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The Fishery and Population Dynamics of *Oreochromis mossambicus* and *Oreochromis niloticus* (Osteichthyes, Cichlidae) in a Shallow Irrigation Reservoir in Sri Lanka

U.S. AMARASINGHE

Department of Zoology
University of Kelaniya
Kelaniya 11600
Sri Lanka

Abstract

The fishery of a shallow irrigation reservoir in Sri Lanka was investigated. Catch and effort data of all species and length frequency data of cichlid species, *O. mossambicus* (Peters) and *O. niloticus* (L.) which form over 80% of landings, collected over a period of 13 months were analyzed. Yield-per-recruit analyses of the two cichlid species, performed using FiSAT computer software package indicated that both cichlid stocks in the reservoir are optimally exploited.

Annual fish yield and monthly mean fishing intensity (FI in boat-days per month) were estimated for two scenarios, i.e., reservoir area at full supply level (FSL) and actual monthly mean reservoir area. They indicate that the estimates of yield (228 $kg \cdot ha^{-1} \cdot yr^{-1}$) and FI (2.9 $boat\text{-}days \cdot ha^{-1} \cdot month^{-1}$), which are computed for the reservoir area at FSL are about 23 and 21% respectively of the estimates of yield (985.5 $kg \cdot ha^{-1} \cdot yr^{-1}$) and FI (13.3 $boat\text{-}days \cdot ha^{-1} \cdot month^{-1}$) based on actual monthly mean reservoir area. Fish stock assessment and fisheries management strategies, which are based on Y and FI estimated on the basis of reservoir area at FSL are therefore bound to be inaccurate. Potential implications of difference of yield and FI estimates based on monthly mean reservoir area and area at FSL, in determining the optimal fishing strategies are discussed.

Introduction

At present, the landscape of the tropical belt of the world is rapidly changing due to the construction of reservoirs at an accelerated rate. Sri Lanka has a high density of standing waters in the form of ancient and new reservoirs close to 2.7% of the island area (Fernando 1993). As in many parts of the world, reservoirs in Sri Lanka were not built for fisheries development alone. Most of them have been constructed to irrigate rice fields and to generate hydroelectricity; fisheries development is a secondary use (De Silva 1988). Due to the multiple uses of these reservoirs, water levels dramatically fluctuate at varying degrees depending on the morphometry of the individual reservoirs.

In shallow tropical reservoirs which offer multiple uses other than fisheries like irrigation and hydroelectricity generation, exploitation patterns in fisheries can be expected to vary seasonally due to fluctuations in water levels. Increased fishing intensity during low water level when fish stocks concentrate in less volume of water may have pronounced effects on fish stocks. In spite of the importance of taking water level fluctuations into consideration in fisheries aspects in shallow tropical reservoirs, fish yields and fishing intensities are often estimated considering the reservoir area at FSL. As stated by Fernando (1984), this perhaps leads to underestimation of fish yield and fishing intensity as a result of possibly inaccurate management strategies for reservoir fisheries. This paper attempts to investigate the status of the fishery of two cichlids in a shallow irrigation reservoir in Sri Lanka, in relation to changes in its surface area.

The fishery

This study was carried out at the Tabbowa reservoir, Sri Lanka (Location 8° 05' N; 79° 57' E; Area at FSL - 591 ha; Fig. 1) which supports a profitable fishery. It irrigates about 667 ha of agricultural lands (Anon. 1975). Some morphometric and edaphic characteristics of the Tabbowa reservoir are given in table 1.

Details of the fishery of Tabbowa reservoir were given in previous publications (Amarasinghe 1988, CEA/Euroconsult 1993). For clarity, the characteristics of the fishery are summarized here. Craft in the fishery of the reservoir is nonmechanized fibre-glass out-rigger canoe with two fishers working on each

