*Vidyodaya J. of Sci., (1994) Vol. 5, No. 1, pp. 23 - 40*

# A SYNTHESIS ON THE MANAGEMENT OF THE CAPTURE FISHERIES OF SRI LANKAN PERENNIAL RESERVOIRS*

**U. S. Amarasinghe**

*Department of Zoology,*
*University of Kelaniya,*
*Kelaniya, Sri Lanka.*

*Received on :* 18 - 03 - 94

*Accepted on :* 19 - 07 - 94

**Abstract**

Sri Lankan reservoir fishery is one of the best documented in the South East Asian region. It is very productive and the average fish yield in reservoirs of the country is about 300 kg $ha^{-1}$, $yr^{-1}$. Nevertheless the Sri Lankan reservoir fishery is not managed scientifically and in some reservoirs, fish stocks are over-exploited. Since recently, some studies have been carried out on the aspects of management of the capture fisheries in perennial reservoirs of the country.

Empirical yield prediction models are found to be useful for setting limits to the size of the fishery. Also by employing surplus yield predictive models, maximum sustainable yield and optimal fishing intensity have been estimated to be 256 kg $ha^{-1}$ $yr^{-1}$ and 3.2 boats $km^{-2}$ respectively. Dynamic pool models are also reliably applicable for the reservoir fisheries of Sri Lanka. Fish yields in reservoirs could further be increased by introducing a subsidiary gillnet fishery for minor cyprinids. Socioeconomics of fishing communities should be better understood for effective implementation of fisheries management strategies in Sri Lankan reservoirs.

* Paper written on invitation.

**Key Words :** Reservoirs, Cichlidae, Morpho-Edaphic Index, Surplus Yield Models, Dynamic Pool Models, Socioeconomics

## 1. Introduction

In Sri Lanka, the total surface area of different types of reservoirs is about 175,000 ha which gives a value of about 2.7 ha of water surface for every $km^2$ of Sri Lanka. With the proposals for the construction of new reservoirs, the total area of reservoirs will be over 250,000 ha giving 4 ha per $km^2$ of standing water for the country as a whole.

These reservoirs are productive biological systems and they support profitable capture fisheries. The total fish production in Sri Lankan reservoirs is about 30,000 metric tons which works out to over 300 kg per ha per year (De Silva, 1988a). When compared to the average annual fish yield of 80 kg per ha in lake and reservoir fisheries in lowland areas of tropical developing countries (Oglesby, 1985), the mean production in the Sri Lankan reservoir fishery is very high.

In Sri Lanka, there are no natural lakes. As such, fish species in the indigenous fish fauna of Sri Lanka are not completely adapted to lacustrine conditions. Hence the indigenous fish species alone are said to be unable to produce high yields (Fernando and Holcik, 1982). The inland fishery of Sri Lanka which is almost entirely dependent on the magnitude of reservoir systems, is a relatively recent development after the introduction of an exotic cichlid species, *Oreochromis mossambicus* to Sri Lankan freshwaters in 1952. Fish yields in reservoirs in Sri Lanka have dramatically increased after this introduction. This trend is best exemplified in the case of the fishery of Parakrama Samudra (Fig. 1). Presently percentage contribution of *O. mossambicus* to the reservior fishery is between 56 and 99 percent of the total catch (De Silva, 1988a).

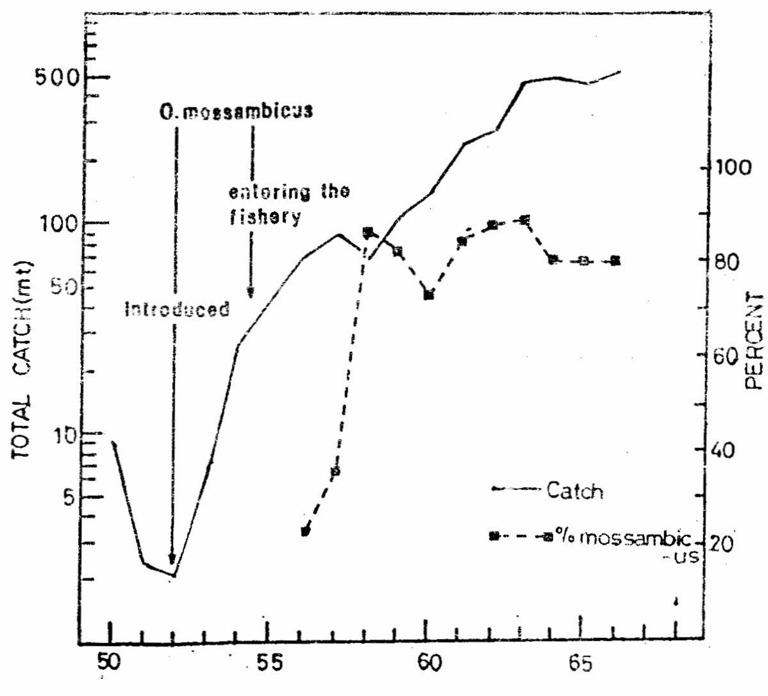


Fig. 1. Development of the fishery of Parakrama Samudra (De Silva, 1988a)

## 2. The reservoir fishery

The craft in the reservoir fishery in Sri Lanka is non-mechanized fibre-g'ass outrigger canoe and the gear is gillnet. Beach seines and cast nets are also used in some reservoirs sporadically.

Fish yields in individual reservoirs vary considerably. Annual fish yields in 19 reservoirs are reported to range from 40 to 650 kg, $ha^{-1}$ with the overall mean value of 258 kg, $ha^{-1}$ (Moreau and De Silva, 1991). In the fisheries of most major perennial reservoirs, there had been nearly a three-fold increase in fishing effort within a period of six years. The overall mean effort per unit area (i.e., fishing intensity) in the reservoir fishery has increased from 0.019 crafts $ha^{-1}$ in 1978 to 0.050 crafts $ha^{-1}$ in 1984 (Fig. 2 ; De Silva, 1988a). This increase in fishing effort was mainly due to the supply of fibre glass crafts and fishing nets under a subsidy scheme.

