary feeds mainly on copepods. Size at first maturity of this species is also higher in the estuarine population than that reported from the reservoir population.

From the length frequency samples collected approximately in bi-weekly intervals, growth and mortality parameters were estimated using FiSAT software package. Total mortality coefficient (5.73) calculated on the basis of asymptotic total length (54.3 mm) and growth constant (2.00 yr^{-1}) indicates that *E. fluviatilis* population in the estuary has a high turnover rate. Relative yield-per-recruit analysis performed by incorporating probabilities of capture indicates that the fish stock is underexploited and that the fishing strategy can be optimized by decreasing size at first capture from the present value of 45.8 mm to about 26 mm at an exploitation rate of about three times higher than the present level. The high total annual production of *E. fluviatilis* of 15.9 tons that is equivalent to an annual yield of 23.2 $kg{\cdot}ha^{-1}$ could be due to its ability to withstand heavy fishing mortalities through high turnover rates.

Introduction

Members of the family Clupeidae are generally marine species, which support productive fisheries all over the world. Nevertheless some clupeids live temporarily or permanently in freshwater. *Limnothrissa miodon* and *Stolothrissa tanganicae* are two clupeid species endemic to Lake Tanganyika, East Africa (Fernando and Holčik 1991). *L. miodon*, which was introduced to the Kariba reservoir and Lake Kivu has been reported to support productive fisheries (Marshall 1993, Pitcher and Hart 1995). *Clupeichthys arsenensis* (earlier named *Corica goniognathus*) is a small clupeid exploited in the Ubolratana reservoir, Thailand (Sirimongkonthaworn and Fernando 1994).

The Malabar sprat, *E. fluviatilis* (Deraniyagala 1929) is a small-sized clupeid that grows up to about 5 cm in rivers and estuaries in Sri Lanka and Southwest India (Deraniyagala 1929, Whitehead 1985, Talwer and Jhingran 1991, Pethiyagoda 1991). This species is found up to 10 km upstream in rivers (Whitehead 1985). In Sri Lanka, *E. fluviatilis* occurs in some irrigation reservoirs in the dry zone of the island. Schiemer and Hofer (1983) and Newrkla and Duncan (1984) have reported the occurrence of this species in Parakrama Samudra, an ancient reservoir in the Mahaweli River basin in Sri Lanka. *E. fluviatilis* was collected by the senior author (U.S.A.) from Rajanganaya reservoir in the Kala Oya River basin in Sri Lanka in 1979. It is likely that they come up the rivers to exploit the existence of the irrigation reservoirs, all of which have quite high and continuous flow of water (Newrkla and Duncan 1984). However, a fishery has not been established for this species in the inland reservoirs of Sri Lanka.

There is a seasonal fishery for *E. fluviatilis* in Bolgoda Lake in the Panadura estuary in the southwestern part of Sri Lanka (Fig. 1). Although some studies on the fishery of Bolgoda Lake have been reported (Jinadasa et al. 1992, Jinadasa and Furst 1996), no detailed account on the biology and fishery of this species is available. The only biological study reported on this species is from Parakrama Samudra where *E. fluviatilis* would have secondarily colonized from marine and estuarine habitats.

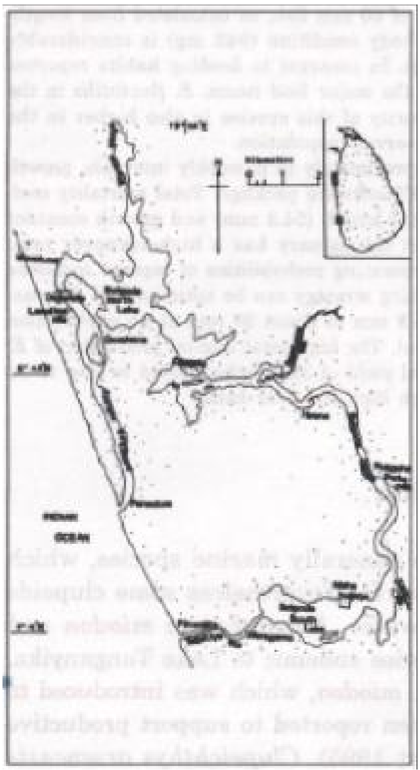

Fig. 1. Map of Bolgoda Lake estuarine system. Inset shows its location in Sri Lanka.

It is well known that one of the major factors that constrain the formulation of appropriate management strategies and policies for estuarine and lagoon fisheries is the lack of sufficient information on basic fish biology and fisheries aspects (Kapetsky 1981). In this paper, an attempt is made to investigate some aspects of the biology and fishery of *E. fluviatilis* in Bolgoda Lake, Sri Lanka. Here, an attempt is also made to compare the relative healthiness of this population with that of a reservoir population.

Location and general features of the Bolgoda Lake

The Panadura estuary consists of two main basins, namely the Bolgoda North Lake and the Bolgoda South Lake interconnected by a channel (Siriwardena and Perera 1986). On one hand, the north lake drains into the Indian Ocean via the Panadura estuary. On the other hand, the south lake is closed due to the formation of a sand bar and is mainly freshwater (Siriwardena and Tissa 1988).

The artisanal fishery of Bolgoda Lake has an annual production of 50 to 60 tons. It has been reported that 53 fin fish species, 5 species of penaeid shrimps and 3 species of palaemonid prawns contribute to this fishery (Jinadasa and Furst 1996). Fish kraals (locally known as Ja-kotu), cast nets, barrier nets, hand lines, drag nets (Jayasinghe 1979) and lift nets (present study) are the main types of fishing gear in this fishery. Two kinds of lift nets locally known as “Kulu dela” (hereafter KUD) and “Kachchi dela” (hereafter KAD) are used to catch *E. fluviatilis*. This fishery is restricted to the north lake in the estuarine system.

