Asian Fisheries Science 3(1989): 57-68.
Asian Fisheries Society, Manila, Philippines

https://doi.og/10.33997/j.afs.1989.3.1.004

Spatial Changes in Growth and Mortality and Effects on the Fishery of *Oreochromis mossambicus* (Pisces, Cichlidae) in a Man-Made Lake in Sri Lanka

U.S. AMARASINGHE

National Aquatic Resources Agency
Crow Island, Colombo 15, Sri Lanka

S.S. DE SILVA*

Departments of Zoology and Fisheries Biology
University of Ruhuna
Matara, Sri Lanka

J. MOREAU

Department of Fisheries
National Polytechnical Institute (ENSA)
145 Avenue de Muret
31076 Toulouse Cedex, France

Abstract

Growth and mortality were estimated from the length-frequency data of *Oreochromis mossambicus* from the gillnet fishery of Parakrama Samudra, a man-made lake in Sri Lanka, separately for its three basins. The asymptotic length (L_∞) and the growth constant (K) of *O. mossambicus* in the northern basin of the lake (34.9 cm and 0.3, respectively) are appreciably different from those in other two basins (middle basin, L_∞ = 38.8 cm and K = 0.24; southern basin, L_∞ = 40.6 cm and K = 0.22). Total mortality rates in the northern, middle and southern basins are 2.22, 1.64 and 1.07, respectively.

The spatial differences in growth are suggested to be due to different fishing pressure and environmental conditions. Yield-per-recruit analyses indicate that in the populations with low L_∞ and high K, exploitation level should be maintained at a low level. Fish yield could be optimized by increasing the size of first capture and exploitation rate in the populations with high L_∞ and low K.

*Present address: Department of Zoology, National University of Singapore, Kent Ridge, Singapore 0511.

Introduction

New methods for estimating growth and mortality of fish using length-frequency data have been developed because of the difficulty in determining the age in most tropical fish species (Pauly 1984; Pauly and Morgan 1987; Sparre 1987). Hence, routine use of dynamic pool approaches instead of surplus yield models in tropical fish stock assessment procedures has become feasible. Moreover, growth and other biological parameters of fish are recorded to be related to fishing pressure (Beverton 1963; Marshall 1987). Also, some fish species such as cichlids exhibit variations in growth from year to year due to changing environmental factors such as water temperature and flood levels (Dudley 1974, 1979). Growth of *Oreochromis mossambicus* (Peters) has been studied as evidence of its adaptability to Sri Lankan reservoirs (De Silva et al. 1988). In the present study, an attempt is made to investigate the spatial differences in growth and mortality of *O. mossambicus* in a man-made lake in Sri Lanka and their possible effects on the commercial fishery.

Materials and Methods

Parakrama Samudra (7°55'N; 81°E) is a man-made lake consisting of three basins namely Topa wewa, Eramudu wewa and Dumbutulu wewa which are referred to as northern, middle and southern basins, respectively, in this study. They are connected by narrow channels (Fig. 1). Submerged tree stumps are frequent in the middle basin of the lake. The morphometry of the reservoir is described by Schiemer (1983) and Amarasinghe and Upasena (1985).

The stock densities of *O. mossambicus,* the most abundant species accounting for 70-90% by weight in the landings, in three basins of the lake are found to be different (Amarasinghe and Pitcher 1986). Thus, length-frequency data of *O. mossambicus* were collected from the gillnet catches in the three lake basins separately. The hanging ratio (Hamley 1975) of the gillnets of the fishery is 0.5. Length-frequency data of *O. mossambicus* were collected from randomly selected crafts in the three basins from June 1982 to July 1987. There were 3-5 sampling days per month and 61 to 662 fish were measured in each month to the nearest 0.5 cm below its actual length. During the study period, a total of 17,701 fish were measured. In all length-frequency distributions, 1 cm length-classes were used.