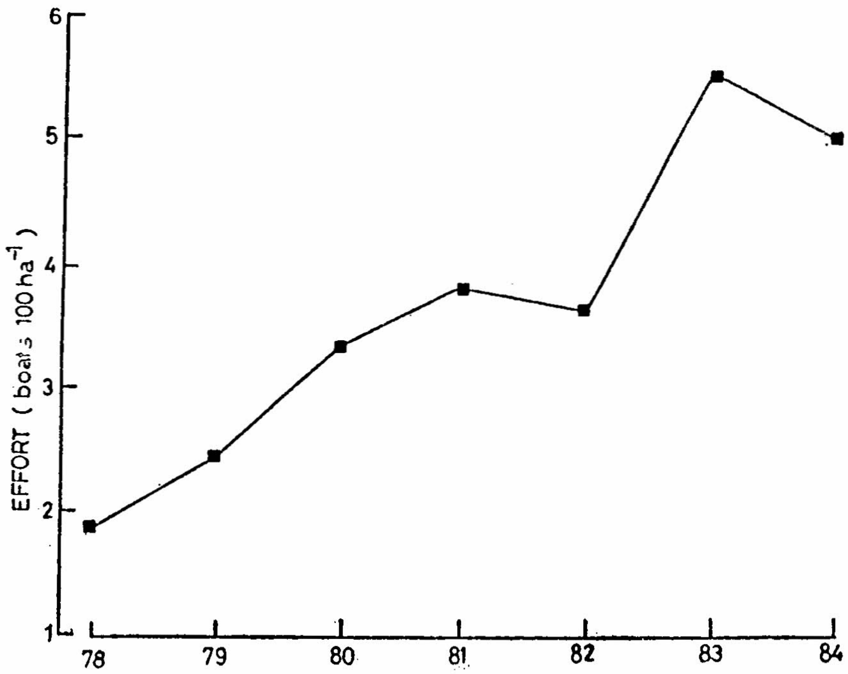


Fig. 2. Changes in the mean number of boats operating in the reservoir fishery of Sri Lanka between 1978 and 1984 (De Silva, 1988a).

The reservoir fishery of Sri Lanka is not managed scientifically. There is some evidence that the fish stocks in some reservoirs are over-exploited (De Silva and Fernando, 1980 ; Amarasinghe, 1988a). The mean landing sizes of the dominant fish species, *O. mossambicus* have declined in some reservoirs such as Parakrama Samudra (Table 1) indicating that over-exploitation takes place in the fishery.

**Table 1. Declining trends in the mean landing size of *O. mossambicus* in Parakrama Samudra (De Silva and Fernando, 1980 ; Amarasinghe *et al.*, 1989). SL - Standard Length ; TL - Total Length.**

| Year | Mean length (cm) |
|---|---|
| 1957 | 34.2 (SL) |
| 1964 | 28.4 (SL) |
| 1966 | 27.2 (SL) Gillnet catches |
| | 23.2 (SL) Beach seine catches |
| 1978 | 21.8 (SL) |
| 1985-86 | 21.0 (TL) |

**Table 2. Official and survey data on fish yields (kg $ha^{-1}$, $yr^{-1}$) in four Sri Lankan reservoirs. K - Kaudulla (2713 ha) ; M - Minneriya (2551) ha) PS - Parakrama Samudra (2662 ha) ; P - Pimburettewa (830 ha) ; * Source : Ministry of Fisheries, Sri Lanka ; a - Amarasinghe and Pitcher (1986) ; b - Amarasinghe and Samarakoon (1988) ; c - Amarasinghe (1987) ; d - Amarasinghe and De Silva (1992a).**

| Year | K | M | PS | P |
|---|---|---|---|---|
| Official data* | | | | |
| 1980 | 287.9 | 197.7 | 507.3 | 618.5 |
| 1981 | 127.9 | 124.2 | 371.4 | 594.1 |
| 1982 | 130.8 | 257.5 | 185.9 | 315.9 |
| 1983 | 162.1 | 255.5 | 280.8 | 717.7 |
| 1984 | 415.5 | 258.7 | 171.2 | 884.6 |
| 1985 | 546.9 | 425.5 | 120.2 | 671.0 |
| 1986 | 590.3 | 461.0 | 129.0 | 391.7 |
| 1987 | 266.5 | 479.3 | 114.7 | 434.0 |
| Survey data | | | | |
| 1982 - 83 | — | — | 120.0[a] | — |
| 1985 | — | — | 46.0[b] | 441.0[c] |
| 1986 - 89 | 192.0[d] | 130.0[d] | | |

Sri Lankan reservoir fishery is one of the best documented in the South East Asian region (De Silva, 1988a). The trends in the growth of the reservoir fishery of Sri Lanka have been documented by various workers (Fernando and Indrasena, 1969 ; Fernando, 1971, 1977, 1984; Fernando and De Silva, 1984 ; De Silva, 1983, 1985a, 1988a ; Amarasinghe 1992). The Inland fishery at present accounts for about 20 percent of the country's total fish production (De Silva 1988a). This paper reviews research on management of the fisheries of Sri Lankan reservoirs.

## Catch and effort statistics

The official fishery statistics in Sri Lanka seem to be unrealistic (Amarasinghe, 1992; Table 2). Also in five reservoirs in southern Sri Lanka, fish production figures of the Ministry of Fisheries were 2.7 times higher than the actual fish production (Chandrasiri, 1986). Number of crafts which are allocated for individual reservoirs are determined depending on inaccurate fisheries statistics. As such, fish stocks in reservoirs would lead to over-exploitation through the increased fishing effort above the optimal level.

However, collection of fishery statistics in scattered Sri Lankan reservoirs, situated in the rural areas, is rather difficult. As such there is a need to formulate an effective procedure to make fishers active partners in the submission of accurate statistics, either individually or through the co-operative societies with which they are affiliated (De Silva, 1988a; Amarasinghe, 1992).

In most reservoirs of Sri Lanka, fishers beat the water with wooden poles or weighted ropes to drive fishes towards gillnets. The efficiency of this "water beating technique" is significantly higher than that of normal gillnetting (Amarasinghe and Pitcher, 1986 ; Amarasinghe and De Silva, 1992a). As such in catch and effort surveys in reservoirs of Sri Lanka, stratification of data according to fishing methods is shown to be necessary to estimate the fish production more precisely (Amarasinghe and Pitcher, 1986 ; Amarasinghe and De Silva, 1992a).

