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Population dynamics of *Oreochromis mossambicus*, *Oreochromis niloticus* and their hybrids/ introgressed individuals in three reservoirs of Sri Lanka

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Abstract

Introduced cichlids *Oreochromis mossambicus* and *Oreochromis niloticus* are the major contributors to the reservoir fishery of Sri Lanka. Studies have shown hybridization/ gene introgression between these two species has resulted in three main groups; *O. mossambicus, O. niloticus* and hybrids/ introgressed individuals (hybrid x parent species) in many reservoirs. Population dynamics, growth performances, mortality and recruitment are important parameters in stock assessment and information on these is essential for better management of a fishery. Present study compares the growth performance and population dynamics of the three cichlid groups in three reservoirs of Southern Sri Lanka. Monthly length frequency samples of *O. mossambicus* and *O. niloticus* and hybrids/ introgressed individuals were taken from three reservoirs namely, Chandrikawewa, Ridiyagama and Lunugamwehera for a period of 14 months and the data were analysed using FiSAT software package.Growth performance indices of the hybrid genotypes were intermediate to parental genotypes indicating that the hybrids/ introgressed individuals are of intermediate performance compared to parental groups. *O. mossambicus* showed lower growth rate than other two groups. Except in Lunugamwehera reservoir, *O. niloticus* and hybrids/ introgressed groups did not show appreciable difference in growth rates. High natural mortalities were observed in all reservoirs for all groups while hybrid/ introgressed group showed high fishing mortalities compared to other two groups. With the exception for hybrids and *O. mossambicus* genotypes at Chandrikawewa reservoir, all other genotype groups were overexploited. This would lead to depletion of stocks which could adversely affect the fishery in long term. Present study shows that growth and population dynamic parameters are different in three groups within a reservoir and also among three reservoirs. Therefore, management strategies should be adopted after studying different reservoirs separately. A strategy common to all reservoirs may not be successful.

Introduction

The reservoir fishery in Sri Lanka is essentially a capture fishery. Management of the reservoir fishery is based mainly on technical measures *viz.* mesh limitations, gear limitations, and restrictions on the use of fishing crafts. Reservoir fisheries in Sri Lanka are not managed in an effective scientific manner (De Silva 1988). The imposition of technical measures as described earlier, has helped to safeguard fish stocks and to prevent the collapse of individual reservoir fisheries to a certain extent. However, sound scientific management of the fish stocks is urgently required to avoid excessive exploitation due to increasing fishing pressure and to gain maximum sustainable yields in individual reservoirs.

For an effective approach for defining management strategies in a tropical multi-species fishery, identification of major fish stocks, knowledge of their population dynamics and the level of contribution of the constituent fish stocks to the fishery are essential.
Reservoir fishery of Sri Lanka could be considered as a multi species fishery. *Oreochromis* species are the major contributors to the reservoir fishery in Sri Lanka (Amarasinghe 1998). They consist of three main groups, *O. mossambicus*, *O. niloticus* and their hybrids or introgressed individuals (hybrid x parent species) (De Silva and Ranasinghe 1989; De Silva *et al.* 1999). Molecular studies using mitochondrial DNA and microsatellite markers have shown the presence of different levels of hybridization in different reservoirs in Sri Lanka (De Silva 2003).

Growth and mortality of individuals are determined by their genetic make up, the environment or and the combined effects of both these factors. In Sri Lankan reservoirs, *O. mossambicus* and *O. niloticus* appear to occupy the same habitats and therefore are likely to experience similar environmental factors. Different genetic background may determine their relative tolerance and adaptability to local environmental conditions, which will in turn affect their relative growth, mortality, recruitment and reproduction, etc. Hybridization between the two species has resulted in a third class of individuals with intermediate but distinctive genetic attributes (or mixed characteristics) (Gregg *et al.* 1997). Interactions among individuals of the three groups of genotypes in reservoirs may affect the demographic parameters of these 'populations'. As tilapias are the major component of the reservoir fishery in Sri Lanka, a comparative study of the population dynamics of the three tilapia genotypes may provide a basis for designing and implementing better fishery management strategies in reservoir fisheries.