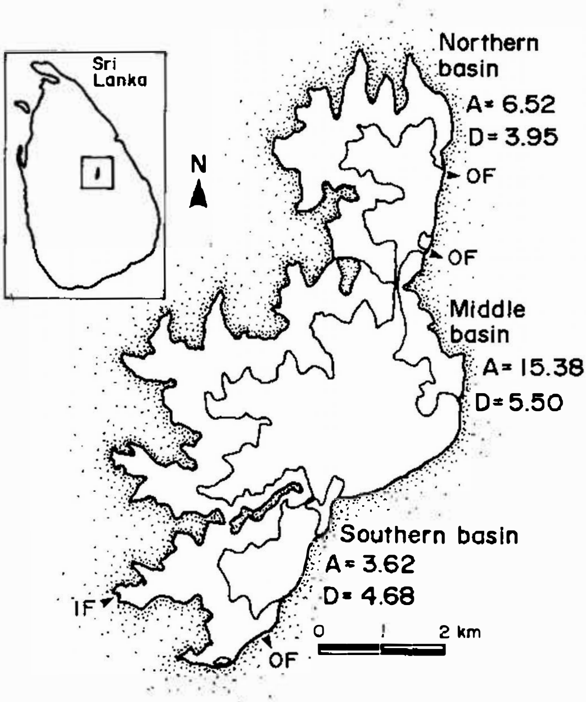

Fig. 1. Map of Parakrama Samudra. Inset shows the location of the lake. Dark areas are islands. Outer contour line corresponds to the full supply depth (59.1 m above mean sea level) and inner contour, the water level at 53 m above mean sea level. Surface area (A) in km ^{2} and mean depth (D) in m of each basin at full supply level (Schiemer 1983) are also indicated. IF - the perennial inflow; OF - outflows.

Number of net pieces of each mesh size in the sampled crafts was also recorded.

From these length-frequency data, von Bertalanffy growth parameters (asymptotic length and growth constant) were extracted using ELEFAN I (Pauly and David 1981; Brey and Pauly 1986). Depending on these estimated growth parameters, total mortality (Z) was calculated using length-converted catch curves (Brey and Pauly 1986). Natural mortality (M) was calculated using the empirical equation of Pauly (1980).

Fishing mortality (F) calculated by subtracting M from Z was used to estimate exploitation ratio (E = F/Z). Mean size of first capture (l_c) was also determined from the catch curve. Relative yield-per-recruit (Y/R) values were obtained for different l_c values at different levels of E (Beverton and Holt 1964; Pauly and Soriano 1986).

Results

Frequency distributions of net pieces in each mesh size in the sampled crafts in three lake basins during different study periods are given in Fig. 2. This indicates that a wide range of mesh sizes (7.0-13.6 cm) are used in the gillnet fisheries of the lake, except in the northern basin where the mesh sizes of gillnets range from 7.0 to 9.4 cm. The overall length-frequency distribution of *O. mossambicus* for each basin of the lake is given in Fig. 3. L_∞ and K of *O. mossambicus* populations in the three basins during different study periods are given in Table 1. In the northern basin, L_∞ (34.9 cm) and K (0.3) were appreciably different from the populations in the other two basins.

The growth curves for *O. mossambicus* populations in the three basins of the lake, calculated using L_∞ and K during 1985-86 are given in Fig. 4. The plots of $\log_e$ (%N/Δt) against t (N = the number of fish in a size-class, Δt = the difference in age between the upper and