## Management of the capture fishery in perennial reservoirs

According to existing fishery regulations, mechanization of crafts is not allowed and seine nets cannot be operated in reservoirs. The minimum permissible mesh size for the gillnet fishery is 7.5 cm. These regulations, albeit not determined through scientific studies, are useful to an extent, to limit the fishing effort in the reservoir fishery of Sri Lanka.

Empirical models are useful for setting limits to the size of the fishery in reservoirs of Sri Lanka which are scattered throughout the dry zone of the country. Wijeyaratne and Amarasinghe (1987) have found that the Morpho-Edaphic Index (MEI = ratio of Electrical Conductivity in $\mu S$ to Mean Depth in m) is significantly correlated with the Maximum Sustainable Yield (MSY) in kg $ha^{-1}$ $yr^{-1}$ in several Sri Lankan reservoirs which is described by the following equation.

$$\text{Ln MSY} = 0.9005 \text{ Ln MEI} + 1.922$$

Subsequently hovever, De Silva (1988a) indicated that MEI could not be used for yield prediction in Sri Lankan reservoirs due to the relative shallowness, high draw-down and flushing rates of Sri Lankan reservoirs which do not permit them to act as basins releasing nutrients. On the other hand, presence of a significant relationship between MSY and MEI in several reservoirs perhaps indicates that reservoirs of Sri Lanka can be classified into different categories depending on the hydrobiological characteristics. De Silva (1988b) suggested that such a classification would be useful for effective management of the reservoir fisheries.

Moreau & De Silva (1991) have used data of 19 Sri Lankan reservoirs (Table 3) to develop empirical models for predicting fish yields using morphometric, physico-chemical, biological and fisheries data. Accordingly, relationships between the total annual fish production, reservoir area, catchment area and fishing effort are as follows :

$$Y = -67.3 + 0.111 \text{ A} + 5.898 \text{ f}$$

$$Y = -67.6 + 0.101 \text{ A} + 5.539 \text{ f} + 0.064 \text{ CA}$$

where Y = Annual fish production (metric tons) ; A = reservoir area (ha) ; Cuc=catchment area ($km^2$) ; f = fishing effort (number of fishers).

Furthermore Moreau & De Silva (1991) have derived regression relationships between the annual fish yields (kg $ha^{-1}$) and morphometric, biological and fishery data of Sri Lankan reservoirs. The relationships are given in Table 4. Depending on these relationships, Moreau & De Silva (1991) have indicated that morphometric parameters are useful for yield prediction in Sri Lankan reservoirs.

Based on an analysis of catch and effort data of the fisheries of Sri Lankan reservoirs (De Silva *et al.*, 1991a), the maximum sustainable yield (MSY) is deducted to be 256 kg, $ha^{-1}$, $yr^{-1}$ and optimal fishing effort per unit area (i.e., optimal fishing intensity ) is 3.2 boats, $km^{-2}$ (Fig. 3). The estimated MSY is lower than the present average yield of 283 — 307 kg, $ha^{-1}$, $yr^{-1}$ of the, reservoir fishery of the country where the average effort per unit area (i.e., fishing intensity) is about 3.1 boats, $km^{-2}$. When the individual reservoirs are considered separately, the fisheries of most reservoirs seem to be exploited at a sub optimal level (Fig. 4). However, when all the reservoirs are considered as a single unit on an yearly basis, rather than each reservoir as separate entity, the fishery has a tendency to be over-exploited (Fig. 3).

**Table 3.** **Some morphometric, physico-chemical and biological characteristics and features of the fisheries of Sri Lankan reservoirs (CA = catchment area ; TAL = Total alkalinity ; Chl - a = Chlorophyll - a content). Source: Moreau & De Silva (1991).**

| | Reservoir | Area ha | CA $km^2$ | Mean depth | TAL mg/l | Chl-a mg/l | Effort boats | Fishing intensity boats/$km^2$ | Catch MT/yr | Yield kg/ha,yr | Yield per boat,yr MT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Badagiriya | 482 | 346 | 4.3 | — | 39.7 | 24 | 5.0 | 230 | 476 | 9.6 |
| 2. | Huruluwewa | 225 | 197 | 6.2 | 2.24 | — | 19 | 0.9 | 94 | 40 | 4.4 |
| 3. | Kalawewa | 2583 | 827 | 4.8 | 2.10 | — | 83 | 3.2 | 897 | 347 | 10.8 |
| 4. | Kaudulla | 2537 | 82 | 9.2 | 2.47 | 58.5 | 72 | 2.8 | 536 | 211 | 7.4 |
| 5. | Lunugamwehera | 3023 | 904 | 12.0 | — | — | 20 | 0.6 | 400 | 132 | 20.0 |
| 6. | Maduru Oya | 2548 | 453 | — | — | — | 80 | 3.4 | 692 | 272 | 8.6 |
| 7. | Mahakanadarawa | 1457 | 323 | 5.8 | 2.54 | — | 25 | 1.7 | 122 | 84 | 4.9 |
| 8. | Mahawilachchiya | 927 | 364 | 4.2 | 2.72 | — | 38 | 2.6 | 251 | 258 | 6.6 |
| 9. | Minneriya | 2550 | 240 | 11.7 | 2.74 | 12.5 | 74 | 2.9 | 478 | 188 | 6.5 |
| 10. | Nachchaduwa | 1785 | 604 | 3.1 | 1.74 | — | 66 | 3.7 | 874 | 497 | 13.2 |
| 11. | Padaviya | 2357 | 272 | 12.2 | — | — | 47 | 2.0 | 308 | 131 | 6.5 |
| 12. | Parakrama Samudra | 2662 | 1382 | 5.3 | 2.42 | 23.8 | 102 | 3.8 | 844 | 317 | 8.4 |
| 13. | Pimburettewa | 830 | 112 | 6.0 | 3.52 | 58.5 | 93 | 11.2 | 539 | 650 | 5.8 |
| 14. | Rajangana | 1600 | 1592 | 6.4 | 3.16 | — | 105 | 6.6 | 638 | 399 | 6.1 |
| 15. | Ridiyagama | 888 | 31 | 3.8 | 2.61 | 19.7 | 26 | 0.3 | 171 | 193 | 6.6 |
| 16. | Senanayaka Samudra | 7825 | 983 | 12.8 | — | — | 54 | 0.7 | 1165 | 149 | 21.6 |
| 17. | Udawalawe | 3362 | 1162 | 15.3 | 1.40 | 12.0 | 41 | 1.7 | 496 | 208 | 12.1 |
| 18. | Weerawila | 570 | 82 | 4.8 | — | — | 8 | 1.4 | 46 | 81 | 5.8 |
| 19. | Yodawewa | 488 | 46 | 2.6 | — | 23.4 | 12 | 2.4 | 77 | 157 | 6.4 |