Studies on growth parameters and population dynamics of *O. mossambicus* and *O. niloticus* using dynamic pool models have been carried out in many reservoirs in Sri Lanka (Amarasinghe 1987; Amarasinghe *et al.* 1989; Amarasinghe and De Silva 1992b; Amarasinghe 2002), as well as in other countries (Moreau *et al.* 1986; Khoo and Moreau 1990).

Comparative studies of growth parameters in *O. mossambicus* and *O. niloticus* and their hybrids in aquaculture systems have shown that hybrids grow faster in general compared with parents (Moreau and Pauly 1999). Similar studies on growth performance and population dynamics of hybrids/ introgressed individuals and the parent species, in reservoirs of Sri Lanka have been hindered due to the difficulties associated with unambiguous identification of hybrids/ introgressed individuals from the parents. The Morphological Index developed by De Silva (2003) enabled the effective discrimination of hybrids/ introgressed individuals from the parent species.

Therefore the objectives of the present study was to investigate and compare the growth, mortality parameters and exploitation levels of hybrids/ introgressed individuals and their parent species in three reservoirs.

Materials and Methods

Sampling was carried out in three reservoirs, namely Chandrikawewa, Lunugamwehera and Ridiyagama from June 2000 to August 2001. Sampling days varied from 05 - 22 days per month for Chandrikawewa, 04 - 09 days per month for Lunugamwehera and 04 - 30 days per month at Ridiyagama depending on the availability of the fish. Gill nets were the main gear used in all three reservoirs sampled. *Oreochromis* species caught by gill nets were used for this study. Total length, standard length, maximum depth and number of caudal fin bars of each fish from the commercial landings of randomly selected crafts were recorded. Standard length, maximum depth and number of caudal fin bars were used in morphological index to separate the *Oreochromis* species into 03 groups i.e. *O. mossambicus, O. niloticus* and hybrids/ introgressed. The length frequencies of each group were recorded separately. These data were analysed using the FiSAT software package (Gayanilo *et al.* 1996). Samples of *O. mossambicus* in Ridiyagama reservoir were not used in the analyses due to low sample sizes.

L_∞ and K were estimated using the method described by Amarasinghe and De Silva (1992). The Growth performance index (ϕ'), which is known to be a species-specific parameter, was then computed and (Pauly and Munro 1984) ϕ' value was used to judge the biological reasonability of L_∞ and K estimates. Approximate values for t_0 for three groups in three reservoirs were estimated using Pauly's (1983) empirical equation. Total mortality rate (Z) was estimated using length converted catch curves and the natural mortality rates (M) were estimated using the empirical equation of Pauly (1980). Fishing mortality (F) was then estimated as Z - M. Exploitation rate (E) was calculated as F/ Z length at first capture (L_{50} or L_c) was estimated by probability of capture curves.

The length of fish at different age groups was estimated using the von Bertallanfy Growth Function (VBGF) equation. The length (total length) and age data were computed to obtain growth curves for the three groups in three reservoirs.

Results

VBGF growth curves superimposed on length frequency distributions for three groups in Lunugamwehwera is shown in Figure 1. Similarly, length frequency distributions for three groups in other two reservoirs were also obtained (results not shown). Table 1 shows the growth parameters and growth performance indices (ϕ') for the three groups of fish in the three reservoirs.