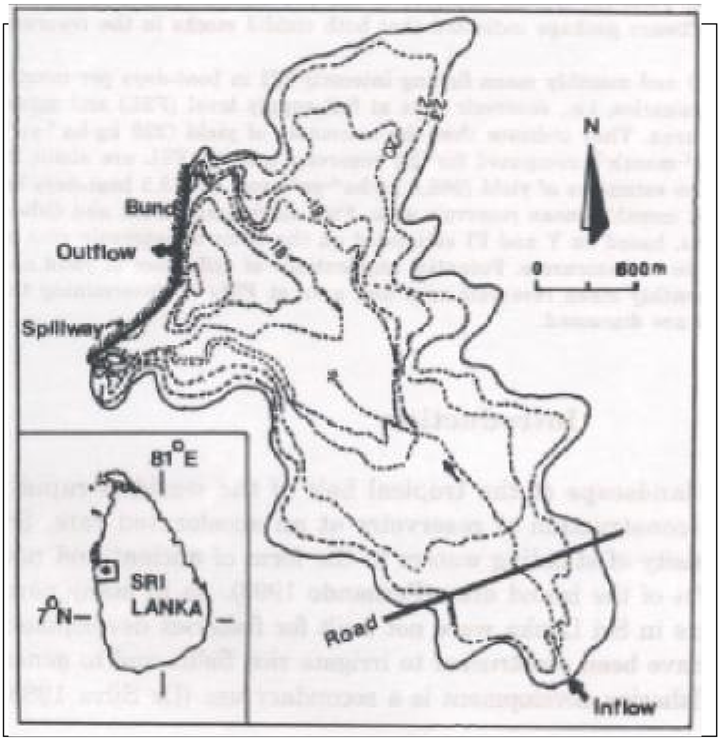

Fig. 1. Map of Tabbowa reservoir. Inset shows location of the reservoir in Sri Lanka. Contour lines are in meters above mean sea level Source: Irrigation Department, Sri Lanka.

craft. Four fishing methods in the fishery are employed: normal gillnetting, trammel netting, cast netting and encircling. For normal gillnet- ting, fishers use 7.6 to 12.7 cm stretched-mesh gillnets whose filament characteristics and dimensions are identical. During the months of December to January and May to June, when juveniles of target species were abundant, in addition to gillnets of 7.6 to 12.7 cm mesh sizes, fishers use gillnets of mesh sizes as low as 6.4 to 6.9 cm, which are illegal in the reservoir fishery of Sri Lanka. Fishers who use trammel nets (6.4 to 8.9 cm mesh size in the middle net screen and 12.7 cm mesh size in the outer net screens) beat the water with wooden poles to drive fishes towards the trammel nets. Amarasinghe and Pitcher (1986) have shown that the efficiency of this water beating technique is significantly higher than that of normal gillnetting. Mesh sizes of cast nets ranged from 5.2 to 8.4 cm and the perimeter of a net was about 15 m. Encircling nets were used when the water level in the reservoir was low.

Sixteen fish species were recorded at the Tabbowa reservoir, but only two exotic cichlid species, *O. mossambicus* (Peters) and *O. niloticus* (L.) were dominant in the landings accounting for over 80% of the wet weight (CEA/ Euroconsult 1993). Mean sizes at maturity of female *O. mossambicus* and *O. niloticus* were 15.1 cm (Amarasinghe 1988) and 26.0 cm (Amarasinghe, unpubl. data) respectively.

Materials and Methods

Data on fish catch, fishing effort, species composition and length frequency distributions of the dominant species were collected from July 1986 to July 1987. Fish landing sites in the reservoir were visited at least five days a month during the study period. Except in December 1986 and April 1987 when there were only 28 and 25 fishing days respectively, fishers engaged in fishing every day. Out of the 2,238 crafts operated over the 69 sampling days during the study period, 1,524 crafts were selected randomly for data gathering (Table 2). When there were only a few number of crafts for a particular fishing method, almost all the crafts were examined to collect data. Consequently, 93% of the crafts with cast netting and 100% of the crafts with encircling nets were examined (Table 2). The fishing methods used in majority of the boats were

Table 1. Some morphometric and edaphic characteristics of the Tabbowa reservoir.

Characteristics	Value		Source
Area at full sully level (ha)	591.0		A
Mean depth (m)	2.5		A
Catchment area (km^2)	388.5		A
Total storage volume (m^3 x 10^6)	14.8		A
Dead storage volume (m^3 x 10^6)	0.2		A
pH	7.9	(6.3 – 8.9 range)	B
Conductivity (µS)	660	(360– 980 range)	B
Dissolved oxygen (mg·l)	5.9	(2.3 – 8.0 range)	B

Sources: A- Anon. (1975); B - CEA/Euroconsult (1993).

gillnetting and trammel netting and about 85% of the crafts with gillnetting and about 61% of the crafts with trammel netting were observed to collect catch and effort data. Bathymetric map, hypso-graphic curve (relationship of area to water depth of reservoir), and daily water levels during the study period were obtained from the Irrigation Department.

Catch per unit effort (c/f) of each fishing method was determined as kg per boat-day. Total fish catch (C) in each month was estimated by summing up estimated catches ($C = S((c/f)_i \times f_i)$ where $(c/f)_i$ and f_i are c/f and fishing effort of i^{th} fishing method). Total fishing effort in standard units (f_{STD}) was determined for each month by dividing C from c/f of gillnetting ($(c/f)_{GN}$) which was treated as standard ($f_{STD} = C/(c/f)_{GN}$) (Gulland 1983).