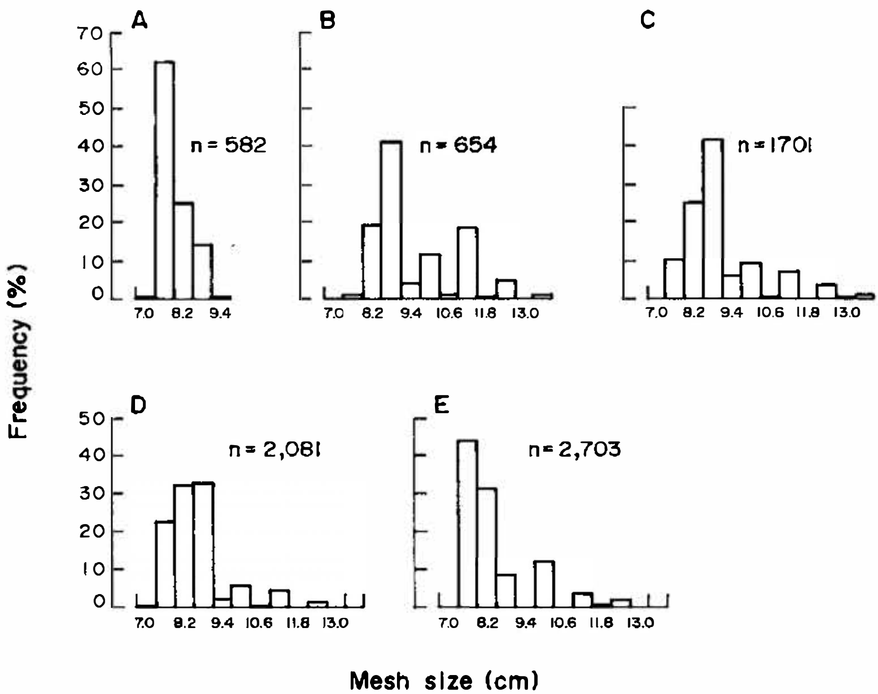

Fig. 2. Frequency distributions of net pieces in each mesh size in the sampled crafts in three basins of Parakrama Samudra. n = Total number of net pieces. (a) Northern basin 1985-86, (b) Southern basin 1985-86, (c) Middle basin 1982-83, (d) Middle basin 1985-86, (e) Middle basin 1986-87.

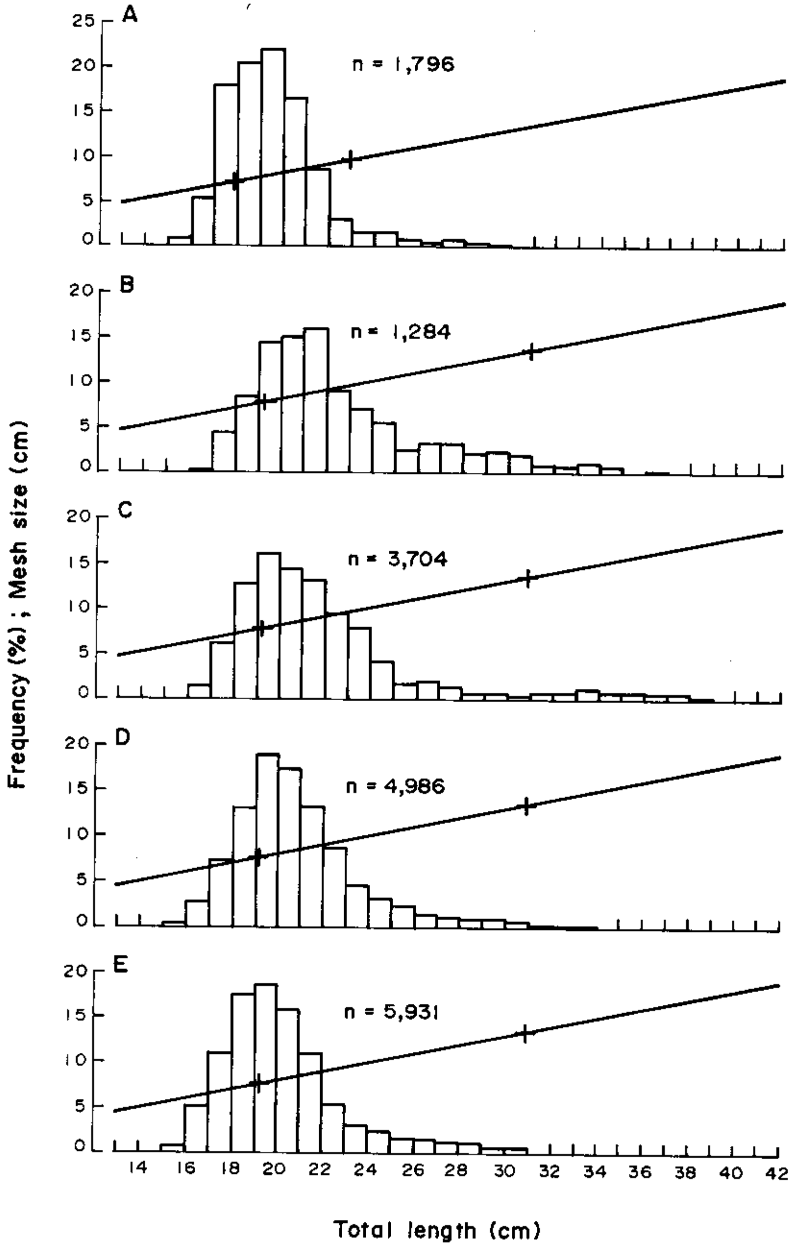

Fig. 3. The overall length-frequency distributions of *O. mossambicus* in the three basins of Parakrama Samudra. n = number of fish measured. (a) Northern basin 1985-86, (b) Southern basin 1985-86, (c) Middle basin 1982-83, (d) Middle basin 1985-86, (e) Middle basin 1986-87. The solid lines indicate the mesh sizes of gillnets corresponding to each length group, calculated using the relationship, total length = 3.4763 + 2.0237 mesh size (Amarasinghe 1988a). The portion delineated by crosses in each graph represents the range of mesh sizes used in each basin.