Lift net fishing methods

KUD consists of a conical shaped net bag (mesh size 8 mm) and vertical wooden bars at the mouth of the net bag (Fig. 2A). The wooden bars help keep the mouth of the net open. The length and width of KUD are 6 and 5 m respectively. This gear is operated by two persons in waist deep water. Two fishers hold two vertical bars at either ends of the mouth of the net bag. The net is towed at the middle part of the water column. After towing for about 10 min (approximately 100 m distance), the net is lifted and *E. fluviatilis* caught in the net bag are collected in a container. Nontarget species (by-catch; insignificant) consisting mainly of juveniles of various fin fish species and plant debris are discarded into the estuary. During the fishing period of *E. fluviatilis* from December to May, this method is operated at daytime and at dawn in shallow areas of the Bolgoda Lake. The average period of operation of this fishing gear is about 8 h per day.

KAD consists of three main parts (Fig. 2B); the distal collecting net with mesh size 8 mm, main net with mesh size 16 mm and wing net consisting of 16 mm mesh distal part and 30 mm mesh proximal part. Six to seven fishers working on three nonmechanized crafts (wooden out-rigger canoes) operate this fishing gear. The net is set at the middle of the lake by the three crafts. After setting, three fishers who get into the water hold the drag lines at the end of the two wing nets and the distal collecting end (Fig. 2C). The two fishers who hold the two wing nets then wave the net so that *E. fluviatilis* are driven towards the distal collecting end of the net. The fish are then collected and placed in the craft. This gear is also operated during daytime and at dawn. The average period of operation is about 8 h per day during the fishing season from December to May.

Materials and Methods

This study was carried out from December 1997 to May 1998. Fishers were provided with data sheets to record their daily catches of *E. fluviatilis* and the number of fishing units operated each day. During regular visits to the landing site in Bolgoda Lake, the fishers' records were validated for accuracy. Since 7 KAD and 18 KUD were operated in Bolgoda Lake during the study period, the total enumeration of catch and effort in the *E. fluviatilis* fishery was possible.

From 13 January to 21 April 1998, seven samples of *E. fluviatilis* (a total of 2,122 specimens) were obtained from the catches of KAD in biweekly intervals. Since the size of KUD is much smaller than KAD, it is thought that large fish can escape from the nets. As such, no samples were obtained from KUD for the present analysis. Samples were preserved in 5% buffered formalin and taken to the laboratory for further analysis. In the laboratory, the total length (TL) of each specimen in the samples was measured to the nearest mm using a measuring board and TL data were grouped in 1 mm length classes for each sample. Six hundred and fifty six specimens of *E. fluviatilis*, which ranged from 20 to 54 mm TL were analyzed to determine the length-weight relationships, and to study their reproductive biology and feeding habits.

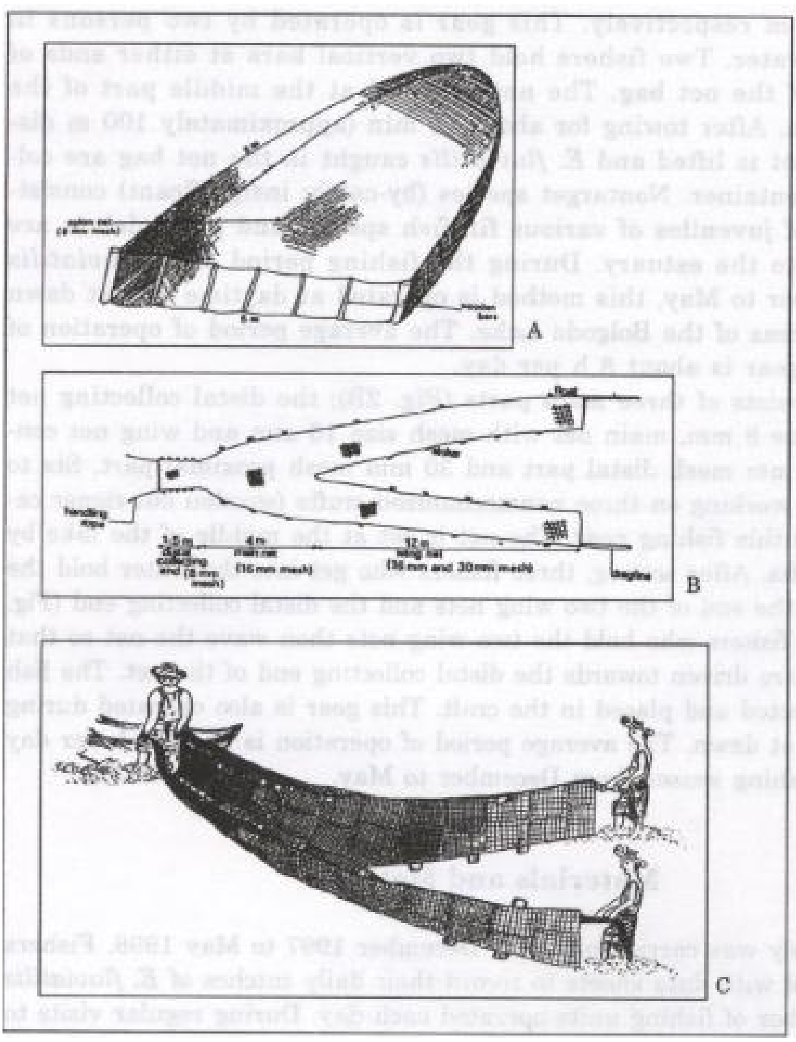

Fig. 2. Two kinds of fishing gear used in the *E. fluviatilis* fish ery in Bolgoda Lake. A. Kulu dela; B. Kachci dela; C. Method of operation of Kachchi dela.