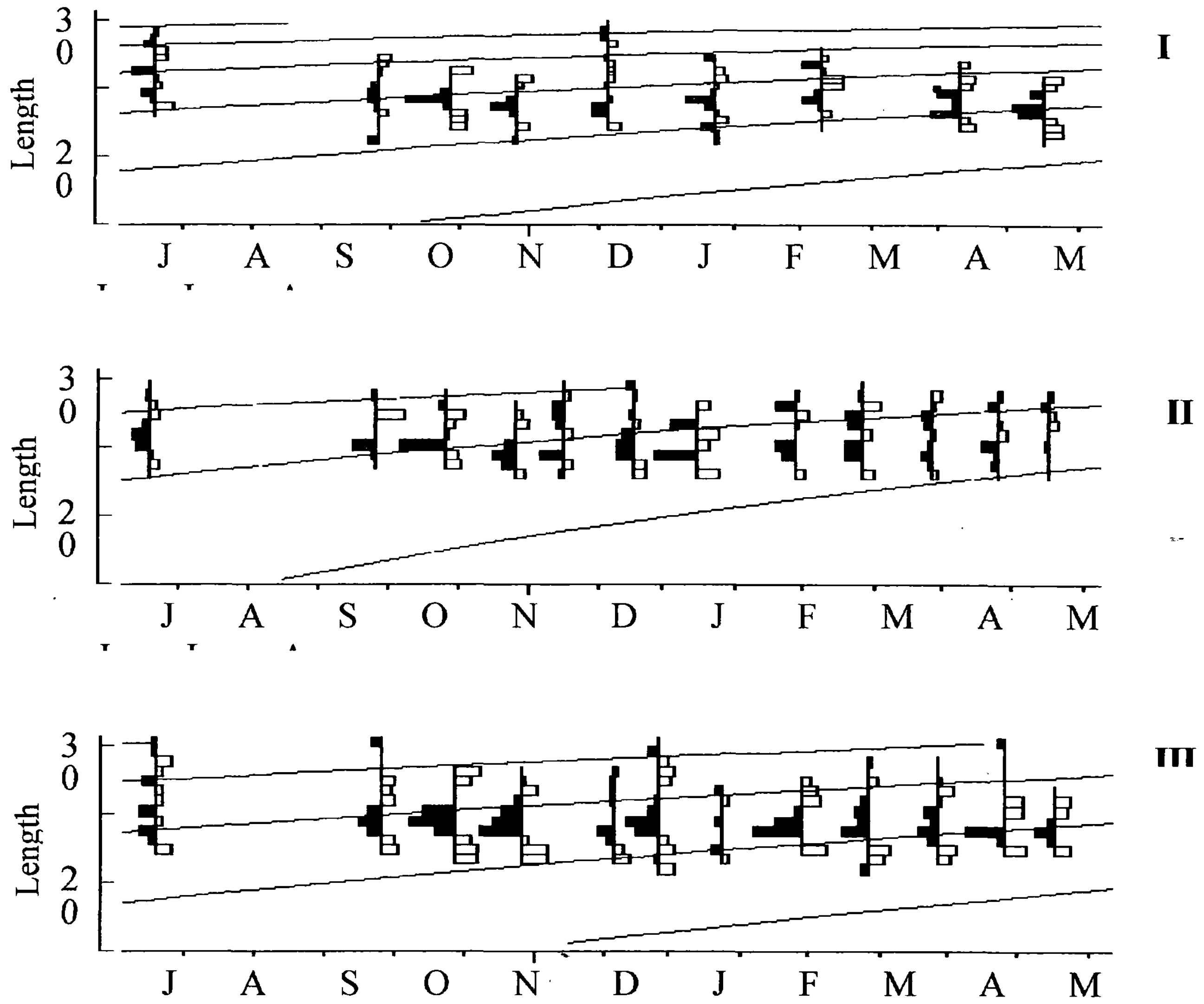

Figure 1. Von Bertalanffy growth curves of (I) *O. mossambicus*, (II) *O. niloticus* and (III) hybrids/ intogressed individuals in Lunugamwehera reservoir superimposed on the length frequency distributions of the samples.