Length frequency data of the two dominant species, *O. mossambicus* and *O. niloticus*, which formed over 80% of the total landings, were collected from the catches of trammel nets. Fishers increased efficiencies in trammel nets by beating the water with wooden poles to drive fishes towards the nets. When the overall length frequencies of the two species of cichlids caught in trammel nets and encircling nets were compared (data not given), it was evident that the effect of gear selection on the catch samples in trammel nets was more or less similar to a sigmoid (trawl-type) selection ogive. Unlike the other fishing methods, trammel netting was the major fishing method used during the sampling dates (Table 2) hence it was possible to collect monthly length frequency samples of the two cichlid species from the catches of trammel nets.

Length frequency data of *O. mossambicus* and *O. niloticus* were analysed using FiSAT (Version 1.10) software package (Gayanilo et al. 1995). The von Bertalanffy growth parameters of the two cichlid species were determined following the Powell-Wetherall method (Powell 1979, Wetherall 1986, Pauly 1986) and

Table 2. Number of sampling days and number of crafts of different fishing methods operated and sampled during sampling days in each month.

Month	No. of sampling days	No. of crafts operated during sampling days				No. of crafts observed during sampling days			
		GN	TN	CN	EN	GN	TN	CN	EN
July 1986	5	90	95	-	-	80	30	-	-
August	5	30	190	-	-	30	90	-	-
September	5	35	158	-	-	35	90	-	-
October	6	39	219	3	-	39	102	3	-
November	5	45	110	-	-	30	80	-	-
December	5	27	104	-	-	27	70	-	-
January 1987	5	-	208	18	-	-	110	18	-
February	5	15	126	5	3	15	90	5	3
March	6	54	54	15	30	30	54	15	30
April	5	35	50	3	18	25	45	3	18
May	5	41	70	-	-	35	55	-	-
June	6	31	134	9	12	31	102	9	12
July	6	8	118	-	36	8	72	-	36
Totals	69	450	1636	53	99	385	990	50	99

GN - Gillnetting; TN - Trammel netting; CN - Cast netting; EN - Encircling nets.

ELEFAN technique as implemented in FiSAT software package.

For this purpose, the step-wise procedure described by Amarasinghe and De Silva (1992a) was used. Mortality parameters were estimated using the ELEFAN technique assuming that they were described by negative exponential curves. Total mortality (Z) was estimated following the length-converted catch curve method (Pauly 1983, Gayanilo and Pauly 1997) from the pooled length frequency data for the study period. Natural mortality (M) was estimated using Pauly's empirical relationship between M, asymptotic total length ($L\infty$ in cm), growth constant (K per year) and temperature (T in ºC) (Pauly 1980). Mean annual temperature at the Tabbowa reservoir was 28ºC (CEA/Euroconsult 1993). Fishing mortality (F = Z-M) and exploitation rate (E = F/Z) were also determined.

A sigmoid selection curve was assumed (see above) in estimating sizes at first capture (L_c) of the two cichlid species from the detailed analysis of the ascending part of the length-converted catch curves (Gayanilo and Pauly 1997). Relative yield-per-recruit analyses incorporating probabilities of capture, as estimated on the basis of growth and mortality parameters (Pauly and Soriano 1986, Gayanilo and Pauly 1997), were performed to investigate long-term effects of exploitation of the two cichlid species at different levels of L_c and exploitation rates. As in many artisanal fisheries, the efficiency of fishing effort tends to increase in many Sri Lankan reservoir fisheries. Therefore the E value which corresponds to 10% of the maximum rate of Y'/R increase with increasing E ($E_{0.1}$) at the existing L_c which was also determined as an index in assessing the status of the fishery (Gayanilo and Pauly 1997).

Fishing intensity (i.e., fishing effort in standard units per ha expressed as boat-days·ha) was estimated for each month. Similarly, fish yield in each month was estimated as kg per ha. For each month, fishing intensity and fish yield were estimated using two different approaches. First estimate was based on the reservoir area at FSL, which is the conventional method of estimating fish yield and fishing intensity in reservoirs. Secondly these estimates were obtained from actual mean reservoir area as determined from the hypsographic curve of reservoir (Fig. 2A).

Finally, mean annual fish yield (kg·ha) and mean annual fishing intensity (boat-days·ha, yr) were estimated by multiplying from the factor 12, the monthly averages of fish yield and fishing intensity as determined for each month on the basis of actual mean monthly reservoir area. Annual fish yield and fishing intensity using the conventional method (i.e., on the basis of reservoir area at FSL) were also computed to make a comparison with the proposed method of estimation.