To determine the feeding habits, each specimen was dissected and the stomach was opened longitudinally. The contents were teased out to a watch glass and diluted to a 1 ml volume. The suspension was then placed into a sedgewick rafter counting cell and examined under a light microscope. Food items were identified to the genus level using the keys given by Fernando (1990). For the reproductive biology, the gonads were observed to determine the sex and maturity stage of each fish. Females with yellowish ovaries that extend to more than ½ of the body cavity, and males with creamy white testes that extend to more than ½ of the body cavity, were treated as mature individuals (Stage III and above).

The length–weight (L–W) relationship of *E. fluviatilis* was determined using the least square linear regression analysis, for the log-transformed version of the relationship, $W = aL^b$ where a and b are constants. The number of each food item as a percentage of total food items was determined for each specimen. Relative importance (%) of food items was determined for four size classes (20 to 30 mm, 30 to 40 mm, 40 to 50 mm and >50 mm) as well as for all size classes combined. From a plot of percentage maturity in 5 mm length classes, mean sizes at maturity (i.e., length at 50% maturity) were calculated for males and females separately.

Length frequency data of *E. fluviatilis* were analyzed using the FiSAT software package (Gayanilo et al. 1995). As length data were obtained with varying time intervals, actual time intervals between sampling dates were used in this analysis. Since *E. fluviatilis* is a short-lived species (Pethiyagoda 1991) with small maximum body size, length frequency data obtained from shorter time intervals (i.e., fortnightly) offer an advantage to estimate von Bertalanffy growth parameters using ELEFAN and similar methods in which modal progressions in length frequency data sequentially arranged with time are examined. As the catch efficiencies of KUD and KAD were different from each other, it was necessary to use length frequency data from one fishing method (KAD in the present case) for the analysis.

In analyzing the length frequency data, an initial estimate of asymptotic total length (TL_∞) and a value for Z/K (Z = Total mortality and K = Growth constant) were estimated using the Powell-Wetherall method (Powell 1979, Wetherall 1986; Pauly 1986). Length frequency data were corrected using probabilities of capture by means of the routine implemented in the ELEFAN technique of the FiSAT package (Gayanilo et al. 1995). To determine growth parameters using ELEFAN method, 2 mm length classes were used. The step-wise procedure of this analysis is given in Amarasinghe and De Silva (1992).

Total mortality (Z) of *E. fluviatilis* was estimated from the length-converted catch curve method. Natural mortality coefficient (M) was estimated using Pauly's empirical relationship (Pauly 1980) between M, TL_∞, K and mean annual water temperature (28°C). Here TL_∞ used was in cm and K was on an annual basis. Fishing mortality (F = Z-M) and exploitation rate (E = F/Z) were also estimated to assess the status of the fishery.

Since *E. fluviatilis* is a short-lived species, Beverton and Holt's (1966) relative yield-per-recruit model based on knife-edge recruitment and selection is not appropriate to investigate the long-term effects of fishing on the stock. As such, the relative yield-per-recruit analysis incorporating the probabilities of capture of different size classes (Pauly and Soriano 1986) was performed to assess the long term effect of fishing on the stock of *E. fluviatilis* in Bolgoda Lake. However in this model, L_∞ should always be greater than the maximum size of fish in the catch sample. In the present analysis, L_∞ defined as the mean length of the oldest age group in the stock, was smaller than the maximum length in the catch sample. As such the value of 58.8 mm (a greater value than the maximum length) was taken as L_∞ and the corresponding K value was estimated from the relationship, $Ø' = 2 \text{Log } L_\infty + \text{Log } K$ (Pauly and Munro 1984) where Ø' is a species–specific parameter, called growth performance index. Here Ø' value was estimated by means of TL_∞ and K of *E. fluviatilis* determined in the present study.

Total monthly catch, fishing effort and catch per unit effort (CPUE expressed as catch per net-day) of *E. fluviatilis* in Bolgoda Lake were calculated for the two fishing methods separately.

Results

Biological aspects

Length-weight relationship of *E. fluviatilis* in Bolgoda Lake ($W = 0.0004 L^{3.7505}$; $r = 0.9797$; $p < 0.0001$) is shown in figure 3. Body condition factor ($C = W/L^3$) is 0.0054 (SE = 0.000043). The theoretical weight of 50 mm fish, as calculated from length-weight relationship is 942 mg.