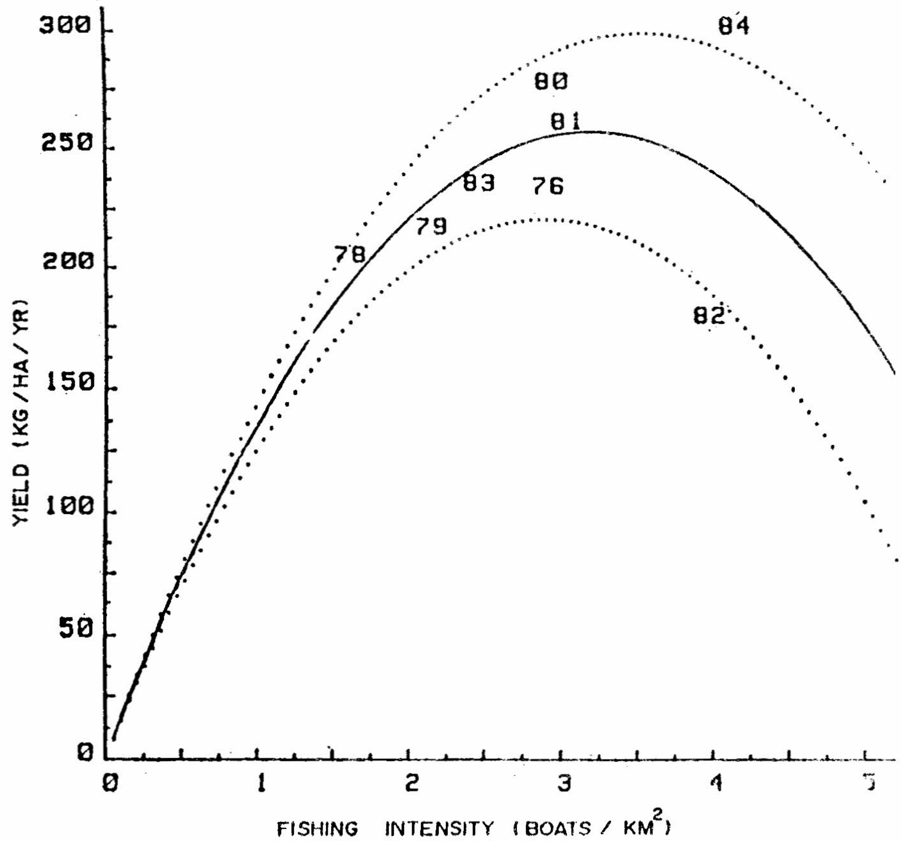


Fig. 3. The relationship of the mean annual yield (kg, ha$^{-1}$, year$^{-1}$) tc fishing effort per unit area (boats, km$^{-2}$) in the Sri Lankan reservoir fishery. Adopted from De Si.va *et al.* (1991a).

In some reservoirs fishers practise beach seining (which is illegal) sporadically. Using a multiple regression technique, an approach similar to the method employed by Marten (1979) to investigate the inshore fishery of Lake Victoria (East Africa), it has been shown that beach seining would lead to diminished returns through depletion of fish stocks (Amarasinghe and De Silva, 1992a).

Stocking of perennial reservoirs to enhance the natural recruitment is another management option for the reservoir fishery in the country. In Sri Lankan major reservoirs, attempts have been made to use Chinese and Indian major carps to increase reservoir production by regular stocking during the last three decades. However as shown in Table 5, the percentage recovery rates of Chinese and Indian carps in Sri Lankan reservoirs are very low.