Results

Number of sampling days in each month, number of crafts operated and sampled during the sampling days for different fishing methods separately and number of fish measured in each month are given in table 2. List of fish species caught at the Tabbowa reservoir is given in table 3. Percentage species

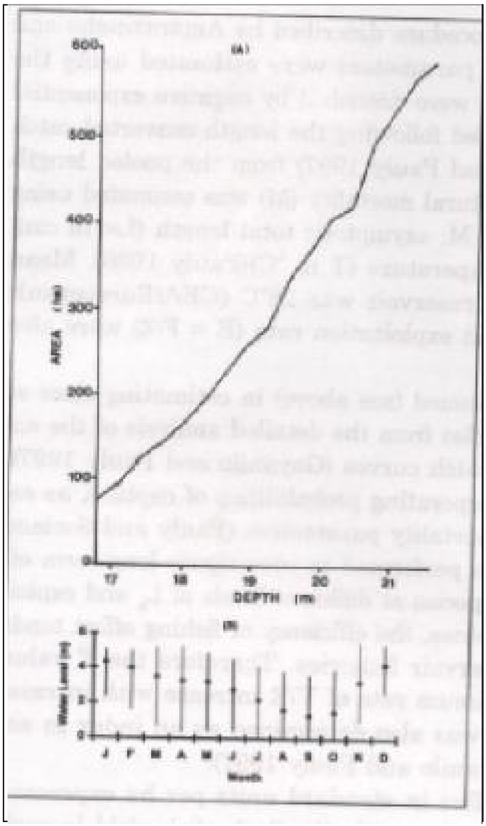

Fig. 2a. Hypsographic curve of Tabbowa reservoir. (2b) Mean monthly water levels (Vertical bars-range) in Tabbowa reservoir from 1978 to 1986 (Source: Irrigation Department, Sri Lanka.).

Table 3. List of fish species found in Tabbowa reservoir.

Family/species	Maximum total length (cm) recorded
Cyprinidae	
Amblypharyngodon meletinus (Valenciennes)[+]	7.5
Ctenopharyngodon idella (Cuvier and Valenciennes)*	90
Labeo rohita (Hamilton)*	75
Puntius chola (Hamilton-Buchanan)[+]	8.75
P. dorsalis (Jerdon)[+]	23.5
P. sarana (Hamilton-Buchanan)	30
Rasbora daniconius (Hamilton-Buchanan)[+]	10
Bagridae	
Macrones kelatius (Valenciennes)	12.5
Clariidae	
Clarias teysmanni brachysoma (Günther)#	30
Cichlidae	
Oreochromis mossambicus (Peters)*	42
O. niloticus (L.)*	52
Tilapia rendalli (Boulanger)*	34
Etroplus suratensis (Bloch)	24
Gobiidae	
Glossobobius giuris (Hamilton-Buchanan)	35
Ophiocephalidae	
Ophicephalus striatus Bloch	68
Anabantidae	
Anabas testudineus (Bloch)[+]	15

*Exotic species; #Endemic species; [+]Caught only in a subsidiary cast net fishery (Amarasinghe 1990)). Source: CEA/Euroconsult (1993).

compositions (by weight) of catches in different fishing methods are shown in figure 3. Over 80% of the landings was formed by *O. mossambicus* and *O. niloticus*. Monthly length frequency distributions of *O. mossambicus* and *O. niloticus* in the landings are given in tables 4 and 5 respectively. Powell-Wetherall plots, monthly length frequency distributions together with von Bertalanffy growth curves and length-converted catch curves of *O. niloticus* and *O. mossambicus* are shown in figure 4. Growth and mortality parameters including Z, M, F, E and $E_{0.1}$ together with L_c of *O. mossambicus* and *O. niloticus*, estimated by means of FiSAT software package are presented in table 6. Relative yield-per-recruit isopleths of the two species are given in figure 5, which indicate that during the study period, both cichlid species are optimally exploited. However, when $E_{0.1}$ values at the existing sizes of first capture of the two cichlids are considered (Table 6), it is evident that *O. mossambicus* ($E_{0.1}$ = 0.57) tends to be over exploited whereas *O. niloticus* ($E_{0.1}$ = 0.50) remains under exploited.

Monthly mean water levels, surface area, fishing intensity and fish yields during the study period are given in table 7. As evident from figures 1 and 2b, water levels in the reservoir fluctuate considerably which result to significant monthly changes in the reservoir area. As such, monthly fishing intensities and fish yields were estimated for the reservoir area at FSL as well as the actual mean monthly reservoir area (Table 7). Mean annual fish yield and the mean monthly fishing intensity computed from monthly estimates based on reservoir area at FSL were 228 kg·ha and 2.9 boat-days·ha respectively. Mean annual yield and mean monthly fishing intensity, which were based on actual monthly mean reservoir area on the other hand, were 985.5 kg·ha and of 13.3 boat-days·ha respectively. These estimates were appreciably higher than those computed by considering reservoir area at FSL. According to these computations, estimates of mean annual fish yield and fishing intensity based on reservoir area at FSL are 23 and 21%