For the stomach contents, 2 genera of copepods, 2 genera of cladocerans, 1 genus of mollusc and 1 genus of rotifer were observed (Table 1). Mean relative abundance (in numbers) of the food items in different size

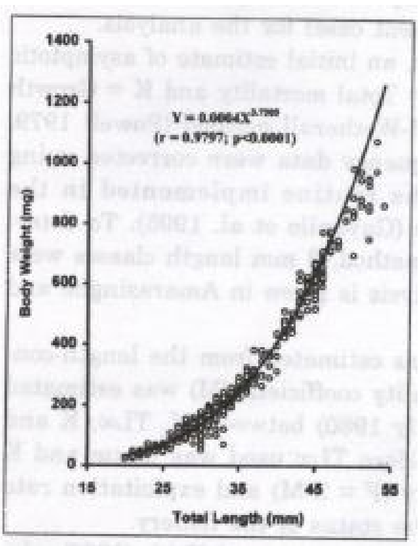

Fig. 3. Length-weight relationship of *E. fluviatilis* in Bolgoda Lake

Table 1. Food items present in the stomach contents of *E. fluviatilis* in Bolgoda Lake and their size ranges as measured by a micrometer eye-piece in a light microscope

Food item	Size range (mm)
Copepods	
Cyclops sp.	0.56-0.82
Diaptomus sp.	1.02-1.30
Cladocera	
Daphnia sp.	0.80-0.92
Diaphanosoma sp.	0.56-0.65
Mollusca	
Pisidium sp.	0.16-0.23
Rotifera	
Brachionus sp.	0.15-0.18

groups of fish and for all size classes of fish combined is shown in figure 4. Copepods form the major food type in all size classes.

The male:female sex ratio was 1:1.18 and was not significantly different from the 1:1 ratio (G = 0.330; $p > 0.05$; Fowler and Cohen 1990). The plot of percentage maturity against length is shown in figure 5. Mean sizes at maturity of males (39 mm) and females (41 mm) are not appreciably different from each other.

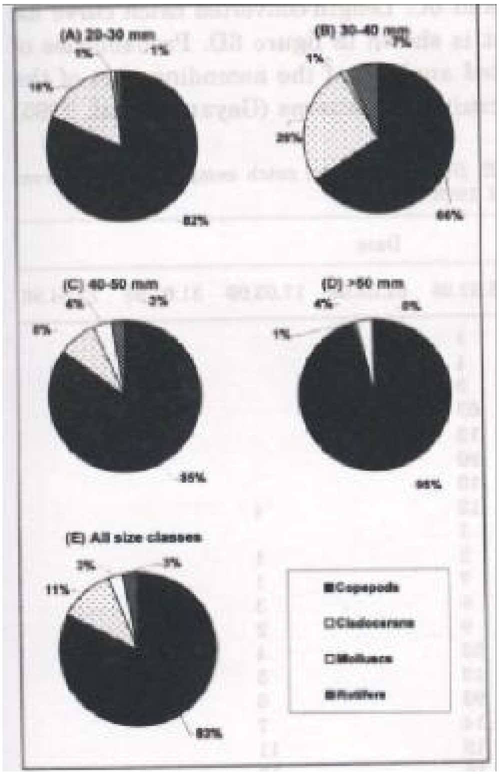

Fig. 4. Mean relative abundance (in numbers) of food items in stomachs of different size groups of *E. fluviatilis* in Bolgoda Lake

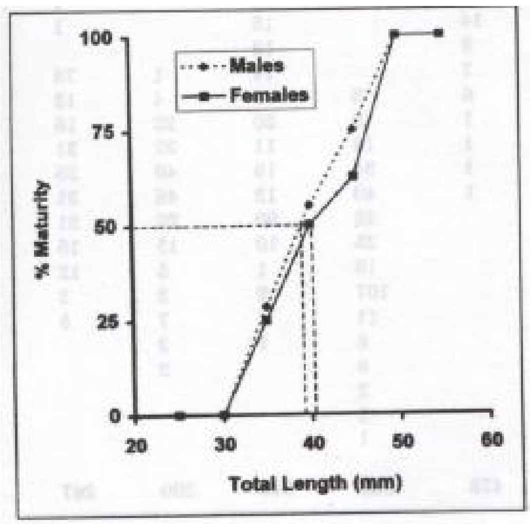

Fig. 5. Percentage maturity of male and female *E. fluviatilis* against length of fish in Bolgoda Lake

Length frequency data are given in table 2. The Powell-Wetherall plot for *E. fluviatilis* is shown in figure 6A. Length frequency data corrected for probabilities of capture with the growth curve estimated by means of ELEFAN technique (both percentage length frequencies and length frequencies restructured for identifying 'pseudo-cohorts' [Gayanilo et al. 1995] respectively) are shown in figures 6B and 6C. Length-converted catch curve for estimating total mortality coefficient is shown in figure 6D. Probabilities of capture as determined by the detailed analysis of the ascending part of the length-converted catch curve and recruitment patterns (Gayanilo et al. 1995)

Table 2. Length frequency distributions of *E. fluviatilis* in the catch samples obtained from KAD in Bolgoda Lake from January to April 1998

Mid-point of length class (mm)	Date						
	13.01.98	26.01.98	13.02.98	01.03.98	17.03.98	31.03.98	23.04.98
18.5			1				
19.5			1				
20.5		3	3				
21.5		16	63				
22.5		26	13				
23.5	1	16	90				
24.5	2	18	10				
25.5	1	12	12		4		
26.5	1	13	7				
27.5	9	16	2		1		
28.5	28	17	7		1		
29.5	44	13	5		3		
30.5	85	14	9		2		
31.5	72	11	52		4		
32.5	35	7	12		5		
33.5	19	4	92		6		
34.5	9	4	14		7		
35.5	4	4	19		11		
36.5	5	1	16		12		
37.5	6	2	11		66		1
38.5	2	1	14		15		1
39.5	1	2	8		13		
40.5	1		7		14	1	73
41.5			6	5	18	4	13
42.5			1	2	20	22	16
43.5			1	13	11	32	31
44.5			1	34	16	40	35
45.5			1	40	12	46	31
46.5				32	90	22	31
47.5				25	10	15	15
48.5				16	1	5	12
49.5				107	2	2	3
50.5				11	1	7	5
51.5				8	1	2	
52.5				8		2	
53.5				2			
54.5				2			
55.5				1			
Total	325	200	478	306	346	200	267