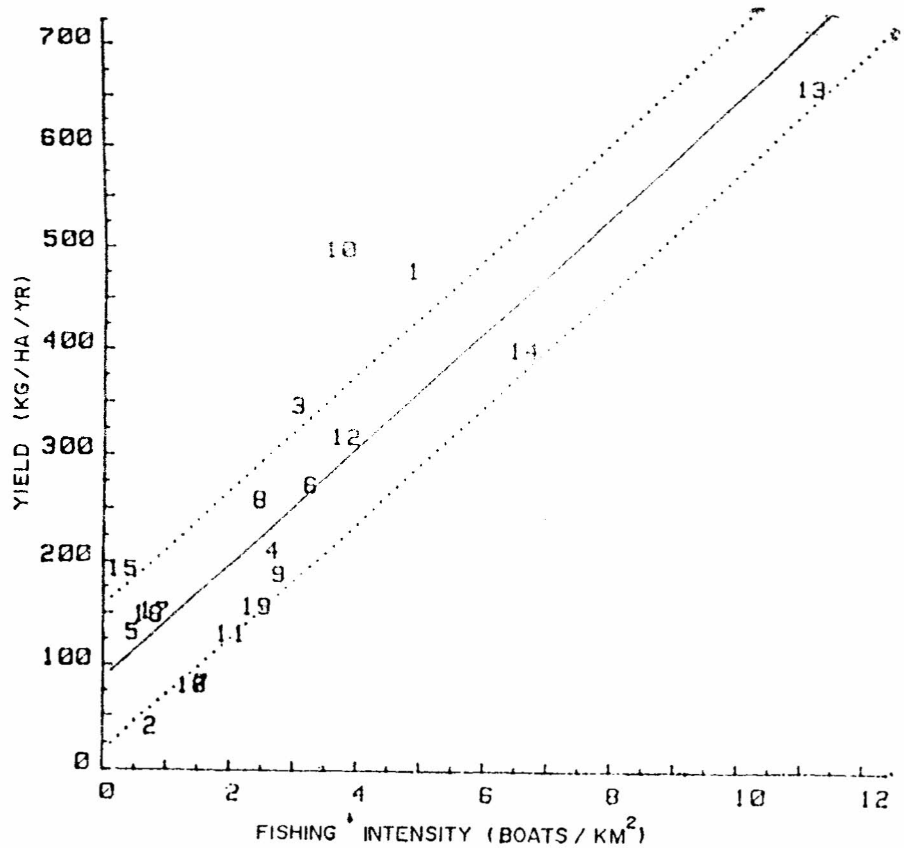


Fig. 4. Relationship of the yield (kg, $ha^{-1}$, $year^{-1}$) to fishing efforts per unit area (boats, $km^{-2}$) for the different reservoirs in Sri Lanka. 1 - Badagiriya ; 2 - Huruluwewa ; 3 - Kalawewa ; 4 - Kaudulla ; 5 - Lunugamwehera ; 6 - Maduruoya ; 7 - Maha kanadarawa ; 8 - Mahawilachchiya ; 9 - Minneriya ; 10 - Nachchaduwa ; 11 - Padaviya ; 12 - Parakrama Samudra ; 13 - Pimburettewa ; 14 - Rajanganaya ; 15 - Ridiyagama ; 16 - Senanayake Samudra ; 17 - Udawalawe ; 18 - Weerawila ; 19 - Yodawewa Adopted from De Silva *et al.* (1991a).

Stocking-recapture fisheries are successfully practised in some countries such as China. The stocking size of carp fingerlings in Chinese reservoirs range between 10 and 13 cm. Sophisticated methods are used for prevention of escape of fish through sluices and intake and the fishing techniques for harvesting fish are very efficient (De Silva *et al.*, 1991b). However in Sri Lankan perennial reservoirs, the initial size of stocking is about 5 cm. Due to the limited pond space in fish breeding stations which are presently owned by the private sector, raising them upto 10 cm is practically difficult. The stocking densities of major carps in Sri Lankan major reservoirs are very low. Also, heavy natural mortality rates due to predation by carnivorous fish species in reservoirs and piscivorous birds may reduce the population sizes of carps stocked in reservoirs. However, as indicated in Table 4, in medium-sized (<1000 ha) where higher stocking densities could be used than in larger reservoirs, fish production could perhaps be increased through stocking. Nevertheless Chandrasoma (1992) has shown that using data of a few reservoirs, stocking of *Labeo rohita* in perennial reservoirs is profitable.

**Table 4. Relationship between annual fish yields (kg ha $^{-1}$) and morphometric, biological and fishery data of Sri Lankan reservoirs. CA = catch ment area (km$^2$); A = reservoir area (ha;) Z = mean depth (m); FI = Fishing Intersity (fishermen km$^{-2}$); Chl = Chlorophyll - a content (mg $^{-1}$). Source : Moreau & De Silva (1991).**

| Relationship | n | $r^2$ |
|---|---|---|
| Yield = 117.5+4.242 (CA/A) | 17 | 0.433 |
| Yield = 71.2+1093 Z | 19 | 0.27 |
| Yield = 88.9+54.6 FI | 19 | 0.749 |
| Yield = 28.2+10.6 Chl | 8 | 0.902 |

As stated by De Silva (1998a), all strategies adopted to increase yield in the inland fishery should aim at providing animal protein at the lowest possible price and not providing a variety of table fish. As such establishing a stocking-recapture fishery is not necessary in major perennial reservoirs of Sri Lanka where ther is a profitable fishery based on exotic cichlids. One can suggest that yield from the stocking recapture fishery, based on major carps could be increased by employing highly efficient fishing methods. However if such highly efficient fishing methods as practised in Chinese reservoirs are used they will lead to overexploitation of the cichlid fish stocks. In Sri Lanka reservoirs.

Recently developed length-based stock assessment methodologies (Pauly and Morgan, 1987 ; Sparre and Venema, 1992) have made possible to select appropriate techniques to assess exploited fish stocks in reservoirs. Consequently, dynamic pool models (Beverton and Holt, 1957, 1966) have success fully been employed to assess the exploited stocks in several reservoirs (Amarasinghe, 1987 ; Amarasinghe *et al.*, 1989; Amarasinghe and De Silva, 1992b).

**Table 5. Recoveryates of the stocked carps in selected reservoirs of Sri Lanka. The weight of an average fish harvested has been assumed to be 3 kg. (Amarasinghe, 1992).**

| Reservoir | Species | Total stocked 1983—87 | Total catch (tons) 1984—88 | No. of fish recovered | % recovery |
|---|---|---|---|---|---|
| Giritale (308 ha) | Bighead | 365,000 | 89.3 | 29,800 | 8.2 |
| | Common carp | 11,000 | 5.0 | 1,700 | 15.5 |
| | Mrigal | 56,000 | 12.9 | 4,300 | 7.7 |
| | Rohu | 148,000 | 38.5 | 12,900 | 8.7 |
| | Silver carp | 25,000 | — | — | — |
| Kaudulla (2713 ha) | Catla | 4,000 | — | — | — |
| | Common carp | 4,000 | — | — | — |
| | Rohu | 10,000 | — | — | — |
| Maduru Oya (6280 ha) | Bighead | 131,000 | 3.5 | 1,200 | 0.9 |
| | Common carp | 24,000 | — | — | — |
| | Rohu | 60,000 | — | — | — |
| Minneriya (2551 ha) | Bighead | 90,000 | 72.6 | 24,200 | 26.9 |
| | Mrigal | 34,000 | 10.6 | 3,500 | 10.3 |
| | Rohu | 135,000 | 58.2 | 19,400 | 14.4 |
| Parakrama Samudra (2262 ha) | Bighead | 64,000 | — | — | — |
| | Catla | 10,000 | 7.4 | 2,500 | 25.0 |
| | Common carp | 92,000 | — | — | — |
| | Rohu | 304,000 | 61.4 | 20,500 | 6.7 |
| Pimburettewa (830 ha) | Bighead | 6,000 | — | — | — |
| | Catla | 2,000 | 2.2 | 730 | 36.5 |
| | Common carp | 72,000 | 1.0 | 300 | 0.4 |
| | Mrigal | 128,000 | 2.9 | 1,000 | 6.2 |
| | Rohu | 34,000 | 13.5 | 4,500 | 13.2 |
| | Silver carp | 86,000 | 36.6 | 12,200 | 14.1 |

According to the yield-per-recruit analyses, the biologically optimum size at first capture of *O. mossambicus*, the dominant fish species in the country's reservoir fishery accounting for over 70% of the landings, is found to be about 20 cm total length (Amarasinghe *et al.*, 1989 ; Amarasinghe and De Silva, 1992b). Also, mean size of *O. mossambicus* and *O. niloticus* which is acceptable to consumer is about 24 cm total length (Amarasinghe, 1987). The gillnet selectivity studies in Sri Lankan reservoirs (Amarasinghe 1988b ; Amarasinghe and De Silva, in press) indicate that the mesh size corresponding to the mean size of *O. mossambicus* which is acceptable to consumer (about 24 cm. ) is about 10 cm.