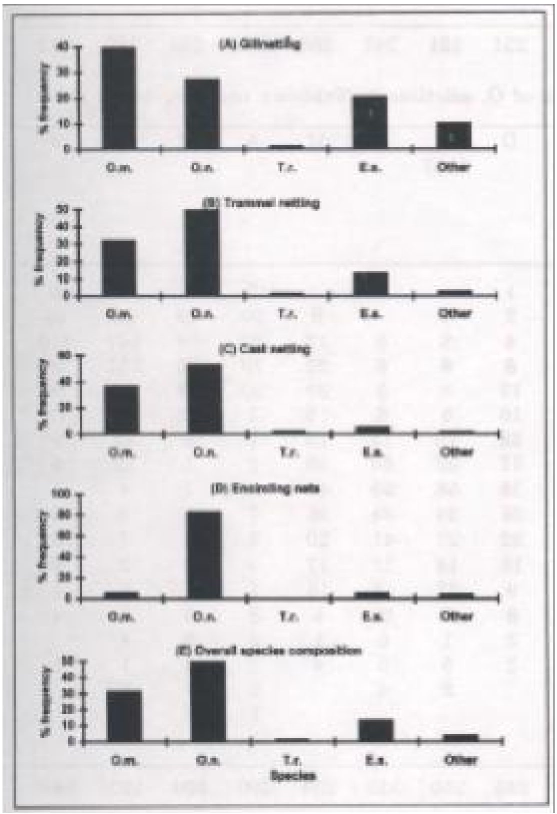

Fig. 3. Percentage species composition (by weight) in the catches of different fishing methods and overall species composition. O.m. - *Oreochromis mossambicus*; O.n. - *O. niloticus*; T.r. *Tilapia rendalli*; E.s. - *Etroplus suratensis*.

Table 4. Monthly length frequency data of *O. mossambicus* in Tabbowa reservoir (1986-1987).

Mid-pt. of length class (cm)	J 1986	A	S	O	N	D	J 1987	F	M	A	M	J	J
11.5												1	
12.5						1	1		1		3	1	
13.5						1	1				1	6	3
14.5				3		2	1	1	8	1	15	37	45
15.5	1	1		3	1	10	6	3	13	8	32	54	113
16.5	11	4	3	7	10	12	6	11	37	19	80	86	122
17.5	26	7	8	26	27	32	22	14	66	30	88	92	75
18.5	49	31	28	72	45	51	48	36	85	48	69	55	47
19.5	56	94	55	89	56	42	70	35	72	49	42	30	25
20.5	38	67	33	77	52	29	38	34	44	51	22	13	5
21.5	33	46	29	67	42	11	17	33	29	27	23	6	4
22.5	21	35	17	47	22	11	8	16	12	6	9	8	2
23.5	20	48	31	49	15	12	4	11	7	4	1	3	1
24.5	15	27	29	55	15	5	2	11	7	1	2	1	1
25.5	9	16	16	31	8	1	1	12	3				
26.5		2	8	20	6	6	2	8	1				
27.5		1	1		3	2	2	5	2				
28.5		1		3		1		7					
29.5		1	1		1			2			1		
30.5				1	1	1	1	2					
31.5		1	1		1			1			1		
32.5							1	1	1				
33.5			1			1							
34.5				1									
Total	279	382	261	551	305	231	231	243	388	244	389	393	443

Table 5. Monthly length frequency data of *O. niloticus* in Tabbowa reservoir (1986-1987).

Mid-pt. of length class (cm)	J 1986	A	S	O	N	D	J 1987	F	M	A	M	J	J
13					1	1				5	6	1	6
15		1		1	3	2	4		9	30	49	23	55
17	3	3	9	8	3	4	8	5	12	80	98	147	110
19	16	13	12	12	17	8	6	6	22	79	79	151	98
21	18	25	38	31	25	17	8	5	28	26	39	77	56
23	11	28	44	45	34	16	5	6	13	7	22	44	18
25		34	38	55	34	28	16	11	15	7	3	24	9
27	4	12	35	27	27	37	32	50	30	2	1	12	9
29	2	5	10	9	16	38	58	65	41	10	1	4	1
31	1	15	13	15	8	35	34	64	28	7	1	3	6
33	5	9	16	12	6	22	27	41	20	6	4	4	3
35		3	9	14	5	13	14	21	17	4	6	2	3
37	2	4	3	6	1	9	22	18	16	1	1	6	4
39		4	1	6		8	8	10	8	8	5	3	1
41	1	8	2	6		3	1	6	1	2	2	4	
43		4		5	1	2	5	5	4	2	3	1	1
45				1			2	4		2		2	
47										1			
49								1		1			
Total	74	168	230	253	181	243	250	318	264	280	320	503	380

respectively of the estimates based on the actual monthly mean reservoir area. It is interesting to note that in spite of the high degree of underestimation of fish yield and fishing intensity when reservoir area at FSL is used, mean reservoir area (185.3 ha; Table 7) is only about 31% of the area at FSL. Total catch and fishing effort of different fishing methods have close relationships with fluctuations in water-level and mean monthly reservoir area (Fig. 6).

