Cey. J. Sci. (Bio. Sci.), Vol. 24, No.2, 1995

ASPECTS OF THE REPRODUCTIVE BIOLOGY AND ECOLOGY OF THE YELLOW MAHSEER *TOR KHUDREE* (SYKES)[1] (OSTEICHTHYES, CYPRINIDAE) OF SRI LANKA

Padma K. de Silva

Department of Zoology, University of Peradeniya, Sri Lanka

ABSTRACT

The reproductive biology and ecology of *Tor khudree* were studied in Mahaweli river for 18 months. *T. khudree* breeds throughout the year, but the breeding is enhanced in the major rainy periods. There are more males in the population than females, with a male to female sex ratio of 1:1.68. The sex ratio first increases and then decreases over the size classes. It may be that the female grows faster than the male. The largest male and female observed were, respectively, 47.0 cm and 60.1 cm in total length. Mean maturity size of male is 20.4 cm, whereas that of female is 41.0 cm. The fecundity was estimated to vary from 10,404 to 23,436 in the total length range 40.1 to 60.1 cm, and appears to be related to the length. The mature ova measured 2.1-2.6 mm. Egg size-frequency distribution shows about four modes indicating that the fish breeds more than once in a breeding season. The presence of partially spawned females with widely differing numbers of mature eggs indicates that *T. khudree* is a serial spawner, laying the batch of mature eggs over a period of several days. Mature fish ascending streams for spawning were observed, but the presence of partially spawned females in the littoral of Victoria reservoir indicates that the fish spawns in the lake littoral as well.

INTRODUCTION

Several species of Mahseer (*Tor* spp.) are found distributed mainly in India and adjacent areas. The principal ones of these are *T. khudree* (Sykes), *T. mosal* (Hamilton), *T. mussullah* (Sykes), *T. putitora* (Ham.), *T. tor* (Ham.). *T. khudree* has a wide distribution in the peninsular India and occurs in the northern parts of India such as Narbada, Gujarat, Uttar Pradesh and Orissa as well (Kulkarni & Ogale, 1978). The Sri Lankan Mahseer is sometimes recognised as a subspecies of *T. khudree*, namely, *T. khudree longispinnis*, which is endemic to the island (see Taxonomic Note). It is mostly found in the hill streams of the wet zone of the country, but has also been recorded in the rivers of low country wet zone and also in the dry zone Irrigation reservoirs and rivers.

[1]Taxonomic note: The species found in Sri Lanka apparently had first been described as *Barbus longispinnis* by Günther (1868). Deraniyagala (1930) assigned the specimens of *Tor* that he collected to *Tor tor*, probably the same species as Günther's *B. longispinnis*. Later, Deraniyagala (1952) changed the identification of his *T. tor.* to *T. khudree longispinnis*. Mendis & Fernando (1962) apparently followed Deraniyagala (1952) in identification of the species. This identification has recently been questioned by Pethiyagoda (1991). The identification of the fish species in this work follows that of Deraniyagala (1952) and Mendis & Fernando (1962) and therefore should be regarded as tentative.

T. khudree is the largest indigenous cyprinid in the island, and perhaps the largest indigenous freshwater fish in Sri Lanka. It grows to more than 75 cm in length and could weigh above 10 kg (Deraniyagala, 1952). (In India, a 42 kg *T. khudree* has been recorded in 1978 in Cauvery basin (Kulkarni & Ogale, 1978)). So far no detailed work has been published on the reproductive biology or ecology of this fish species in Sri Lanka, although Deraniyagala (1952) made some important observations on these aspects. The present paper reports some of the observations made on the reproductive biology and ecology of *T. khudree*, in Mahaweli river.

MATERIALS AND METHODS

Habitat

Reproductive biology of the fish species was studied in the upper parts of Mahaweli river (Fig.1). The study was carried out from June 1986 to May 1987 in the streams and the main river in Ginigathena area (Fig.1), where the juveniles were commonly found. However, the number of breeding adults available in the area was limited, and therefore, the study was extended to the Victoria reservoir (Fig.1) and environs during the period January to December 1987. The Ginigathena sampling area was situated at an elevation of about 690 m (7°00'N,80°30'E). The sampling area of the Victoria reservoir (which was created by damming the Mahaweli river) was situated in the area in which its major tributary "Hulu ganga" opens into the reservoir at an elevation of about 430 m a.s.l. (7°20'N, 80°44'E). The river at the Ginigathena sampling area was 10-15 m wide and the substratum of the river as well as that of the streams was mostly stony and/or sandy. The water flow was moderate (5-15 cm sec^{-1}) and the river was 1.0-1.5 m deep in the sampling region, and contained several dense patches of the submerged exotic aquatic weed *Elodea canadensis*. Aufwuchs were common on the substratum in the areas with slow water flow. The Hulu ganga sampling area was part reservoir, part river, with a substratum containing rocks and boulders.

Sampling

Monthly samples were obtained from the Ginigathena sampling area using a cast net of 1 cm stretched mesh size and a hand net of 1 mm mesh size. Fish were injected with 10% formalin into the body cavity immediately after capture, and the entire sample was preserved in 10% formalin.

Most of the specimens in the samples in this area consisted of immature fish, although some adults were caught in the main river. Therefore, larger specimens were obtained from the "Hulu ganga" sampling area. The samples from this second sampling area were obtained mainly from the fishermen's catch during the period January 1987 to December 1988. These fishermen set the gill nets around midnight and hauls them early morning. The nets are set in the mouths of feeder streams and shallow areas in the reservoir. Fish were obtained early morning as soon as the fishermen reached the shore and were injected with formalin as soon as they were collected. In addition to these, some samples were obtained from the Hulu ganga area during daytime using gill nets.