are shown in figures 7A and 7B, respectively. Growth and mortality parameters estimated from various methods are presented in table 3. Both the Powell-Wetherall method (54.7 mm) and ELEFAN techniques (54.3 mm) gave more or less similar values for TL_{∞}. As estimated using the Powell-Wetherall method Z/K (2.693) and the ratio of Z (5.73 yr-1) to K (2.00 yr-1) estimated by means of length-converted catch curve and ELEFAN respectively were in close agreement indicating the reliability of growth and mortality estimates. As the lift nets are selective for lower size range of fish than the fully selected length, sigmoid selection ogive as a result of the present analysis (Fig. 7A) correctly describes the mean selection pattern of the sampled gear. The recruitment pattern showed a single prominent peak (Fig. 7B). Relative yield-per-recruit isopleth at different levels of E and L_c is shown in figure 7C. This indicates that the *E. fluviatilis* stock in Bolgoda Lake is underexploited.

Fish production

The monthly variations in total *E. fluviatilis* production, the fishing effort exerted by the two fishing methods, and the CPUE of KAD and KUD are shown in figure 8. Total production of *E. fluviatilis* during the fishing season in 1997 to 1998 was 15.9 tons (Table 4). As this fishery is entirely restricted to the Bolgoda North Lake, it is assumed that the *E. fluviatilis* stock is distributed only in this portion of the estuary. The absence of fishing activities for *E. fluviatilis* in the Bolgoda South Lake could be an indication that there is no sizeable population of the species to support a fishery in the south lake. As the present analysis was based on the landings of the artisanal fishery, it was not possible to sample the south lake. The annual fish yield of *E. fluviatilis* is estimated to be 23.2 $kg \cdot ha^{-1}$.

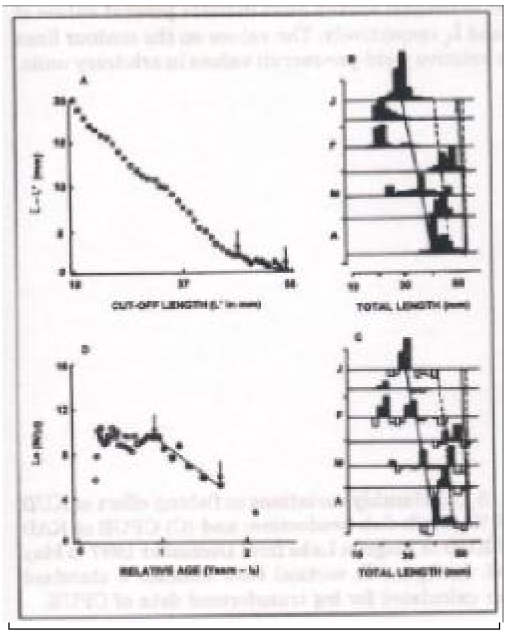

Fig. 6. (A) Powell-Wetherall plot ($\bar{L}$ is the mean length of fish greater than L') for *E. fluviatilis* in Bolgoda Lake; (B) Growth curve of *E. fluviatlis* superimposed on percentage length frequency distributions of the samples; (C) Growth curves of *E. fluviatilis* superimposed on restructured length frequency data for identifying 'pseudo-cohorts' which are shown by peaks in the length frequency diagrams; (D) Length converted catch curve for *E. fluviatilis*. Note: In figures B and C, length frequency data corrected for gear selection are presented. Solid and broken curves represent two growth curves corresponding to two recruitments. The goodness-of-fit (Rn value; Gayanilo et al. 1995) associated with the solid growth curve is 0.316. In figures A and D, ranges of data shown by arrows (dark circles) were used in the regression analyses.

Table 3. Growth parameters, mortality rates and size at first capture of *E. fluviatilis* in Bolgoda Lake

Parameter	Value
Powell-Wetherall method	
L_∞ (mm)	54.7
Z/K	2.693
ELEFAN I	
L_∞ (mm)	54.3
K (per yr)	2.00
Growth performance index (∅)	3.771
Total mortality (Z per yr)	5.73
Natural mortality (M per yr)	4.52
Fishing mortality (F per yr)	1.21
Exploitation rate (E)	0.21
Length at first capture (L_c in mm)	45.8

Table 4. Total production of *E. fluviatilis* in Bolgoda Lake from December 1997 to May 1998. KAD – Kachchi dela; KUD – Kulu dela

Month	Production (kg)		
	KAD	KUD	Total
December 1997	125.3	136.3	261.5
January 1998	943.9	844.7	1788.7
February 1998	1621.2	1470.7	3091.9
March 1998	2127.5	2312.0	4439.5
April 1998	2125.2	1280.2	3405.4
May 1998	2301.3	576.3	2877.6
Total	9244.4	6620.2	15864.6

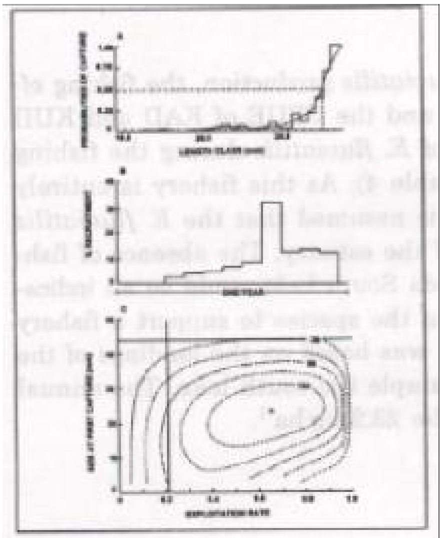

Fig. 7. (A) Probabilities of capture (curve indicates moving averages); (B) Recruitment patterns; and (C) Relative yield-per-recruit as a function of E and L_c in *E. fluviatilis* in Bolgoda Lake. In figure C, the vertical and horizontal broken lines indicate present values of E and L_c respectively. The values on the contour lines are relative yield-per-recruit values in arbitrary units.