Of the fish populations studied, the highest L_{∞} value was recorded for *O. niloticus* in Ridiyagama reservoir. Of the hybrids/ introgressed individuals, those in Ridiyagama reservoir showed the highest L_∞. As a whole, *O. niloticus* and hybrids/ introgressed individuals had higher L_∞ than *O. mossambicus*.

Table 1. Growth parameters of three groups of tilapia in three reservoirs

Reservoir	Chandrikawewa			Lunugamwehera			Ridiyagama	
Group	*O. mossambicus*	*O. niloticus*	hybrids/ introgressed individuals	O. mossambicus	*O. niloticus*	hybrids/ introgressed individuals	O. niloticus	hybrids/ introgressed individuals
ϕ'	2.47	2.78	2.66	2.54	3.07	2.79	3.08	3.0
L_∞ TL (cm)	35.0	47	50.5	35.0	38.2	47.0	53.0	51.8
K (year^{-1})	0.44	0.83	0.38	0.38	0.65	0.32	0.67	0.59
t_0 (years)	-0.357	-0.175	-0.376	-0.416	-0.233	-0.458	-0.206	-0.237
Z	1.82	3.42	1.65	2.16	3.14	3.3	3.14	3.75
M	1.02	1.42	0.83	0.92	1.28	0.76	1.19	1.10
F	0.80	2.0	0.82	1.24	1.84	2.54	1.95	2.65
L_{50} (cm)	17.2	28.1	21.2	16.6	19.8	18.2	25.5	23.9
E	0.44	0.58	0.50	0.57	0.59	0.77	0.62	0.71
exploitation status	Under	Over	Optimal	Over	Over	Over	Over	Over

Table 1 also shows total mortality rates, natural mortality rates, fishing mortality rates and exploitation ratios. Except for *O. mossambicus* and hybrids/ introgressed individuals at Chandrikawewa all populations appeared to be heavily exploited.

Mean lengths at first capture (L_{50}) are also shown in Table 1. Although *O. mossambicus, O. niloticus* and hybrids are presently caught using the nets of same mesh sizes, L_{50} varied from fish group to fish group. Differences in body depth: total length ratio of each group has lead to the differences in L_{50}.

Growth curves which were computed from the estimated growth parameters are shown in Figure 2. *O. mossambicus* in Lunugamwehera and Chandrikawewa reservoirs were characterized by growth curves showing lower growth rate than other two groups. In Ridiyagama and Chandrikawewa reservoirs, *O. niloticus* and hybrids did not show appreciable difference in growth curves and hybrids/ introgressed populations in Lunugamwehera reservoir had different growth curves from the *O. niloticus* populations. All *Oreochromis* populations enter the exploitation phase within the first year of their life.