During each sampling session in Ginigathena station, the temperature, pH, conductivity and concentration of dissolved oxygen of water were measured using calibrated portable electronic meters. The speed of water flow was estimated by noting the time taken by a floating cork to travel a specified distance along the middle of the stream. Monthly mean depth of water was calculated by measuring the depth at 1 m intervals along a line transect at each site. The rainfall data were obtained from the Meteorological Station at Blackwater Tea Estate, which is situated at the same elevation about 2 km away from the sampling site. Important physico-chemical parameters of water of Victoria reservoir near the Hulu ganga tributary were also measured monthly in a manner similar to that used in Ginigathena area. The rainfall data for Victoria reservoir area was obtained from the Victoria power station.

Analyses

Initially, each mature fish was examined externally for the extrusion of milt or eggs by applying slight pressure on to the belly. The total and standard lengths of each fish (mature and immature) were measured to the nearest 1 mm and each fish was weighed to the nearest 10 mg. The gonads were dissected out, weighed to the nearest 1 mg and the stage of development noted. Gonads, especially ovaries, were categorised into six stages, which were more or less similar to the stages as described by Nikolskii (1963).

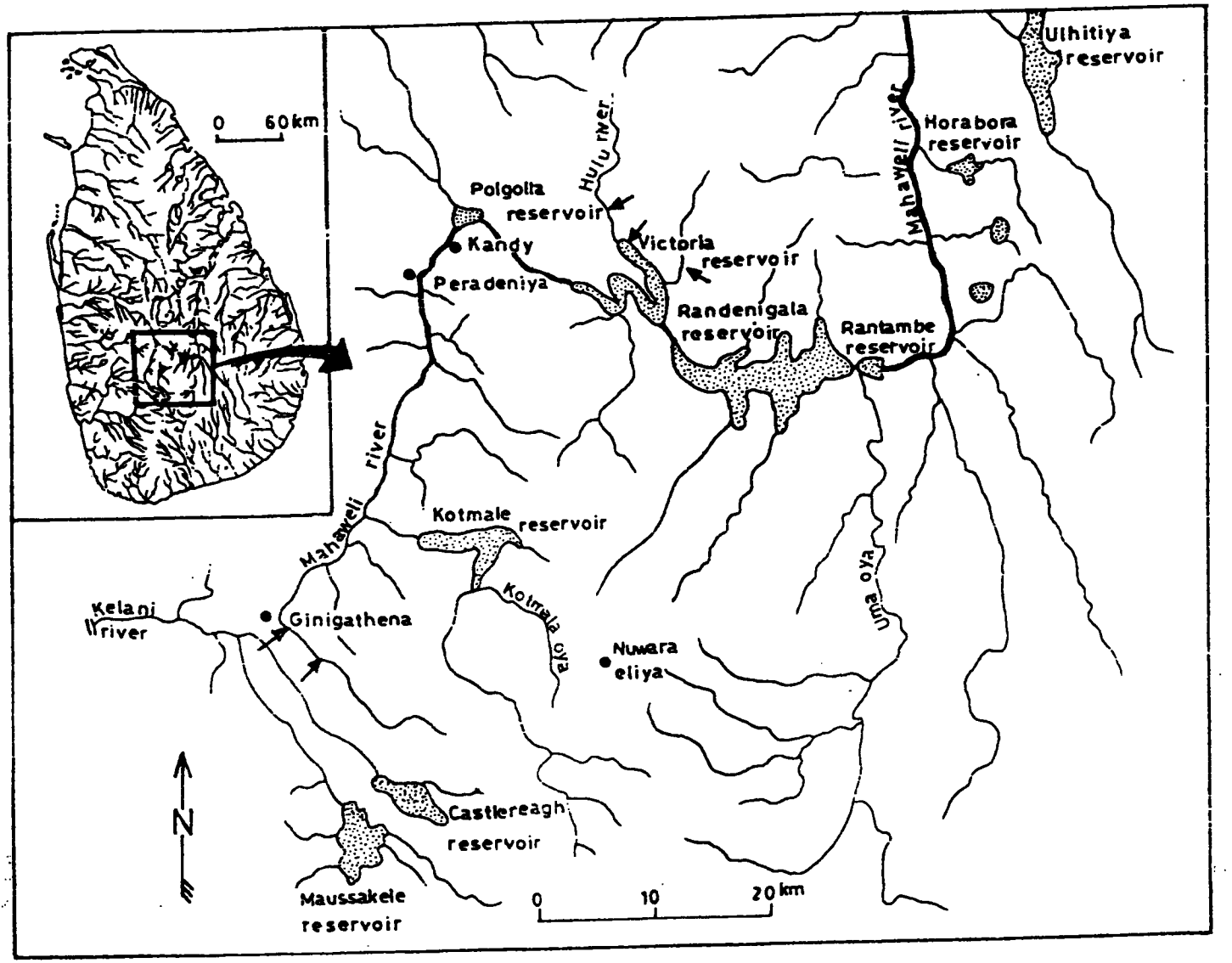

Fig. 1 - Sampling areas (indicated by arrows) of Mahaweli river

The fecundity was estimated using ovaries of stage V. These ovaries were placed in Gilson's fluid, in order to separate ova. The number of ova in each ovary was estimated by counting suitable sub-samples. The diameter of mature as well as immature eggs were measured under a stereo microscope using a graduated ocular lens. Gonado-somatic index (GSI) (i.e. the weight of gonad as a percentage of the body weight) was estimated for each fish of Stages III-VI.

RESULTS

Limnological characteristics of habitat

Monthly temperature, pH and conductivity in the Ginigathena sampling area as well as those of Victoria reservoir near the Hulu ganga tributary, as measured during the sampling period, are shown in Fig.2. The dissolved oxygen concentration remained high in both habitats throughout the year, varying from 7.8 to 9.8 mgl^{-1} in Ginigathena sampling area and from 6.5 to 8.9 in Hulu ganga sampling area.