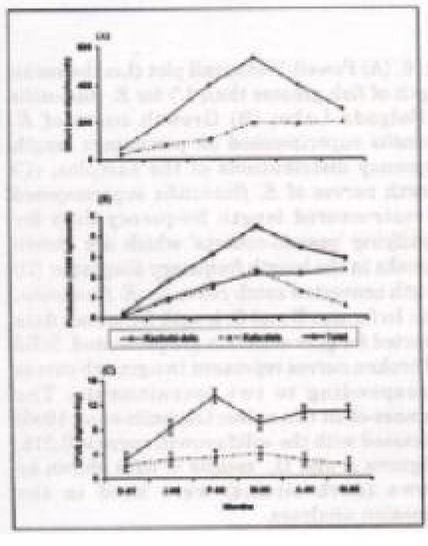

Fig. 8. (A) Monthly variations in fishing effort of KUD and KAD; (B) fish production; and (C) CPUE of KAD and KUD in Bolgoda Lake from December 1997 to May 1998. In figure C, vertical bars indicate ± standard error calculated for log transformed data of CPUE.

Discussion

In Bolgoda Lake, the TL of fish ranged from 18.5 to 55.5 mm. The theoretical weight of 50 mm TL fish (W_{50}), as calculated from length-weight relationship can be considered as an index of body condition. De Silva (1985) used a similar definition of body condition for reservoir populations of *O. mossambicus*. The W_{50} of *E. fluviatilis* in Bolgoda Lake is 942 mg.

As revealed in the present study, the major food items of *E. fluviatilis* in Bolgoda Lake are copepods. Conversely in Parakrama Samudra reservoir, this species feeds mainly on larger rotifers (*Trichocerca similis*, *Brachionus caudatus*) and microcrustaceans to a lesser extent (Duncan 1999). Perhaps the nutritive quality of food of *E. fluviatilis* in Bolgoda Lake is richer than their food in freshwater reservoir. It has been reported that the composition of zooplankton in the Bolgoda Lake was dominated by copepods and nauplii larvae (>70%) while the rest was formed by rotifers, cladocerans and ostracods (Wignarajah and Amarasiriwardena 1983).

There are marked differences in the biological characteristics of *E. fluviatilis* in the Bolgoda Lake from those of a reservoir population found in Parakrama Samudra. In Parakrama Samudra, the maximum size of *E. fluviatilis* caught in a Bongo net was 47 mm Standard Length (SL) (Newrkla and Duncan 1984). This is equal to 55.5 mm TL based on the relationship, TL = 1.18 SL (as determined by a linear regression through origin in the present analysis). The W_{50} is appreciably higher than that of the population in Parakrama Samudra wherein W_{50} value which is based on the relationship $W = 0.021\ SL^{2.710}$ (W in mg; SL in mm; Newrkla and Duncan 1984) is 540 mg (Here 50 mm TL = 42.4 mm SL according to TL-SL relationship). This evidence could indicate that in the estuarine population of *E. fluviatilis*, more food energy is diverted to somatic growth in contrast to reservoir population.

Most clupeids of marine origin are believed to be stenophagous and specialized in their feeding habits, which prefer microcrustaceans from which they obtain essential fatty acids. As such, they lack enzymes to synthesize essential fatty acids (S.S. De Silva, pers. comm). Investigation of feeding ecology of pelagic planktivorous fish in relation to their physiological energetics therefore seems to be an important field of study to better understand their role in 'top-down' and 'bottom-up' impacts on pelagic community structure.

Size at first maturity (TL) of this species in Bolgoda Lake is 35 mm. Nevertheless in Parakrama Samudra, its size at first maturity (SL) is reported to be 17 mm (≈ 20.1 mm TL) (Newrkla and Duncan 1984). Due to differences in life history patterns between estuarine and reservoir populations of this clupeid species, a detailed study appears to be useful to investigate its functional importance in different aquatic ecosystems.

Since spent individuals of fish were not found, it is unlikely that spawning takes place within the estuary. However in Parakrama Samudra, larval and juvenile fish were reported to be abundant in open water indicating that they spawn within the reservoir (Newrkla and Duncan 1984). Surveys are necessary to be carried out in the upper reaches of the river and in the sea to confirm spawning grounds of *E. fluviatilis* in Bolgoda Lake. Mean sizes at maturity of males and females, which are 39 and 41 mm respectively, are lower than the mean size at first capture (43.8 mm). This substantiates the results of the relative yield-per-recruit analysis, which indicate that this fish stock is underexploited.

Although there is a single peak in the recruitment of the *E. fluviatilis* to the fishery, continuous recruitment for a few months with less prominent pulses is evident (Fig. 7B). As such, to determine the growth parameters using length-based methods, sampling with shorter time intervals than one month is effective, as performed in the present study. A single prominent recruitment pulse on the other hand, could indicate the reason for the strong seasonality in the fishery of *E. fluviatilis* in Bolgoda Lake.