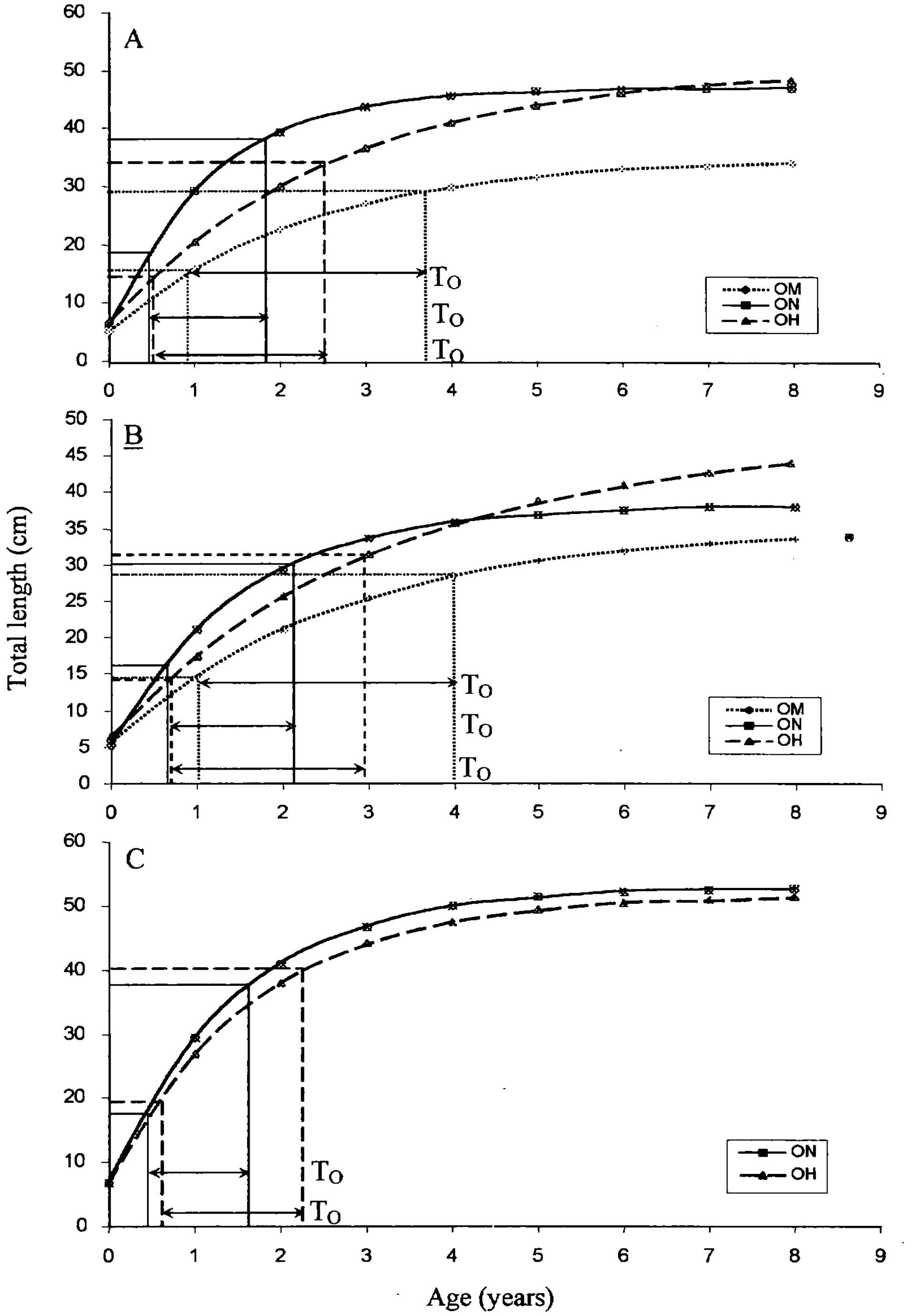

Figure 2. Growth curves of the three Oreochromis groups in (A) Chandrikawewa, (B) Lunugamwehera and (C) Ridiyagama reservoirs indicating the length ranges of the samples and the duration of the exploitation phases (TON, TOM and TOH)

Discussion

Growth performance indices (ϕ') recorded for *O. mossambicus O. niloticus* and hybrids/ introgressed individuals during the present study fall within the range of ϕ'values reported for the three groups in different localities in the world (Sin and Chiu 1983, Moreau *et al.* 1986, Costa-Pierce *et al.* 1989, Amarasinghe and De Silva 1992b. Thus the L_∞ and K values for the Sri Lankan tilapia stocks can be considered biologically reasonable. ϕ' values were more comparable to values obtained in aquaculture systems (Moreau and Pauly 1999) where better growth conditions prevail. De Silva and Senaratne (1988) suggested that exposure to favourable environmental conditions and a wide variety of nutritive foods may be the possible reasons for relatively good growth performances in Sri Lankan reservoirs. ϕ' values of the hybrid genotypes were intermediate to parental genotypes which indicate that the hybrids/ introgressed individuals show intermediate performance compared to parental groups (Figure 2). This may be a consequence of 'genetic mixing' of parental genotypes exposed to identical environmental conditions.