Population

The largest male obtained from the Ginigathena area during the study period was a male measuring 28.4 cm in total length, while the largest female caught obtained from the area measured 30.4 cm in total length. The largest male and female obtained during this study from the Hulu ganga area during the study period measured 47.0 cm and 60.1 cm in total length, respectively.

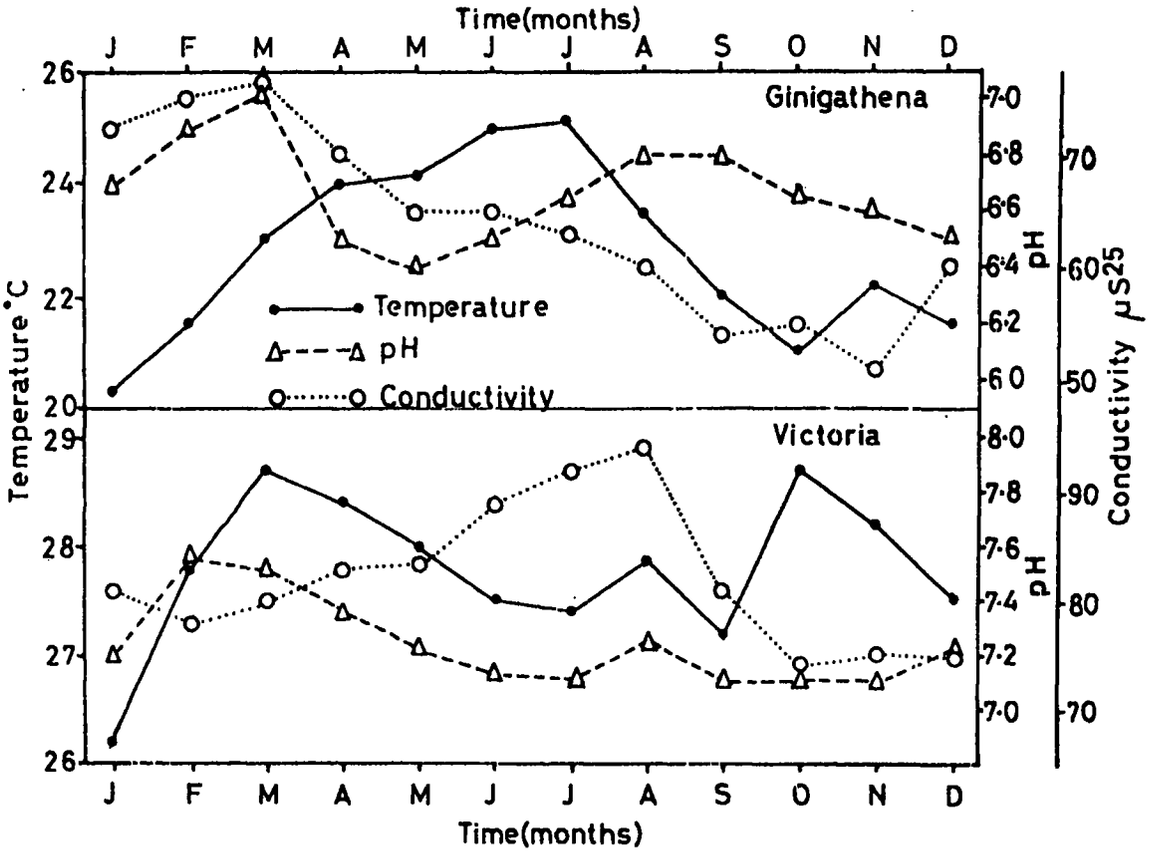

Fig. 2 - Monthly variation of temperature, pH and conductivity of waters in the sampling areas

Sex ratio

Monthly male:female sex ratio was always favouring males and varied from 1:1.12 (n=36) (January) to 1:4.14 (n=36) (March). The overall male:female sex ratio of the pooled samples of 18 months was 1.68 (n=394). When a test for goodness of fit was carried out, the monthly sex ratio was found to deviate significantly from the expected ratio of 1.0 (χ^2=19.23, d.f.=10, n=394, P<0.05). However, the deviation of the monthly ratio from the overall ratio of 1.68 was much less significant (χ^2=5.214, d.f.=10, n=394,P>0.75).

The sex ratio of individual length classes varied from class to class increasing from 0.95 in the size class 0-4.9 cm up to a maximum of 1.91 in the size class 25.0-29.9 cm.

Gonad development and Spawning cycle

Both males and females of the maturity stages IV-VI occurred during all months, but the number of fish in stage IV to VI were high during the periods of April to May and October to December (Table 1). This suggests that breeding occurs during most of the months, if not throughout the year, but it is especially enhanced during the periods of April to May and October to December. Small fingerlings (total length <5 cm) were also observed during all months. The monthly gonado-somatic index (GSI) of females was high during March and during the period of August to November, two peaks occurring in March and September (Fig. 3). After reaching the peak values, it came down during the periods of April-May and October-December. The lowering of the GSI occurred especially during the high rainy periods (Fig. 3). Therefore, it appears that the breeding of *T. khudree* is enhanced during the high rainy periods.

Mean size at Maturity

The smallest mature male (Stage V) was 14.5 cm in total length and the smallest mature female was 35.2 cm in total length. However, the mean size at maturity (Stage V and VI) was 20.4 cm males and 41.0 cm for females (Fig. 4).