Marshall (1993) presented an allometric relationship between the Z and asymptotic body weight (W_∞) of tropical fish ($Z = 13.49W_\infty^{-0.33}$; Z in annual basis; W_∞ in g). W_∞ of *E. fluviatilis* in Bolgoda Lake as determined from the length-weight relationship is 1.28 g. The values of W_∞ and Z (5.73) of *E. fluviatilis* are in good agreement with this allometric relationship (Fig. 9). The Z value however lies below the predicted value by the relationship, which also indicates that the exploitation rate can be further increased. It is known that when instantaneous rates of mortality are described by the negative exponential curves and growth conforms to von Bertalanffy growth function, Z is equal to production/biomass (P/B) ratio or turnover rate (Allen 1971). The rates of most physiological processes in animals are determined by body size (Peters 1983). Being a small-sized fish, *E. fluviatilis* has high P/B ratio. High P/B ratio of *E. fluviatilis* in Bolgoda Lake is indicative of the ability of the population to withstand high fishing mortalities.

The seasonal fishery for *E. fluviatilis* lasts from December to May and produces very high yields. According to the present analysis, it is evident that by increasing E from the present level of 0.21 to 0.65, and by reducing the size at first capture from 45.8 to about 26.0 mm (Fig. 7C) yield could be further increased.

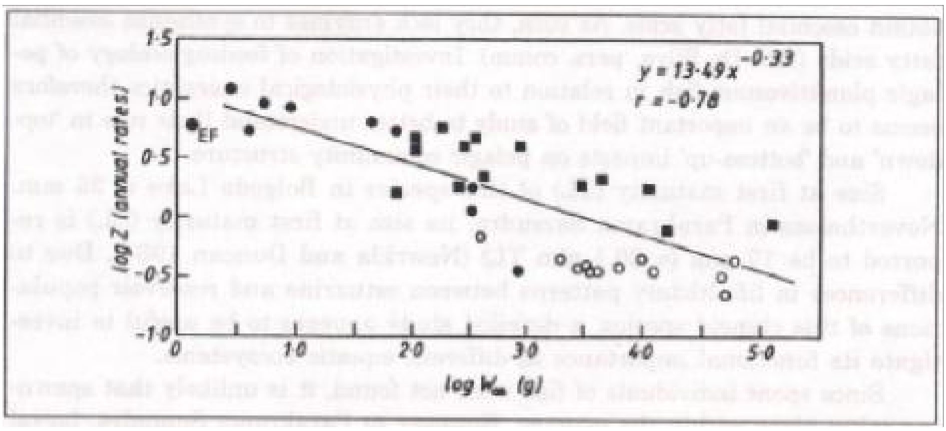

Fig. 9. The relationship between the total mortality rate (Z) and asymptotic weight (W) in tropical fishes (adopted from Marshall 1993). Different marker patterns indicate various sources of data used in the regression. EF indicates the value for *E. fluviatilis* (not used in the regression) in Bolgoda Lake.

During the early part of the fishing season, fishing effort of KUD steadily increases. Fishing effort of KAD increases until the end of the fishing season while that of KUD decreases during the latter half of the season (Fig 8A). Monthly production of *E. fluviatilis* in the two fishing methods also shows the same trend (Fig. 8B). As CPUE of KUD decreases during the latter half of the fishing season (Fig. 8C), it is possible that KUD are not effective for catching *E. fluviatilis* during this period. On the other hand, KAD appears to be more effective than KUD for catching *E. fluviatilis*. The seasonality in this fishery is perhaps due to the seasonality in recruitment. It is apparent that KUD is mainly effective for catching smaller *E. fluviatilis* while KAD is for larger individuals. Small individuals are abundant during the early period of the fishing season while during the latter part of the season, larger individuals dominate the stock (Fig. 6B). Fishers intensify appropriate fishing operations to catch *E. fluviatilis* through the knowledge gained by experience. It has been reported that this species is found in other river estuaries of the island (Pethiyagoda 1991). However a traditional fishery is established only in Bolgoda Lake. Investigation of the fishery potential of this species in other parts of the country will be useful to introduce new fisheries.

Acknowledgment

We are grateful to the fishers of Bolgoda Lake and to their families for the support they have given us.

References

Allen, K.R. 1971. The relation between production and biomass. Journal of the Fisheries Research Board Canada 28: 1573-1581.

Amarasinghe, U.S. and S.S. De Silva. 1992. Population dynamics of *Oreochromis mossambicus* and *O. niloticus* (Cichlidae) in two reservoirs in Sri Lanka. Asian Fisheries Science 5: 37-61.

Beverton, R.J.H and S.J. Holt. 1966. Manual of methods for fish stock assessment. Part 2. Tables of yield functions. FAO Fisheries Rechnical Paper No. 38 Revision 1. 67 pp.

De Silva, S.S. 1985. Body condition and nutritional ecology of *Oreochromis mossambicus* (Pisces, Cichlidae) populations in man made lakes in Sri Lanka. Journal of Fish Biology 27: 621-633.

Deraniyagala, P.E.P. 1929. Ceylon sardines. Spolia Zeylanica (Ceylon Journal of Science, Section B: Zoology and Geology) 15: 31-47.

Duncan, A. 1999. Pelagic fish and fisheries in Asian and African lakes and reservoirs. In: Fish and fisheries of lakes and reservoirs in Southeast Asia and Africa (eds. W.L.T. van Densen and M.J. Morris), pp. 347-382. Westbury Publishing, Otley.