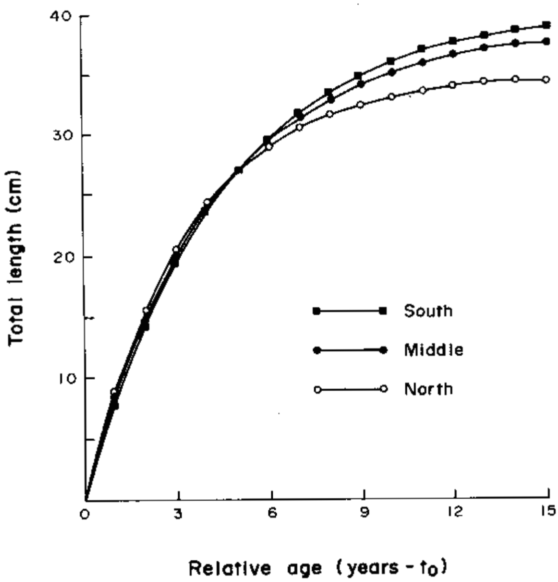

Fig. 4. Growth curves of *O. mossambicus* in the three basins of Parakrama Samudra, derived from ELEFAN I analysis.

lower limits of the size-class and t = the relative age in the size-class) are given in Fig. 5 for the three basins during three sampling periods. The same size ranges (19.5-26.5 cm) in the descending parts of the catch curves were considered in computing Z values from the slopes of the curves in order to compare mortality in the three lake basins. The estimated values of L_∞, K, Z, M, F, E and l_c are given in Table 1. Percentages of under-sized fish (below 20 cm) in the catches which are considered as indices of fishing pressures are also incorporated in Table 1.

Y/R values estimated for different levels of E and different sizes of l_c using the M/K values for northern (2.62), middle (2.75) and southern (2.77) basins in 1985-86 are shown in Fig. 6. In all three basins, l_c was about 18.0 cm during the study period (Table 1). The Y/R analysis indicates that in the northern basins, any increase in l_c from the existing level will result in declining fish yield while decreasing l_c will also lower the fish yields at higher levels of E (Fig. 6a). In the middle basin, the highest yield at the existing level of E could be obtained with an l_c of 18.0 cm (Fig. 6b). The Y/R analysis also indicates that in the middle and southern basins, yield could be increased by increasing l_c at higher levels of E (Figs. 6b and 6c).