Table 6. Growth and mortality parameters of *O. mossambicus* and *O. niloticus* in Tabbowa reservoir (1986 to 1987) estimated by means of FiSAT software package.

Species	L_∞ (cm)		K (yr^{-1})	*Rn*	ϕ	Z	M	F	E	$E_{0.1}$	L_c (cm)
	Powell-Wetherall Method	ELEFAN Method									
Oreochromis mossambicus	36.2	37.8	0.51	0.132	2.699	2.83	1.10	1.73	0.61	0.57	15.9
Oreochromis niloticus	50.7	50.7	0.64	0.159	3.022	1.96	1.17	0.79	0.40	0.50	16.3

L_∞ - Asymptotic Total Length; K - Growth Constant; Z - Total Mortality; M - Natural Mortality; F - Fishing Mortality; E - Exploitation Rate; $E_{0.1}$ – E value corresponding to the 10% of the maximum rate of Y'/R increase with increasing E; L_c - Length at first capture. *Rn* value is an index of goodness-of-fit of the growth curve to the length frequency data in ELEFAN method (Gayanilo et al. 1995). Growth performance indices (f' = $2Log_{10}L_\infty$ + $Log_{10}K$) of the two cichlid species, which were based on Standard Length (SL » 0.8 x Total Length) are also given here.
Note: f' values reported for African lacustrine populations of *O. mossambicus* ranged 2.05 to 2.8 (mean – 2.48) and *O. niloticus* ranged 2.41 to 3.11 (mean – 2.85) (Moreau et al. 1986).

Table 7. Monthly mean water levels, surface area, fishing intensity and fish yields in Tabbowa reservoir from 1986 to 1987.

Month	Mean water level (m)		Area (ha)	Fishing intensity (boat-days·ha,month)		Fish yield (kg·ha,month)	
	above sill of sluice	above mean sea level		I	II	I	II
July 1986	4.00	19.50	335.1	2.6	4.6	12.5	22.0
August	3.75	19.25	286.5	3.9	8.1	35.3	72.9
September	3.46	18.96	262.2	4.3	9.7	26.3	59.3
October	2.27	17.77	148.1	4.5	17.8	32.9	131.1
November	3.94	19.44	320.5	2.4	4.4	13.8	25.5
December	3.70	19.20	279.2	1.8	3.7	9.5	20.2
January 1987	2.80	18.30	191.8	3.0	9.2	26.9	82.8
February	1.74	17.24	109.3	2.0	10.7	24.8	134.2
March	1.27	16.77	72.8	1.9	15.8	17.8	144.6
April	1.21	16.71	70.4	1.1	9.1	11.1	93.3
May	1.49	16.99	85.0	1.9	13.5	7.7	53.8
June	1.34	16.84	80.1	4.8	35.7	14.5	107.1
July	1.13	16.63	68.0	3.5	30.2	13.9	120.8

I-Estimated for area at full supply level; II-Estimated for actual monthly mean reservoir area

Discussion

When the water level at the Tabbowa reservoir recedes, fish stocks concentrate in the reduced reservoir volume. As a result, efficiencies of fishing methods increase. Furthermore fishers tend to switch to different fishing methods during periods of low water level such as use of encircling nets, as evident from Fig. 6b. It has been reported that in many Sri Lankan reservoirs, beach seining is carried out during periods of low water level (Fernando 1967, Amarasinghe and De Silva 1992b). The potential influence of possible increased fishing intensity due to receding water level on fish stocks at the Tabbowa reservoir was investigated through length-based stock as-sessment procedures.