Fernando, C.H. 1990. Freshwater fauna and fisheries of Sri Lanka. Natural Resources, Science and Energy Authority, Colombo, 444 pp.

Fernando, C.H. and J. Holcik. 1991. Fish in reservoirs. Internationale Revue der gesamten Hydrobiologie 76: 149-167.

Fowler, J. and L. Cohen. 1990. Practical statistics for field biology. Open University Press, Buckingham. 226 pp.

Gayanilo, F.C. Jr., P. Sparre and D. Pauly. 1995. The FAO-ICLARM Stock Assessment Tools (FiSAT) User's guide. FAO Computerized Information Series (Fisheries) No. 8, FAO, Rome, 126 pp.

Jayasinghe, J.M.P.K. 1979. Some aspects of hydrobiology of Panadura river estuary. Unpublished M.Phil. thesis, University of Colombo, Sri Lanka, 276 pp.

Jinadasa, J. and M. Furst. 1996. Fishery resources and their management in Bolgoda estuary (Abstract). Proceedings of the Regional Workshop on Research for the Management of Coastal Resources in the Tropics, 9-10 October, NARA, Colombo.

Jinadasa, J., H.D.S. Jayantha and W.V.J. Perera. 1992. Species composition, distribution and economic importance of fishes in the Bolgoda lagoon. Vidyodaya Journal of Science 4: 107-115.

Kapetsky, J.M. (1981) Some considerations for the management of coastal lagoon and estuarine fisheries. FAO Fisheries Technical Paper 218. 47 pp.

Marshall, B.E. 1993. *Limnothrissa* in man-made lakes: Do we understand the implications of their small size? In: Papers presented at the Symposium on Biology, Stock Assessment and Exploitation of Small Pelagic Fish Species in the African Great Lakes Region, 25-28 November 1992, Bujumbura, Burundi (eds. B.E. Marshall and R. Mubamba), pp. 1-17. CIFA Occasional Paper No. 19.

Newrkla, P. and A. Duncan. 1984. The biology and density of *Ehirava fluviatilis* (Clupeoid) in Parakrama Samudra, Sri Lanka. Verhhandlungen der Internattional Vereinigung für theoretische und angewandte Limnologie 22: 1572-1578.

Pauly, D. 1980. On the relationship between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil. Conseil International Exploration de la Mer 39: 175-192.

Pauly, D. 1986. On improving operation and use of the ELEFAN programs. Part II. Improving the estimation of L_∞ Fishbyte 4: 11-13.

Pauly, D. and J.L. Munro. 1984. Once more on the comparison of growth in fish and invertebrates. Fishbyte 2(1): 21.

Pauly, D. and M.L. Soriano. 1986. Some practical extensions to Beverton and Holt's relative yield-per-recruit model. The First Asian Fisheries Forum: 491-495.

Peters, R.H. 1983. The ecological implications of body size. Cambridge University Press, Cambridge. 324 pp

Pethiyagoda, R. 1991. Freshwater fishes of Sri Lanka. Wildlife Heritage Trust of Sri Lanka, Colombo. 362 pp.

Pitcher, T.J. and P.J.B. Hart. Editors. 1995. The impact of species changes in African lakes. Chapman and Hall, London. 601 pp.

Powell, D.G. 1979. Estimation of mortality and growth parameters from the length frequency data of a catch. Rapport et Procés-Verbaux des Réunions, Conseil International pour l'Exploration de la Mer 175: 167-169.

Schiemer, F. and R. Hofer. 1983. A contribution to the ecology of fish fauna of Parakrama Samudra reservoir. In: Limnology of Parakrama Samudra, Sri Lanka: A case study of an ancient man-made lake in the tropics (ed. F. Schiemer), pp. 135-140. Dr. W. Junk Publishers, The Hague.

Sirimongkonthaworn, R. and C.H. Fernando. 1994. Biology of *Clupeichthys arsarnensis* (Clupeidae) in Ubolratana reservoir, Thailand, with special reference to food and feeding habits. Internationale Revue der gesamten Hydrobiologie 79: 95-112.

Siriwardena, P.P.G.S.N. and W.K.T. Perera. 1986. Topography and substratum of Bolgoda Lake. Journal of Inland Fisheries (Sri Lanka) 3: 15-25.

Siriwardena, P.P.G.S.N. and R.P.K. Tissa. 1988. Seasonal and diurnal changes in some physico-chemical parameters of Bolgoda Lake. Journal of Inland Fisheries (Sri Lanka) 4: 69-93.

Talwar, P.K. and A.G. Jhingran. 1991. Inland fishes of India and adjacent countries. Oxford and IBH Publishing Company, New Delhi 541 pp.

Wetherall, J.A. 1986. A new method for estimating growth and mortality parameters from length frequency data. Fishbyte 4: 12-14.

Whitehead, P.J.P. 1985. FAO species catalogue Volume 7. Clupeid fishes of the world. An annotated and illustrated catalogue of herrings, sardines, pilchards, sprats, schads, anchovies and wolf-herrings. Part 1 - Chirocentridae, Clupeidae and Pristigasteridae. FAO Fisheries Synopsis 125, Volume 7(1): 303 pp.

Wignarajah, S. and P. Amarasiriwardena. 1983. Some aspects of the limnology of Bolgoda Lake, Sri Lanka 1. Composition and seasonal fluctuation of Zooplankton. Journal of the National Science Council of Sri Lanka 11(2): 255-268.

Manuscript received 20 September 2000; Accepted 26 June 2002