Table 1

Monthly frequency of gravid, spawning and post-spawning (Stages IV, V, VI) individuals among the mature (Stage III onwards) individuals

Month	Frequency	
	Male	Female
January	.33	.45
February	.40	.36
March	.60	.50
April	.67	.67
May	.50	.67
June	.20	.20
July	.33	.33
August	.33	.40
September	.67	.56
October	.70	.86
November	.75	.91
December	.67	.76

Egg diameter distribution

Egg diameter distribution of Stage V ovaries (Fig. 5) shows the presence of more than one mode. Usually, three to four batches of eggs of different diameters were seen. The mature eggs probably ranged in diameter from 2.1-2.6 mm (Fig. 5). The occurrence of several modes in the egg-frequency distribution indicates that the fish spawns more than once during a particular season. The

occurrence of partially spawned females with different number of mature eggs indicates that the female does not spawn all her mature eggs all at once but release them in batches over a period of several days.

Fecundity

Fecundity was found to vary from 10,404 to 23,436. Sometimes the ovaries of Stage V contained much lesser number of eggs than could be expected from the body size. This indicates that the fish does not release all mature eggs at once but spawns over several days. Because of this, the lower limit of the fecundity was difficult to estimate. Thus, it was difficult to distinguish between ovaries at Stage V (ready to spawn) and those at Stage V/VI (partially spawned). The relationships between the fecundity (F) and the total length in cm (L) was found to be

$$F=156.33L^{1.15}(r^2=0.37,n=23)$$

However, in estimating the fecundity, the ovaries in stages V/VI (i.e. partially spawned) may have been taken into account. For instance, in Fig 6, the ovaries of the fishes of total lengths 49.2, 50.6, 51.3 and 58.0 cm (the points that are encircled) had very low fecundities and may have been partially shed ovaries. If these points are not taken into account, then the relationship becomes

$$F=66.47L^{1.39}(r^2=0.70,n=19)$$

and has a much higher correlation coefficient.

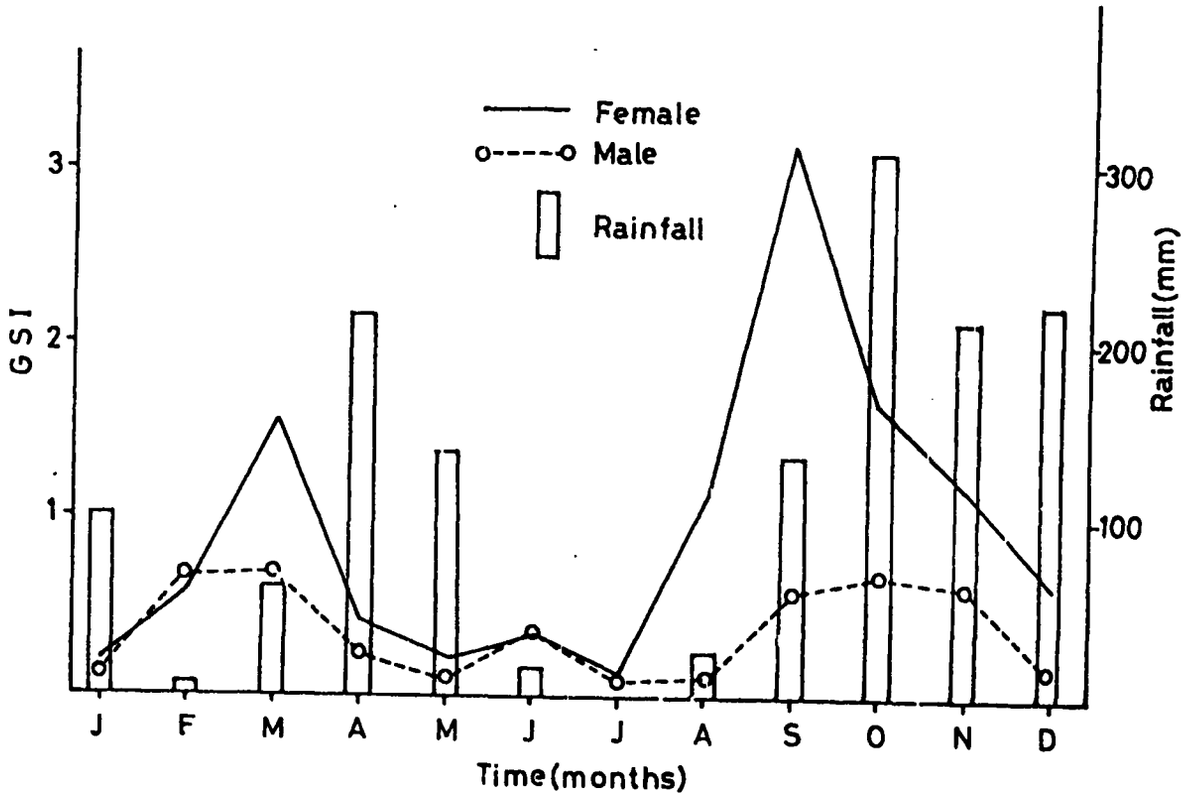

Fig. 3 - Monthly gonado-somatic index (GSI) of males and females. Monthly rainfall is also indicated