## Development of a subsidiary fishery for minor cyprinids

Minor cyprinids especially *Amblypharyngodon melettinus, Barbus dorsalis, B. chola* and *B. filamentosus* are abundant in reservoirs of Sri Lanka (Amarasinghe, 1985). They remain unexploited as they are not caught in the gillnets of the existing fishery in which the minimum mesh size is about 7.5 cm. Also, the use of fishing gear other than gillnet is virtually impossible due to the presence of submerged tree stumps in most reservoirs. Experimental fishing trials conducted in a number of reservoirs of Sri Lanka indicated that four species of minor cyprinids which are abundant in reservoir fish fauna viz. *Amblyphaytngodon melettinus, Barbus dorsalis, B. Chola,* and *B. filamentosus* could be exploited using 15 mm to 52 mm mesh gillnets without affecting the existing *O. mossambicus* fishery (Amarasinghe, 1985 ; De Silva and Sirisena, 1987). The annual potential yield of minor cyprinids in Parakrama Samudra is about 632 kg, $ha^{-1}$ (Amarasinghe, 1990) and in some reservoirs in southern Sri Lanka is about 900 kg $ha^{-1}$ (De Silva and Sirisena, 1989 ; see Table 6).

**Table 6. Fishery potential of minor cyprinids in some reservoirs of Sri Lanka.**

| Reservoir (ha) | Fishery Potential (kg, $ha^{-1}$, $yr^{-1}$) | Authority |
|---|---|---|
| Badagiriya (482) | 2191 | De Silva and Sirisena (1989) |
| Lunugamwehera (3023) | 635 | - do - |
| Muruthawela (516) | 35 | - do - |
| Ridiyagama (888) | 1234 | - do - |
| Tissa wewa (234) | 679 | - do - |
| Yoda Wewa (488) | 688 | - do - |
| Parakrama Samudra (2262) | 632 | Amarasinghe (1990) |

Also small-scale fisheries for minor cyprinids are practised in some reservoirs. They have a commercial value as dried fish so that this resource is a potential supplementary source of income for fishers (Amarasinghe 1990). However, these estimated potential yields of minor cyprinids would not perhaps be sustained once the fish populations come into equilibrium with the exploitation (Amarasinghe 1990 ; Amarasinghe and De Silva, 1992c). Nevertheless fish yields in reservoirs could undoubtedly be increased by introducing a small-mesh gillnet fishery for minor cyprinids.

**Implementation of management strategies**

The inland fishers could be divided into two categories, "organized" and "unorganized" and the income of "unorganized" sector is lower than that of "organized" fishers (Chandrasiri 1986.) The fishery regulations could be effectively imposed in the reservoir capture fisheries through well-organized co-operative societies of fishers (Amarasinghe, 1988c).

**Research needs**

Fish production is a secondary use of reservoirs in Sri Lanka which have been constructed primarily for irrigation and/or generation of hydroelectricity. Some evidence is found that fish yields in reservoirs are influenced by water level fluctuations (Welcomme, 1970 ; Beam, 1983 ; De Silva, 1985b). As such there seems to be potential for maximizing fish yields in reservoirs through coordination between irrigational and fisheries authorities. Since reservoir system is an integral part of the rural living, rational utilization of the reservoir resource is useful for maximum socioeconomic benefits.

Development of empirical models for predicting fish yields in reservoirs in extremely important due to the reason that comparative approaches are more useful than detailed assessment of individual reservoirs scattered all over the dry zone of the country. In this context, refining the models already developed ( Wijeyaratne and Amarasinghe, 1987 ; Moreau and De Silva, 1991 ; De Silva *et al.*, 1991a) and developing new models using easily measurable parameters are of vital importance.

Most research on the reservoir fisheries are based on resource-oriented approaches and very few studies are reported on the socioeconomic aspects of the reservoir fisheries in Sri Lanka (Chandrasiri, 1986 ; Amarasinghe, 1988c). Lack of information on socioeconomics has hampered the development of the fishery.

Multi-species approaches such as ecosystem modelling can be used to evaluate the reservoir fisheries in Sri Lanka. This is of importance due to the reason that impact of anthropogenic changes on the reservoir ecosystems can be understood for effective management of the fishery. For example, effect of exploitation of non-conventional fishery resources such as minor cyprinids which has been suggested to be an additional approach for achieving high fish yields in reservoirs (Amarasinghe, 1985, 1990 ; De Silva and Sirisena, 1987, 1989), on the rophic status of reservoirs can be evaluated through ecosystem modelling. New methodologies are available for parameter estimation for ecosystem modelling (Pauly, 1986 ; Palomares and Pauly, 1989 ; Jarre *et al.*, 1990 ; Christensen and Pauly, 1992).

**Present status of the inland fishery and future strategies for management**

In 1990, state patronage for the development of the inland fishery was discontinued Under this government policy however, no restrictions were imposed for the private sector and NGOs to develop the inland fisheries in Sri Lanka. Also field officers have been assigned to carry out extension work pertaining to the capture fisheries in reservoirs such as imposing fishery regulations, organizing fisheries co-operative societies, welfare activities etc. After this policy decision, however the inland fisheries division of the Ministry of Fisheries was closed down and the regional fisheries stations were leased out to private sector. As a result of low priority for inland fisheries development since 1990, there had been no proper monitoring of the reservoir capture fisheries of Sri Lanka so that over-exploitation of fish stocks has been taking place in most reservoirs due to the use of small-mesh ($<$7.5 cm ) gillnets and beach seines.

Despite the absence of state patronage for the development of the inland fisheries in Sri Lanka, the inland fishers in the dry zone are exclusively engaged in fishing in major reservoirs. This is due to the vital importance of the reservoir fishery as a cheap animal protein source for rural communities.