Growth parameters estimated by means of FiSAT software package are biologically reasonable because growth performance indices (f' = $2Log_{10}L\infty$ + $Log_{10}K$) of *O. mossambicus* (f' = 2.699) and *O. niloticus* (f' = 3.022), which were based on Standard Length (SL » 0.8 x Total Length) were closely similar to those estimated for African lacustrine populations of the two cichlid species (Moreau et al. 1986; Table 6). It has been shown that although $L\infty$ and K are not species-specific, f' value falls within a narrow range for a given species (Moreau et al. 1986). The length-converted catch curves of the two cichlid species (Figs. 4e and 4f) consist of ascending parts which fall on gradually increasing data points and descending parts with wide ranges of data points which fall on straight lines. Therefore it is reasonable to consider that the negative exponential curves for estimating mortality parameters and sigmoid selection curves which have been assumed in the present analysis are valid. Furthermore as the samples of the two cichlids were obtained from the catches of trammel nets in which fishes get entangled, the probabilities of capture of fish within a wide size range can be considered to be close to unity. As such the assumptions behind the ELEFAN technique to estimate growth parameters using length frequency data are thought to be fulfilled in the present analysis. However the goodness-of fit values of the growth curve on length frequencies for *O. mossambicus* and *O. niloticus*, which were estimated as *Rn* values (Gayanilo et al. 1995) were 0.132 and 0.159 respectively. It is well-known that in cichlid stocks, there are more than one recruitment pulses per year (Iles 1977). The length frequency data of this study (Tables 4 and 5; Figs. 4c and 4d) also indicates that from December to January and from May to June, small (<18 cm) *O. mossambicus* and *O. niloticus* are abundant in the length frequency samples. In figures 4c and 4d for each of the two cichlid species, two growth curves are superimposed which represent two major recruitment pulses. It must also be noted that the growth curves are superimposed on the length frequency data which have not been corrected for gear selection whereas growth parameters corresponding to the growth curves were from length frequency data corrected for gear selection (Gayanilo et al. 1995).

As evident from the yield-per-recruit analysis (Fig. 5), the two cichlid species at the Tabbowa reservoir are optimally exploited. However, as mentioned above, in artisanal fisheries fishers tend to increase efficiency of fishing gear. Amarasinghe and Pitcher (1986) and Amarasinghe and De Silva (1992b) have

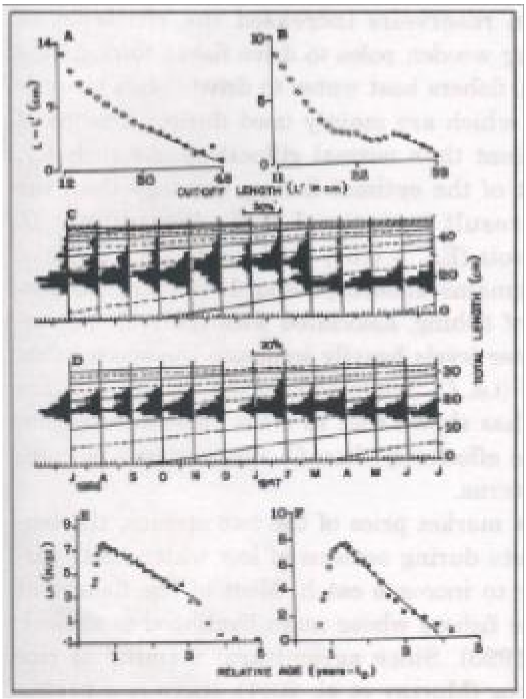

Fig. 4. Powell-Wetherall plots for *O. niloticus* (a) and *O. mossambicus* (b) (L' = Cut off length in cm; L = Mean length of fish bigger than L' in cm); von Bertalanffy growth curves superimposed on percentage length frequency distributions of *O. niloticus* (c) and *O. mossambicus* (d); and length-converted catch curves of *O. niloticus* (e) and *O. mossambicus* (f) (N = Number of fish in a length class; Dt = Time (yrs) needed to grow through the length class). Note: In Figures 4a,b,e and f, only dark circles were used in the regression analysis. In figures c and d, two types of growth curves (solid and broken) represent two recruitments of the two cichlid species. Six divisions in the percentage frequency axis are equal to 30% in figure c and to 20% in figure d.

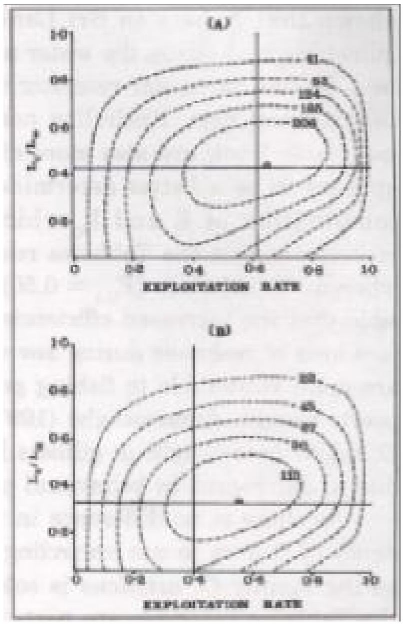

Fig. 5. Relative yield-per-recruit (Y'/R) isopleths (i.e., Y'R contours drawn as functions of exploitation rate (e) and ratio of length at first capture (L_c) to asymptotic length (L∞)) for, (a) *O. mossambicus* and (b) *O. niloticus* in Tabbowa reservoir during 1986-87. Vertical and horizontal solid lines indicate exploitation rates and L_c/L∞ ratio respectively during the study period. Y'/R values indicated on the contour lines are in arbitrary units.