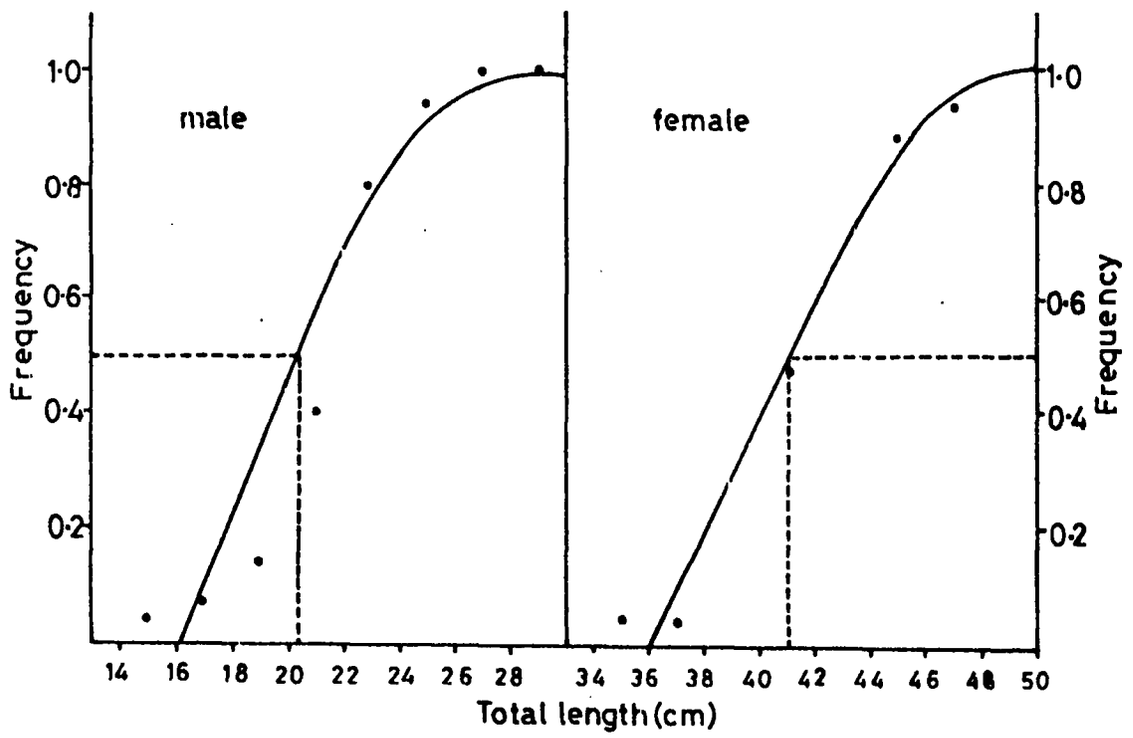

Fig. 4 - The frequency of mature males and females in different size classes. The mean size at maturity is taken as the size at which 50% are mature (broken lines)

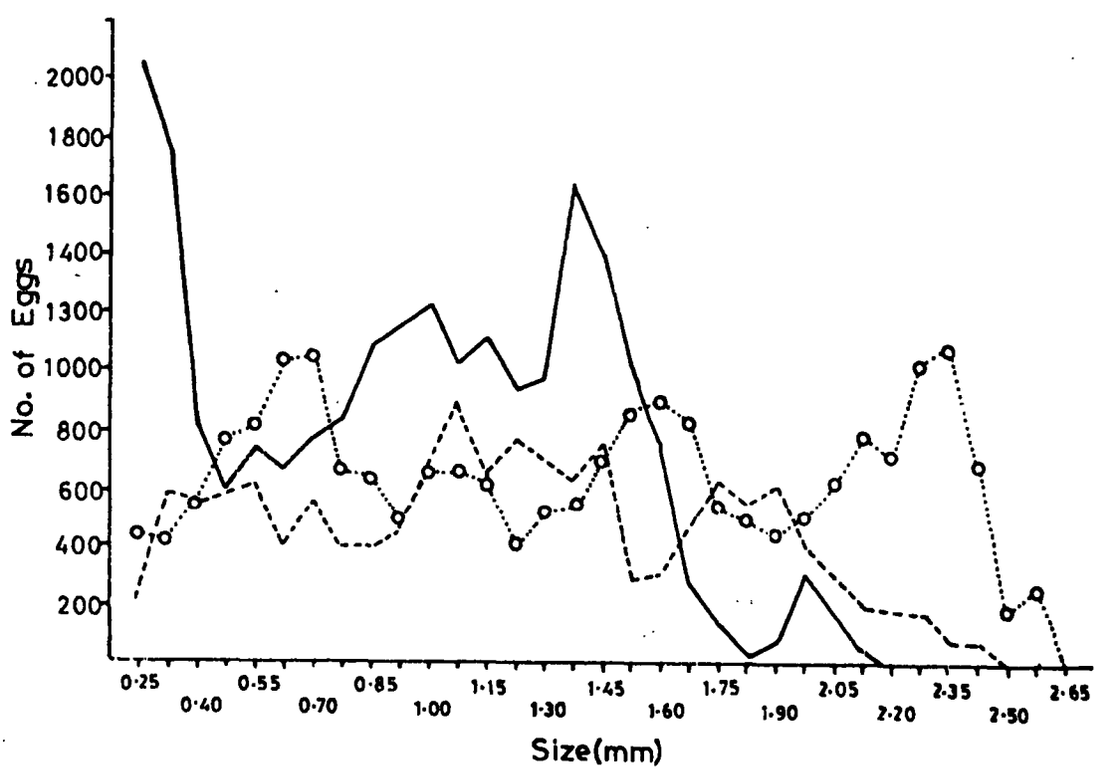

Fig. 5 - Diameter-frequency distribution of mature eggs of three females. Note the three or four modes in each females