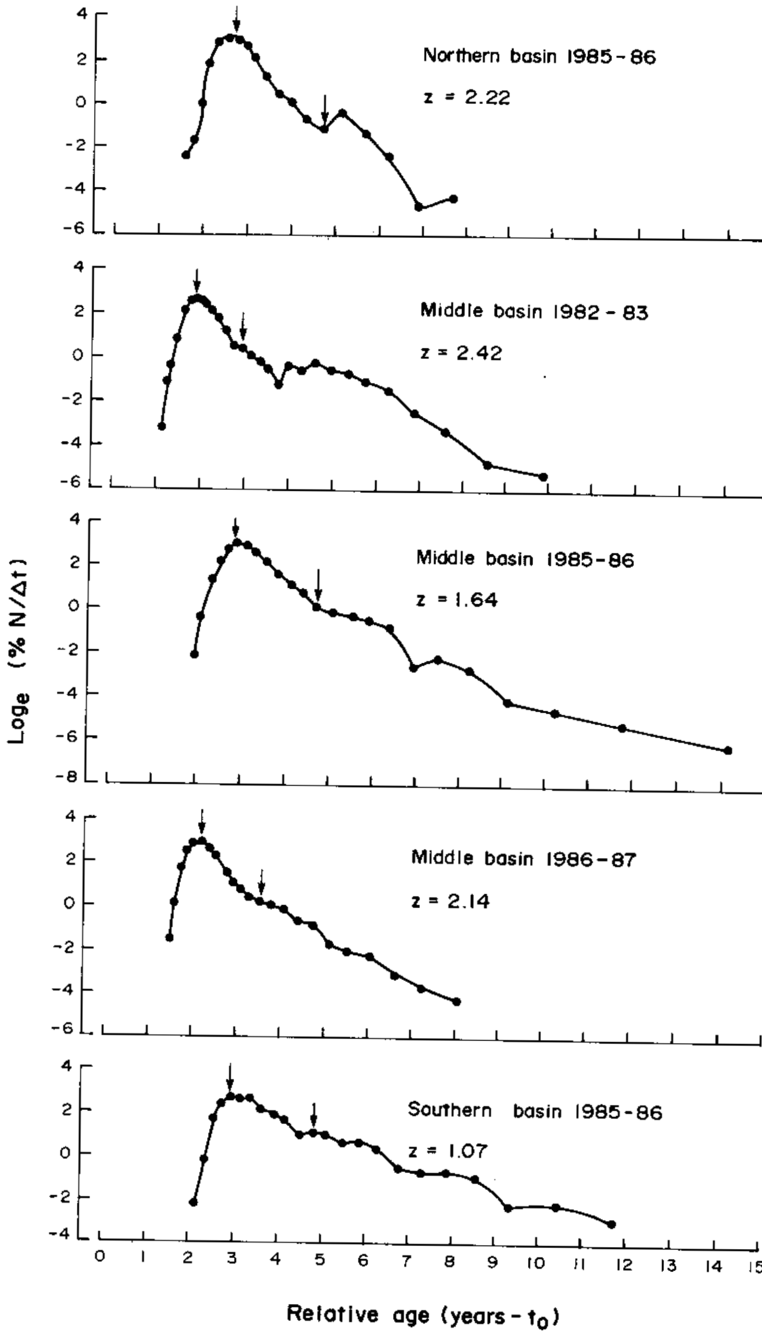

Fig. 5. Estimates of total mortality (Z) of *O. mossambicus* in the three basins of Parakrama Samudra. The portion of the curve delineated by arrows was used in computation of Z.

Table 1. Growth, mortality, size of fish capture (l_c) and % individuals below 20 cm of length of *O. mossambicus* in the three basins of Parakrama Samudra during different sampling periods.

Lake basin	Year	L_∞ (cm)	K (year^{-1})	Z	M	F	E	l_c	% < 20 cm
North	1985-86	34.9	0.30	2.22	0.78	1.44	0.65	18.0	65.8
Middle	1982-83	43.3	0.32	2.42	0.77	1.65	0.68	18.0	36.7
Middle	1985-86	38.8	0.24	1.64	0.66	0.98	0.60	18.2	43.1
Middle	1986-87	40.0	0.30	2.14	0.76	1.38	0.64	17.9	53.6
South	1985-86	40.6	0.22	1.07	0.61	0.46	0.43	18.3	27.4

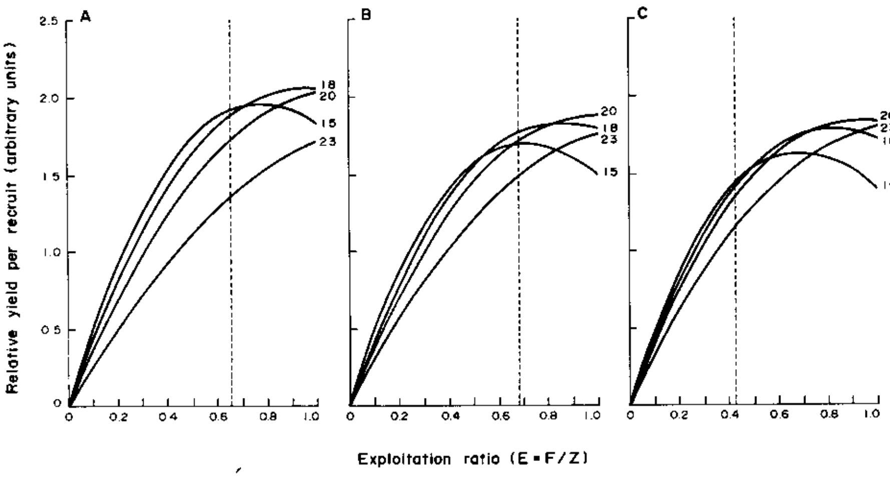

Fig. 6. Relative yield-per-recruit values of *O. mossambicus* in the three basins of Parakrama Samudra as a function of exploitation ratio for different sizes of first capture in 1985-86. (a) Northern basin, (b) Middle basin, (c) Southern basin. The values on the curves represent the sizes of first capture (in cm) corresponding to each curve. Vertical broken lines indicate the exploitation ratio in 1985-86 in each lake basin.