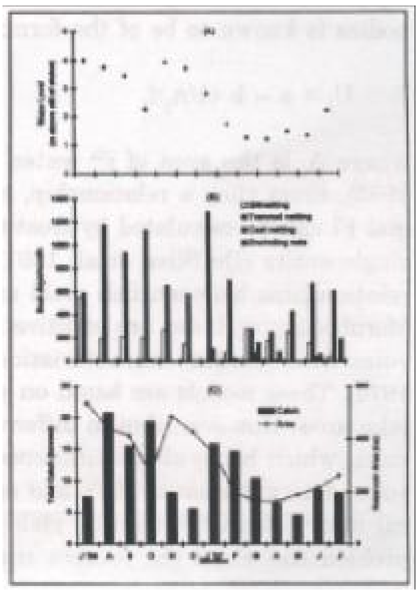

Fig. 6.a. Mean water level (Vertical bars - range), (6b) Monthly fishing effort of different fishing methods, (6c) Total catch and monthly mean reservoir area in Tabbowa reservoir from July 1986 to July 1987.
(Source: Irrigation Department, Sri Lanka)

shown that fishers in Sri Lankan reservoirs increased the efficiency of gillnetting by beating water using wooden poles to drive fishes towards the nets. In this particular reservoir too, fishers beat water to drive fishes towards the trammel nets. Encircling nets, which are mainly used during the seasons of low water level, are also more efficient than normal gillnetting. As such $E_{0.1}$ appears to be a better determinant of the optimal fishing strategy than the combination of E and L_c which result in optimal Y'/R. Accordingly *O. mossambicus* at the Tabbowa reservoir ($E_{0.1}$ = 0.57) tends to be overexploited whereas *O. niloticus* ($E_{0.1}$ = 0.50) still remains underexploited. It is therefore possible that the increased efficiencies of fishing, associated with the reduced surface area of reservoir during low water levels heavily influence the species that are more vulnerable to fishing gear (i.e. *O. mossambicus*) than those that are poorly caught. Amarasinghe (1997) has shown that in a Sri Lankan reservoir, *O. niloticus* is caught in gillnets less effectively than *O. mossambicus* perhaps due to differences in behavioral patterns.

As there is no difference in the market price of the two species, the tendency of fishers to use encircling nets during the seasons of low water level, targeting mainly *O. niloticus* is solely to increase catch. Most of the fishers at the Tabbowa reservoir are part-time fishers whose main livelihood is agricultural farming (CEA/Euroconsult 1993). Since agricultural farming of rice paddy requires manual labor seasonally (Murray et al. 2001), there is a perfect synchronization of nonfarming season and labor-intensive fishing (i.e., use of encircling nets) during the low water level, that somehow helps to sustain the fishery.

As accurate data on catch and effort over a long period are not available to determine optimal fishing effort in individual reservoirs, comparative approaches that relate yield (kg per unit area per unit time) to FI (craft-days per unit area per unit time) in separate water bodies, as proposed by Gulland (1983), are useful for determining optimal FI for the reservoir fisheries. Accordingly the relationship between c/f (U_j) and fishing effort (f_j) in individual water bodies is known to be of the form, $U_j = a - b\,(1/A_j)f_j$ where A_j is the area of j^{th} water body and, a and b are constants (Gulland 1983). From such a relationship, maximum sustainable yield (MSY) and optimal FI can be calculated by treating the fisheries of individual reservoirs as a single entity (De Silva et al. 1991). Moreover, empirical models based on the relationships between fish yield and productivity related parameters such as Morphoedaphic Index are effective means of yield prediction in lakes and reservoirs with similar characteristics (Ryder 1965, Henderson and Welcomme 1974). These models are based on yield and/or FI estimated using the reservoir/lake area. However, due to the differences in bathymetry of individual reservoirs, which bring about differences in area-depth relationships among reservoirs, determination of MSY and optimal FI, and yield prediction using empirical models from the data on yield and FI based on reservoir area at FSL are problematic. From the present study it is evident that the estimates of mean annual fish yield and fishing intensity based on reservoir area at FSL are 23 and 21% respectively of the estimates based on the actual monthly mean reservoir area. This high degree of underestimation of fish yield and fishing intensity when reservoir area at FSL is used is not directly related to changes in the surface area of the reservoir. The mean reservoir area (185.3 ha; Table 7) is only about 31% of the area at FSL. This might be due to the reason that the amplitude of variation of catch efficiencies is different from that of change reservoir surface area. As such it appears that the fluctuations in water-level in reservoirs have some implications on fisheries management in reservoirs. This is of particular importance due to the fact that in irrigation and hydroelectric reservoirs, water level is maintained at FSL only for a brief period, mostly less than one month. The present study is therefore a useful extension in fish stock assessment in multiple-purpose reservoirs in which water regimes are controlled by various users of water resources other than fisheries authorities.

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