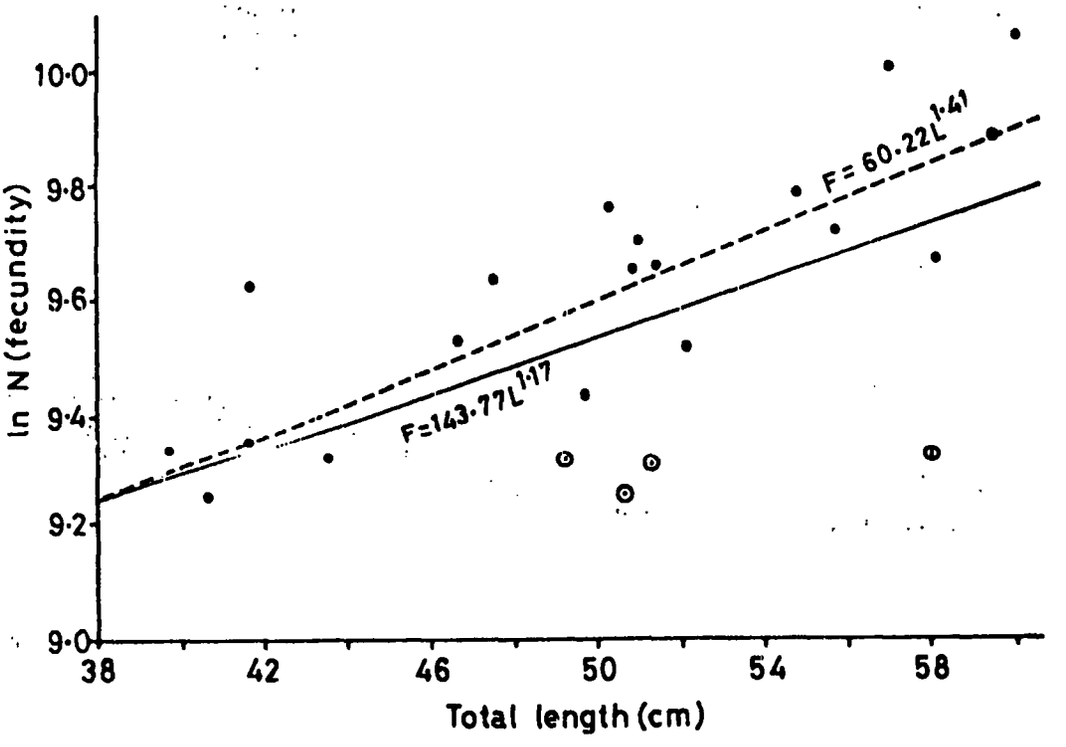

Fig. 6 - Total length - fecundity relationship. (The relationship represented by the broken line, which has a high correlation coefficient, is obtained by disregarding the ncircled points)

DISCUSSION

Freshwater fish in the tropical region could be expected to breed throughout the year as there are no clear-cut seasons as in the temperate region. Despite the absence of clear-cut climatic seasons, the pattern of rainfall could impose some seasonality in the breeding activities of tropical freshwater fish. Thus,the breeding of tropical freshwater fish species could be seasonal or continuous with or without peak activities in certain months, and the breeding is usually related to the monsoons (Welcomme, 1985; Lowe-McConnell, 1987).

The mahseers (*Tor* spp.) have been described to have continuous breeding or seasonal breeding depending on the locality (Table 2). The Sri Lankan mahseer in the areas studied appears to breed during most of the months, if not all, because mature individuals with ripe gonads and small juveniles (fingerlings) were found throuhout the year. However, the frequency of females of developmental stages IV-VI and the GSI of different months indicate two peak breeding activities from April to May and from October to December, both periods experiencing heavy rains. Mahseer species in India also show seasonal breeding or increased breeding during the rainy months (Karamchandani *et al.* 1967; Kulkarni & Ogale, 1978; Nautiyal, 1984). In fact, all indigenous cyprinids of Sri Lanka so far studied (*Puntius* spp.) appear to breed throughout the year, although, in most species, there appear to be breeding peaks in some months (De Silva & Kortmulder, 1977; Chandrasoma & De Silva, 1981; De Silva *et al.*, 1985; de Silva & Somarathna, 1994). For instance, Chandrasoma & De Silva (1981) showed that although *P. sarana* spawns throughout the year in Parakrama Samudra reservoir, it has a clearly marked breeding peak during the rainy season.

Mahseer species in India are known to ascent rivers for spawning (David, 1953; Nautiyal & Lal, 1984). *Tor khudree* of Sri Lanka is also said to ascent rivers for spawning. For instance, Willey (1903) stated that the Sri Lankan mahseer travels long distances up stream during the monsoon rains for spawning. Deraniyagala (1952) and Pethiyagoda (1991) also report that the mature fish ascend streams for spawning. Deraniyagala (1952) gives a brief description of the spawning process. During the

present study, mature fish with Stage V ovaries were caught in upstream of Hulu ganga tributary as well as in Mahaweli river above the sampling area of Ginigathena. In other river systems also (e.g. Gin and Kalu river systems), partially spawned fish (Stage V/VI), as observed by their low number of mature ova compared to high number of ova in others from the same locality in the same season, were found in shallow streams in the upper reaches (P.K. de Silva, unpublished data). These observations indicate that *T. khudree* of Sri Lanka does ascend rivers for spawning. However, nests or the spawning activity were not observed during the present study. Partially spawned fish (Stage V/VI) were also caught in the shallow areas (lake littoral) of the Victoria reservoir. This indicates that the fish may be spawning in the littoral region of the reservoir itself, without ascending the rivers. Both *Tor tor* and *T. putitora* are also shown to spawn in the shallow littoral of Lake Bhimtal in North India (Pathani, 1981), although both species are known to ascend rivers for spawning in other areas (Nautiyal & Lal, 1984).

Ascension of rivers for spawning appears to be a characteristic especially of those mahseers that have seasonal spawning. These may have separate feeding and breeding (and over-wintering) grounds (Pathani, 1981). Mahseers ascend rivers to cooler waters for spawning. In Sri Lanka also the hill streams in the mountains have a lower temperature. The change in temperature in rivers (and streams) and the dilution of lake water by rain water during the monsoons are said to trigger the breeding response in North Indian Mahseers (David, 1953; Desai, 1973; Nautiyal, 1984). In Sri Lanka, however, the seasonal water temperature changes are within a very low range. The seasonal changes in day-length is also not marked. The annual range of water temperature in Mahaweli river in Ginigathena area was only 20.3°-25.1°C, whereas that of Victoria reservoir in Hulu ganga tributary region ranged only from 26.4° to 28.7°C, and these changes occurred quite gradually. Although the rain was distributed throughout the year, there were two peak rainy periods during the inter-monsoon periods of April-May and October-December. The temperatures are high during April-May (and in October in Victoria region) (Fig.2). The enhanced breeding observed in April-May and October to December may indicate that the fish responds to dilution of river/reservoir water by rain water. The optimum temperature ranges for the breeding of *T. tor* and *T. putitora* have been given as 19.9°-28.4°C (Desai, 1973) and 21°-25°C (Nautiyal, 1984). The ranges observed in the Sri Lankan habitats studied are within the optimum ranges given for these two species, and may be within that of *T. khudree* as well.