Hybrids/ introgressed individuals showed higher L_∞ (except in Ridiyagama reservoir) compared with the other genotype groups suggest better energy allocation for somatic growth and less energy allocation for gonadal growth. This has been suggested by Iles (1973) too. This could result from genetic differences in consumption rate, metabolism, assimilation efficiency or a combination of these factors as shown by Wootton (1994).
High natural mortalities were observed in all reservoirs. Predatory pressure from piscivorous birds and presence of predatory fish including *Anguilla bicolor*, *Ophicephalus striatus* in reservoirs can be identified as the most likely explanation. High mortalities due to piscivorus birds have been recorded for Parakrama Samudra too (Winkler 1983). Estimated high fishing mortalities of the hybrid category at Lunugamwehera and Ridiyagama reservoirs and to a lesser extent in Chandrikawewa reservoir could perhaps be attributed to different behavioural patterns. Amarasinghe and De Silva (1992) have suggested that the high proportion of male *O. niloticus* and *O. mossambicus* in the beach seine catches in Kaudulla reservoir were due to their behavioural selection i.e. territorial behaviour of males in shallow inshore areas. Caulton and Hill (1973) also recorded that *O. mossambicus* confined to certain depth depending upon maturity, sex and water temperature. Likewise, hybrid/ introgressed individuals of these reservoirs may be occupying certain depths more frequently where fishing is commonly taking place. This may have brought about their high vulnerability to fishing gear. Alternatively, they may be more active than the parental groups or attain comparatively larger size. These may be the reasons, amongst others, which have led to high fishing mortality rates of hybrid/ introgressed individuals.

Present study shows that, with the exception for hybrids and *O. mossambicus* genotypes at Chandrikawewa reservoir, all other genotype groups are over exploited. This adversely affect on long term fishery which will lead to depletion of stocks thereby yields. Tilapia fishery in the reservoirs can be optimised by decreasing the exploitation rate. However, it is impractical and would be very difficult to reduce fishing mortality by excluding some fishers or by withdrawing fishing crafts. Control of length at first capture by setting mesh limits therefore is an effective option for scientific management.

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References

Amarasinghe US. 1987 Status of the fishery of Pimburettewa wewa, a man-made lake in Sri Lanka. Aquacult. Fish. Manage. 18: 375-385.

Amarasinghe US. 1988 The role of fishermen in implementing management strategies in the reservoirs of Sri Lanka. In: De Silva SS. (ed.). Reservoir Fishery Management and Development in Asia. IDRC, Ottawa, Canada. 158-163pp.

Amarasinghe US. 2002 The fishery and population dynamics of *Oreochromis mossambicus* and *O. niloticus* (Osteichthyes, Cichlidae) in a shallow, irrigation reservoir in Sri Lanka. J. Fish. Sci. 15(1): 7-20

Amarasinghe US, De Silva SS and Moreau J. 1989 Spatial changes in growth and mortality and effects on the fishery of *Oreochromis mossambicus* (Pisces, Cichlidae) in a man-made lake in Sri Lanka. Asian Fish. Sci. 3: 57-68.

Amarasinghe US and De Silva, SS. 1992 Population Dynamics of *Oreochromis mossambicus* and *O. niloticus* (Cichlidae) in two reservoirs in Sri Lanka. Asian Fish. Sci. 5: 37-61.

Caulton MS and Hill BJ 1973 The ability of *Tilapia mossambica* (Peters) to enter deep water. J. Fish Biol. 5:783-788.

Costa-pierce BA, Hadikusumah HY and Dhahiyat F. 1989 Tilapia (*Oreochromis* sp.) and Carp (*Cyprinus carpio*) production in cage systems in West Java, Indonesia 84-86pp. In: Huisman, E.A., Zonneveld, N. and Bouwmans, A.H.M. (eds). Aquaculture research in Asia: Management techniques and nutrition. Pudoc, Wageningen, The Netherlands.