As indicated above, stocking of fingerlings of non-tropical carps and increasing fishing effort are not effective management options for the reservoir fishery of Sri Lanka. As such the main reason for the dramatic decline in the inland fish production from about 39,000 MT in 1989 to about 12,000 MT in 1994 (*Source :* Ministry of Fisheries and Aquatic Resources Development) is not the discontinuation of stocking of fish fingerlings and supply of fishing boats and nets under subsidy schemes but the overfishing of the resource due to the absence of an effective procedure for monitoring the fishery.

This government policy has adversely affected the development of aquaculture in seasonal tanks too. The technology for extensive aquaculture in seasonal tanks which has been developed by the inland fisheries division of the Ministry of Fisheries has not been adequately delivered to the private sector when the policy decision was taken to discontinue government support for inland fisheries development. In the absence of a state-sponsored mechanism to introduce a community-based technology for extensive aquaculture in seasonal tanks, further development of this sub-sector was not possible. However there is a potential that aquaculture in seasonal tanks could be developed through private sector by adopting an approach where private enterprises and farmers can enter into agreement to raise fish under a buy-back scheme (Amarasinghe, 1992a) Such a system is in operation in agricultural sector in which farmers cultivate crops for export and raise poultry where farmers are provided with the inputs and technical advice and then produce is purchased by entrepreneurs at the end of the growing period.

In 1994, Sri Lankan government has made arrangements to revise the short-sighted policy decision which was taken in 1990. Presently inland fisheries and aquaculture development is given a high priority. It is likely that under the exsting fisheries development plans, effective strategies for inland fisheries management be developed because the country has experienced the consequences of mismanagement and unscientific political decision which have been detrimental to the reservoir fishery resources, hence rural economy.

In the dry zone of Sri Lanka, the life styles of the rural communities are significantly dependent on the reservoirs. As such, strategies for the reservoir fishery development in the country should be viewed from the context of rural development. The management plans for inland capture and culture fisheries could be implemented effectively only when the aspirations of the rural communities are identified through socio-economic studies (Amarasinghe, 1988c). As such, research on the development of inland fisheries in Sri Lanka should be deviated from the conventional resource-oriented approaches to the integrated approaches which consider resource component as well as the social component which makes use of the resource. Amarasinghe *et. al.* (1993) have defined a management strategy on this line for the management of the fishery of Minneriya reservoir which is presently being implemented by the Central Environmental Authority, Sri Lanka under a wetland conservation project.

### References

Amarasinghe, U. S., 1985. Studies on the exploitation of minor cyprinids in Parakrama Samudra, a man-made lake in Sri Lanka, using gillnets. *J. NARA (Sri Lanka)*, 32 : 11-23.

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

Amarasinghe, U. S., 1988a. Growth overfishing : a potential danger in the Sri Lankan reservoir fishery. *In* Reservoir Fishery Management and Development in Asia, edited by S. S. De Silva, International Development Reseacrh Centre, Ottawa, pp. 105-112.

Amarasinghe, U. S. 1988b. Empirical determination of a desirable mesh size for the gillnet fishery of *Oreochromis mossambicus* (Peters) in a man-made lake in Sri Lanka. *Asian Fish. Sci.*, 2 : 59-69.

Amarasinghe, U. S., 1988c. The role of fishermen in implementing management strategies in reservoirs of Sri Lanka. *In* Reservoir Fishery Management and Development in Asia edited by S. S. De Silva, International Development Research Centre, Ottawa. 158-163 pp.

Amarasinghe, U. S., 1990. Minor cyprinid resources in a man-made lake in Sri Lanka : a supplementary source of income for fishermen. *Fish Res.*, 9 ; 81-89.

Amarasinghe, U. S., 1992. Recent trends in the inland fishery of Sri Lanka. *In* Baluyut, E. A. (ed.) Indo-Pacific Fishery Commission, country reports presented at the fifth session of the Indo-Pacific Fishery Commission Working Party of Experts on Inland Fisheries, Bogor, Indonesia, 24-29, June 1991 and papers contributed to the Workshop on Tilapia in Capture and Culture-Enhanced Fisheries in the Indo-Pacific Fishery Commission, Countries, Bogor, Indonesia, 27-29 June, 1991. FAO Fisheries Report No. 458, Suppl. Rome, FAO. 84-105 pp.

Amarasinghe, U. S., and S. S. De Silva, 1992a. Empirical approaches for evaluating the efficiencies of different fishing methods in tropical, shallow reservoirs : a Sri Lankan case study. *In* De Silva, S. S. (ed.) Reservoir Fisheries of Asia. International Development Research Centre, Ottawa, Canada. 217-227 pp.

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

Amarasinghe, U. S. and S. S. De Silva, 1992c. Cichlidae verses Cyprinidas : experience from the inland fishery of Sri Lanka. *In* Baluyut, E. A. (ed.) Indo-Pacific Fishery Commission, country reports presented at the fifth session of the Indo-Pacific Fishery Commission Working Party of Experts on Inland Fisheries, Bogor, Indonesia, 24-29 June, 1991 and papers contributed to the Workshop on Tilapia in Capture and Culture-Enhanced Fisheries in the Indo-Facific Fishery Commission Countries, Bogor, Indonesia, 27-29 June, 1991. FAO Fisheries Report No. 458, Suppl. Rome, FAO, 218-237 pp.

Amarasinghe, U. S. and S. S. De Silva, in press. Selectivity patterns in the multi-mesh gillnet fishery for cichlid species in a Sri Lankan reservoir. Proceedings of the Third Asian Fisheries Forum, Asian Fisheries Society Manila. 000-000 pp.

Amarasighe, U. S. and T. J. Pitcher, 1986. Assessment of fishing effort in Parakrama Samudra, an ancient man-made lake in Sri Lanka, *Fish. Res.*, 4 : 271-282.

Amarasinghe, U. S. and J. I. Samarakoon, 1988. Some factors affecting contribution of the cichlid species *Etroplus suratensis* and *Tilapia rendalli* to gillnet catches in a man-made lake in Sri Lanka. *Asian Fish. Sci.*, 2 : 17-26.

Amarasinghe, U. S., W. Benthem and K. W. Jeanes (Editors), 1993. *Wetland Site Report and Conservation Management Plan : Minneriya Reservoir.* Wetland Conservation Project, Central Environmental Authority (Sri Lanka) and Euroconsult (The Netherlands). 92 p.