The deviation of the sex ratio from the expected ratio of 1.0 in fish populations has been observed in several fish species, in some male predominating and in others female predominating. For instance, as has been observed in the present work, males predominated in *P. vittatus* population in the river Kalu (De silva *et al.*, 1985). On the other hand, a preponderance of females has been observed in *P. sarana* in the Parakrama Samudra reservoir (Chandrasoma & De Silva, 1981). A male to female ratio closer to 1.0 was reported in *P. bimaculatus, P. titteya* and *P. dorsalis, P. cumingii* and *P. nigrofasciatus* (De Silva *et al.* 1985, although de Silva & Somarathna (1994) reported female predominating populations of *P. cumingii* and *P. nigrofasciatus.*

Change of sex ratio with body length is known in several species and has been attributed to differential growth and/or maturity of males and females (Nikolskii, 1965; De Silva *et al.* 1985, de Silva & Somarathna, 1994). The higher percentage of males in the lower size groups (upto 35 cm TL) may indicate a higher growth rate of females, since there is no reason why there should be a higher selective mortality of females in these size groups. However, the higher percentage of males in the population indicates that the mortality rate of females is higher, especially since the sex ratio of the lowest size classes is not significantly different from 1.0. Preponderance of females in higher size groups has been shown in *T. putitora* (Nautiyal, 1984) as well as in several other cyprinids such as *P. bimaculatus, P. dorsalis, P. vittatus* (De Silva *et al.*, 1985), *P. sarana* (Chandrasoma & De Silva, 1981) and *P. stigma* (Qayyum & Qasim, 1964); however, in *P. titteya,* there were more males then females in the higher size classes (De Silva et al. 1985).

The fecundity of *Tor khudree* was found to be much less than that of both *T. putitora* and *T. tor* (Table 2). This may be because of the smaller size of *T. khudree* compared to the size of the other two species (Table 2). The observed widely varying fecundities of Stage V females of similar length may be due to all mature eggs being not released at a single occasion but over several days. Therefore, *T. khudree* of Sri Lanka appears to be a serial spawner as well.

Table 2
Some breeding characteristics of mahseers of Sri Lanka and India

Species	Study area	Spawning season	Fecundity	Size (mm)	Authority
Tor tor	Narmada river, N.india	July-March	7,000-101,600	283-750	Desai (1973)
	Narmada river, N.India	July/August to December	6,667-43,610	290-750	Karamchandani *et al.*, (1967)
	Lake Bhimtal, N.India	April-September			Pathani (1981)
T. putitora	Nayar river, N.India	July-September	29,633-98583	780-1377	Nautiyal (1984) Nautiyal & Lal (1983)
	Lake Bhimtal N.India	May-September	7,076-18,525	339-517	Pathani (1981)
	Bhakra reservoir N.India	throughout year			Bhatnagar (1964)
	Aligarh, N. India	greater part of the year			Qasim & Qayyum (1964)
T. khudree	Lonavla lakes Eastern India,	July-August	20,000	630	Kulkarni & Ogale (1978)
	Mahaweli river, Sri Lanka	throughout year,with two peaks	10,404-23,436	393-601	present work
T. mussullah	Cauvery river Southern India	November			David (1953)

Multiple peaks in the egg diameter-frequency distribution suggest that *T. khudree* in Sri Lanka is a multiple (or batch) spawner in which successive batches of eggs become mature as the previous ones are relased. When one batch of eggs is at Stage V and ready to be ovulated the next batch is already at Stage III or higher so that batches of eggs can be released at frequent intervals. In fact, Willey (1903), by examining the ovaries inferred that the mahseer of Sri Lanka spawns several times in a season. The egg size distribution indicates that the Sri Lankan mahseer may breed four times within a few weeks or months. It may be that after such intense spawning activity there is a rest period of several months after which the fish is ready to spawn again. The occurrence of breeding peaks indicates that there are such rest periods at least in some individuals. Pathani (1981) also showed four batches of eggs at different stages of development in both *T. tor* and *T. putitora.* Desai (1981) showed that *T. tor* may be spawning four times during the breeding season.

Breeding pattern of the same mahseer species (eg. *T. putitora)* has been shown to vary depending on the locality (ie. due to changes in environmental factors). *T. putitora* in India breeds annually in the northern tributaries of river Ganges (Nautiyal, 1984), twice per year in rivers in the Himachal Pradesh (Sehgal *et al.*, 1971), three times per year in rivers in Punjab (Khan, 1939) and throughout the year in Bhakra reservoir (Bhatnagar, 1964). However, because of the rather uniform temperature pattern in the small island, the temperature is unlikely to be an important factor in determining the breeding or enhanced breeding seasons. Although the pattern of rainfall is important in determining the breeding or enhanced breeding periods, given the high rainfall with the major rainy

season falling during the period October to December throughout its range of hill zone and the foot hills, it is unlikely that the mahseer in different parts of Sri Lanka would show much variation in the breeding pattern.