De Silva MPKSK. 2003 Hybridisation between *Oreochromis mossambicus* and *O. niloticus* in reservoirs of Sri Lanka: Molecular evidence and long-term effects on fishery. Ph.D Thesis, University of Ruhuna, Matara, Sri Lanka.

De Silva SS. 1988 Reservoirs of Sri Lanka and their fisheries. FAO Fisheries Technical Paper 298, Rome, Italy.

De Silva SS. and Senaratne KADW. 1988 *Oreochromis mossambicus* is not universally a nuisance species: The Sri Lankan experience. In: Pullin RSV, Bhukaswan T, Tonguthai K and Maclean JL. (eds.). The Second International Symposium on Tilapia in Aquaculture. Manila, Philippines. 445-450pp.

De Silva CD and Ranasinghe J. 1989 Biochemical evidence of hybrid gene introgression in some reservoir populations of tilapia in southern Sri Lanka. Aquacult. Fish. Manage. 20: 269-277.

De Silva MPKSK Baker N and Mather PB 1999 Microsatellites as genetic markers for identification of exotic cichlids and their hybrids in Sri Lanka- A Preliminary Study. Sri Lanka J. Aquat. Sci. 4: 83-90.

Gayanilo FC Sparre P Jr and Paully FC. 1996 The FAO-ICLARM Stock Assesment Tools (FISAT) User's Guide. FAO Computerized Information Series (Fisheries). No. 8. Rome, FAO.

Gregg RE, Howard JH and Shonohiwa F. 1997 Introgressive hybridisation of tilapias in Zimbabwe. J. Fish. Biol. 52: 1-10.

Iles TD. 1973 Dwarfing or stunting in the Genus *Tilapia* (Cichlidae) a possibly unique recruitment mechanism. Rapport er Proc- Verbaux des Reunions. Conseil International pour l'Exploration de la Mer. 164: 247-254.

Khoo HW and Moreau J. 1990 Population Characteristics of *Oreochromis mossambicus* in the Seletar reservoir (Singapore). In: Hirano R and Hanyu I (eds.). The second Asian Fisheries Forum, Asian Fisheries Society, Manila, Philippines. 855-860pp.

Moreau J, Bambino C and Pauly D. 1986 Indices of overall growth performance of 100 tilapia (Cichlidae) populations. In: Maclean, JL, Dizon LB. and Hosillos LV (eds.). The First Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines. 201- 206pp.

Moreau J and Pauly D. 1999 A comparative analysis of growth performance in aquaculture of tilapia hybrids and their parent species. Asian Fish. Sci. 12: 91-103.

Pauly D. 1983 Length converted catch curves. A powerful tool for fisheries research in the tropics (Part I). ICLARM Fishbyte 1(2): 9-13

Pauly D. 1980 On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil. Conseil International pour l'Exploration de la Mer. 39 (2) 175-192.

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

Ricker WE. 1975 Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada. 191: 382.

Sin AWC and Chiu MTI. 1983 The intensive mono-culture of the tilapia hybrid. *Saratherodon niloticus* (male) x *S. mossambicus* (female) in Hong Kong. Proceedings of the First International Symposium on Tilapia in Aquaculture, Nazarath, Israel. 506-516pp.

Winkler H. 1983 The ecology of comorants (Genus Phalacrocorax). In: Schiemer F (ed.). Limnology of Parakrama Samudra Sri Lanka: A case study of an ancient man- made lake in the tropics. Dr. W. Junk Publishers, The Hague, Netherlands. 193-199pp.

Wootton RJ. 1994 Energy allocation of threespine stickleback. In: Bell, M.A. and Foster, S.A (eds.). The Evolutionary Biology of the Threespine Stickleback. Oxford Science Publications, Oxford. 114-143pp.