Amarasinghe, U. S., S. S. De Silva and J. Moreau, 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.

Beverton, R. J. H. and S. J. Holt, 1957. On the dynamics of exploited fish populations. *Fish, Invest. Mist. Agric. Fish. Food G. B.* (2 *Sea Fish*). 19 : 533 p.

Beverton, R. J. H. and S. J. Holt, 1966. Manual of methods for fish stock assessment Part 2. Tables for yield functions. *FAO Fish. Tech. Pap.*, 38 (Rev. 1) : 67 p.

Chandrasiri, J. K. M. D., 1986. *Socio-economic conditions of inland fishermen in Sri Lanka. a pre-project study of five major reservoirs in the Hambantota districts.* Agrarian Research and Training Institute, Colombo, Sri Lanka, 95 p.

Chandrasoma, J., 1992. Performance of Rohu, *Labeo rohita* (Ham.), in some perennial and seasonal reservoirs of Sri Lanka - an evaluation. *J. Appl. Ichthyol.*, 8 : 228-233.

Christensen, V. and D. Pauly, 1992. *A guide to the ECOPATH II software system (versions* 2.1). ICLARM Software 6, 72 p. International Centre for Living Aquatic Resources Management, Manila, Philippines.

De Silva, S. S., 1983. The reservoir fishery : present status and future strategies. *J. Inland Fish., Sri Lanka*, 2 : 3-13.

De Silva, S. S., 1985a. Status of the introduced cichlid *Sarotherodon mossambicus* (Peters) in the reservoir fishery of Sri Lanka : a management strategy and ecological implications. *Aquacult. Fish. Manage.*, 16 : 91-102.

De Silva, S. S., 1985b. Observations on the abundance of the exotic cichlid *Sarotherodon mossambicus* (Peters) in relation to fluctuations in the water level in a man-made lake in Sri Lanka. *Aquacult. Fish. Manage.*, 16: 265-272

De Silva, S. S., 1988a. Reservoirs of Sri Lanka and their fisheries. *FAO Fish. Tech. Pap.*, 298 : 128 p.

De Silva, S. S., 1988b. The reservoir fishery of Asia. *In* : De Silva (ed.) S. S. *Reservoir fishery management and development in Asia.* International Development Research Centre, Ottawa, Canada, 19-28pp.

De Silva,S.S and C. H. Fernando,1980. Recent trends in the fishery of Parakrama Samudra, an ancient man made lake in Sri Lanka. *In:* Furtado (ed.), *Triopical Ecology and Development*, J. I. Kuala Lumpur, Malaysia, University of Malaya Press, pp. 927-937.

De Silva, S. S. and H. K. G. Sirisena, 1987. New fish resources of reservoirs in Sri Lanka : feasibility of introduction of a subsidiary gillnet fishery for minor cyprinids. *Fish. Res.*, 6 : 17-34.

De Silva, S. S. and H. K. G. Sirisena, 1989. New fish resources of reservoirs in Sri Lanka : 3. Results of commercial - scale trials and yield estimates of a gillnet fishery for minor cyprinids. *Fish. Res.*, 7 : 279-287.

De Silva, S. S., J. Moreau, U. S. Amarasinghe, T. Chukajorn and R. D. Gurrero, 1991a. A comparative assessment of the fisheries in lacustrine inland waters in three Asian countries based on catch and effort data. *Fish. Res.*, 11 : 177-189.

De Silva, S. S., Z. Yu and L. H. Xiang, 1991b. A brief review of the status and practices of the reservoir fishery in mainland China. *Aquacult. Fish. Manage.*, 22 : 73-84.

Fernando, C. H., 1971. The role of introduced fish in Ceylon's freshwaters. *In* D. Durffey and A. S. Watt (eds.) *The Scientific management of Animal and Plant Communities for Conservation*, Blackwell Scientific Publications, Oxford, UK. 298-310 pp.

Fernando, C. H., 1977. Reservoir fisheries in South East Asia : past, present and future *Proc. IPFC* 17 (3): 475-480.

Fernando, C. H., 1984. Reservoirs and lakes of Southeast Asia (Oriental region). In: F. B. Taub (ed.) *Lakes and Reservoirs*, Elsevier Publishers, Amsterdam, The Netherlands, 411-446 pp.

Fernando, C. H. and J. Holcik, 1982. Nature of fish communities : a factor influencing the fishery potential of tropical lakes and reservoirs. *Hydrobiologia*, 97 : 127-140.

Fernando, C. H. and H. H. A. Indrasena, 1969. The freshwater fisheries of Ceylon. *Bull. Fish. Res. Stn Ceylon* 20, 101-134.

Jarre, A., M. L. Palomares, M. Soriano, V. C. ucmbilay, Jr., and D. Pauly, 1990. *A user's manual for MAXIMS.* ICLARM Software 4, International Centre for Living Aquatic Resources Management, Manila, Philippines.

Marten, G. G., 1979. Impact of fishing on the inshore fishery of Lake Victoria (East Africa). *J. Fish. Res. Board Canada*, 36 : 891-900.

Moreau, J. and S. S. De Silva, 1991. *Predictive fish yield models for lakes and reservoirs of the Philippines, Sri Lanka and Thailand. FAO Fisheries Technical Paper* 319. Rome : Food and Agriculture Organization.

Oglesby, R. T., 1985. Management of lacustrine fisheries in the tropics. *Fisheries*, 10 : 16-19.

Palomares, M. L. and D. Pauly, 1989. A multiple regression model for predicting the food consumption of marine fish populations. *Aust. J. Mar. Freshwater Res.*, 40 : 259-273.

Pauly, D., 1986. A simple method for estimating the food consumption of fish populations from growth data and food conversion estimates. *Fish Bull.*, 84(4) : 827-840.

Pauly, D. and Morgan (Editors), 1987. *Length based methods in fisheries research.* ICLARM Conf. Proc. 13, 468 p. International Centre for Living Aquatic Resources Management, Manila, Philippines.

Sparre, P. and S. C. Venema, 1992. *Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fish. Tech. Pap.*, 306/1 *Rev.* 1, 376 p.

Wijeyaratne, M. J. S. and U. S. Amarasinghe, 1987. Estimation of maximum sustainable fish yield and stocking densities of fingerlings in freshwater lakes and reservoirs. *Arch. Hydrobiol. Beih.*, 28 : 305-308.