Discussion

Gillnets are highly selective so that the size distribution of a catch is often a poor representative of a sampled population. Nevertheless, in the fishery of Parakrama Samudra, a wide range of mesh sizes is used and the low hanging ratio (0.5) brings about broad selection range (see also De Silva and Sirisena 1987; Amarasinghe 1988a). Even in the northern basin of the lake where a narrow range of mesh sizes is used (Fig. 2a), the maximum length of *O. mossambicus* in the beach seine (illegal) catches was observed to be

34.0 cm. Therefore, considerable size range of fish in the fully recruited stock can be expected to have a probability of capture near unity and hence the slope of the first few points of the descending part of the catch curve might give a reasonable estimate of Z in each lake basin.

O. mossambicus populations in the three basins of Parakrama Samudra appear to localize due to partial geographical barriers between each basin (Fig. 1). Most cichlids including *O. mossambicus* are suggested to be well-circumscribed populations, fixed to a home range (Philippart and Ruwet 1982). The differences in growth parameters of *O. mossambicus* populations in the three basins of the lake may be due to the external factors which influence each population. The accelerated growth and life cycles of *O. mossambicus* such as those taking place in the northern basin (high K and low L_∞; Fig. 4), correspond to "altrical" or "r-selected" life style which is brought about by relatively unstable environmental conditions (Pianka 1970; Noakes and Balon 1982). Heavy draw-down in Parakrama Samudra (De Silva 1985) and comparatively low mean depth of the northern basin (Fig. 1) may be some reasons for low L_∞ of *O. mossambicus* in the northern basin which would have reflected the relatively unstable environmental conditions. This may influence total mortality and in turn, longevity of fish resulting in high K and low L_∞.

Predation by piscivorous birds is high in Parakrama Samudra (Winkler 1983). As such, high natural mortality rates can reasonably be expected as reported in this study. On the other hand, the differences in fishing mortality in the three basins can be attributed to the differences in fishing pressure. The fishing pressure (f) estimated using fishing effort in the three basins of Parakrama Samudra in 1985 (Table 2; Amarasinghe and Samarakoon 1988) is significantly related to fishing mortality (F) in the three basins in 1985-86 ($F = -2.7916 + 0.1039 f$; $r = 0.99$; $P < 0.05$). Percentage of *O. mossambicus* individuals below 20 cm is the lowest in the southern basin (Table 1). The fishing pressure is moderate in the middle basin because of the submerged tree stumps which prevent intensive exploitation.

Due to the differences in number of streams draining the catchment area in each basin (Table 2), differences in allochthonous input into the basins can be expected. Also, the lowest phytoplankton biomass is reported to occur in the middle basin (Dokulil et al. 1983) which is bound to receive the highest

Table 2. Fishing pressure in the three basins of Parakrama Samudra in 1985 (estimated using the data from Amarasinghe and Samarakoon 1988) and fishing mortality of *O. mossambicus* in the three basins in 1985-86. Also incorporated is number of streams draining the catchment, as counted from aerial photographs together with ground truth, in the three basins of the reservoir.

Lake basin	Fishing pressure (net piece days^{-1} ha^{-1} year^{-1})	Fishing mortality in 1985-86	No. of streams		
			Perennial	Seasonal	
				major	minor
North	40.85	1.44	0	1	4
Middle	36.00	0.98	0	4	2
South	31.43	0.46	1	0	0

allochthonous input from the catchment (Table 2). The differences in allochthonous input into three basins could be a factor influencing, to an extent, growth differences between the three basins.

Although the total mortality in the exploited phase of the stocks is apparently not constant throughout all size-classes (Fig. 5), relative yield-per-recruit analysis gives a reasonable approximation of the optimum fishing strategy, based on biological aspects of the fish stock. In the fish populations with accelerated growth and life cycles which may have been brought about by heavy fishing, a low level of exploitation ratio has to be maintained at a lower size of first capture. On the other hand, in the fish populations with high L_∞ and low K, fish yields could be increased at higher levels of exploitation ratios if the size of first capture is increased. As such, this study gives further emphasis on the importance of maintaining size of first capture at a higher level as shown by Amarasinghe (1988b).

Acknowledgement

The National Aquatic Resources Agency of Sri Lanka provided facilities to carry out this work.

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Manuscript received 27 April 1989; accepted 26 June 1989