ACKNOWLEDGEMENTS

Thanks are due to Ms. Damayanthi Amerasinghe for collecting some of the materials and also for helping with laboratory work. The help of Mr. T.S.B.Alagoda, Department of Zoology, University of Peradeniya, in preparing the figures is gratefully acknowledged. This work was partially supported by the grant No.RG/86/B/2 of Natural Resources, Energy and Science Authority (NARESA) of Sri Lanka.

REFERENCES

Bhatnagar, G.K. (1964). Spawning and fecundity of Bhakra reservoir fishes. *Indian J. Fish.*, **11**: 485-502.

Chandrasoma, C. and De Silva, S.S. (1981). Reproductive biology of *Puntius sarana*, an indigenous species, and *Tilapia rendalli*, an exotic, in an ancient man-made lake in Sri Lanka. *Fish Management*, **12**: 17-28.

David, A. (1953). Notes on the bionomics and some early stages of the Mahanadi mahseer. *J. Asiatic Soc., Calcutta*, **19**: 197-209.

Deraniyagala, P.E.P. (1930). The Evantognathi of Ceylon. *Spolia Zeylanica*, **16**(1): 1-41.

Deraniyagala, P.E.P. (1952). *A Colored Atlas of Some Vertebrates from Ceylon. Vol.1.* Ceylon National Museums, Colombo. 147 pp.

Desai, V.R. (1973). Studies on fishing and biology of *Tor tor* (Ham.) from River Narbada. *Proc. Indian Nat. Sci. Acad.* **39(B)**: 228-248.

de Silva, K.H.G.M. and Somarathna, R.M.D. (1994). Food and feeding biology of the endemic carplets *Puntius cumingii* and *B. nigrofasciatus* (Osteichthyes, Cyprinidae) of Sri Lanka. *Ceylon J.Sci.(Bio Sci.)*, **23**: 12-24.

De Silva, S.S. and Kortmulder, K. (1977). Some aspects of the biology of three species of *Puntius* (=*Barbus*) (Pisces, Cyprinidae), endemic to Sri Lanka. *Neth. J. Zool.*, **27**(2): 182-194.

De Silva, S.S., Schut, J. & Kortmulder, K. (1985). Reproductive biology of six *Barbus* species indigenous to Sri Lanka. *Environmental Biology of Fishes*, **112**(3): 201-218.

Günther, A. (1868). *Catalogue of the fishes in the British Museum.* 7. British Museum, London, xx+512pp.

Karamchandani, S.J., Desai, V.R., Pisolkar, M.D. and Bhatnagar, G.K. (1967). Biological investigation of the fish and fisheries of the Narmada river (1958-1966). *Bull. Inlnd. Fish Res. Inst.* **10**: 1-39.

Khan, H. (1939). Study of the sex organs of mahseer (*Barbus tor*). *J. Bombay nat. Hist. Soc.*, **40**:653-656.

Kulkarni, C.V. and Ogale, S.N. (1978). The present status of mahseer (fish) and artificial propagation of *Tor khudree* (Sykes). *J. Bombay nat. Hist. Soc.* **75**: 651-660.

Lowe-McConnell, R.H. (1987). *Ecological studies in tropical fish communities.* Cambridge University Press, Cambridge, 381 pp.

Mendis, A.S. and Fernando, C.H. (1962). A Guide to the Freshwater Fauna of Ceylon. *Bull. Fish. Res. Stn., Ceylon*, **12**: 1-160.

Nautiyal, P. (1984). Natural history of the Garhwal Himalayan Mahseer *Tor putitora* (Hamilton). II. Breeding Biology. *Proc. Indian Acad Sci. (Anim. Sci.)*, **93**: 97-106.

Nautiyal, P. and Lal, M.S. (1983). Fecundity of the Garhwal Himlayan Mahseer *Tor putitora* (Ham.). *J. Bombay nat. Hist. Soc.*, **82**: 253-257.

Nautiyal, P. and Lal, M.S. (1984). Preliminary observations on the migratory behaviour of the Garhwal Himalayan Mahseer. *J. Bombay nat. Hist. Soc.* **81**: 204-208.

Nautiyal, P and Lal, M.S. (1985). Studies on the natural history of the Garhwal Himalayan Mahseer *Tor putitora* (Hamilton). I. Maturation. *Indian J. Phy. Nat. Sci.* 5(A): 36-43.

Nikolskii, G.V. (1963). *The Ecology of Fishes*. (translated from Russian). Academic Press, London. 352pp.

Nikolskii, G.V. (1965). *Theory of Fish Population Dynamics, as the background for rational explanation and management of fishery resources* (translated from Russian). Oliver & Boyd, Edinburgh, 320pp.

Pathani, S.S. (1981). Studies on the spawning ecology of Kumaun Mahseer *Tor tor* (Hamilton) and *Tor putitora* (Hamilton). *J. Bombay nat. Hist.Soc.* **79**: 525-530.

Pethiyagoda, R. (1991). *Freshwater Fishes of Sri Lanka.* Wildlife Heritage Trust of Sri Lanka, Colombo. 362pp.

Qasim, S.Z. and Qayyum A. (1964). Spawning frequencies and breeding seasons of some freshwater fishes with special reference to those occurring in the plains of Northern India. *Indian J. Fish.* **8**: 24-43.

Qayyum, A. and Qasim, S.Z. (1964). Studies on biology of some freshwater fishes. II. *Barbus stigma* (Cuv. & Val.). *J. Bombay nat. Hist. Soc.* **61**: 330-344.

Sehgal, K.L., Shukla, J.P. and Shah, K.L. (1971). Observations on fisheries of Kangra valley and adjacent areas with special reference to mahseer and other fishes. *J. Inland. Fish. Soc.*, **3**: 63-71.

Welcomme, R.L. (1985). River Fisheries. *FAO Fisheries Technical Paper* No.**262**. 330pp.

Willey, A. (1903). The mahseer and the murrel of Ceylon. *Spolia Zeylanica*, 1(3): 19.