Asian Fisheries Science **14** (2001): 343-351
ISSN: 0116-6514
https://doi.org/10.33997/j.afs.2001.14.3.011

Asian Fisheries Society, Manila, Philippines

Abundance and Aspects of the Reproductive Biology of Common Carp *Cyprinus carpio* in an Upland Reservoir in Sri Lanka

S. NATHANAEL[1] and U. EDIRISINGHE[2]

[1]*Department of Biology*
Faculty of Applied Sciences
Rajarata University
Polgolla, Sri Lanka

[2]*Department of Animal Science*
Faculty of Agriculture
University of Peradeniya
Peradeniya, Sri Lanka.

Abstract

During the period 1984 to 1990, Victoria, a newly impounded hydroelectric reservoir in Sri Lanka, was stocked with different exotic fish species to augment fish production as a secondary use of the reservoir.

A marked increase in relative abundance and CPUE (catch per unit effort) of common carp by the end of 1998, indicates successful natural recruitment to the fishery. The reproductive pattern based on fluctuations of the mean monthly gonadosomatic index (GSI) showed that gonad maturation and spawning were significantly correlated (r_s=0.5638; $p<0.05$)) to rainfall. During peak breeding, the water temperature, pH, total alkalinity, hardness, conductivity, and dissolved oxygen concentrations ranged from 24.4 to 26.0^{0}C, 6.9 to 8.1, 39 to 79 mg·l^{-1}, 44 to 72 mg·l^{-1}, 53 to 70 µs·cm^{-1} and 4.4 to 6.5 mg·l^{-1} respectively.

Co-occurring fish species and conditions necessary for fry survival in the spawning habitat were identified. High percentage fertilization and hatchability of eggs indicate that a suitable system could be developed during peak breeding using "kakabans" (egg collectors) made of commonly available coconut fiber as an effective egg deposition substrate, to improve natural spawning conditions in the reservoir.

Introduction

Sri Lanka is reputed to have a large acreage of reservoirs, mostly located in the dry zone of the country that receives minimum rainfall (Fernando 1971). These reservoirs, mostly irrigational and ranging in age from >2000 years to the present, support an artisanal fishery primarily based on the exotic cichlids *Oreochromis mossambicus* and *Oreochromis niloticus* (De Silva 1988). However, in the recent past, a number of large

reservoirs have been impounded for hydroelectricity generation, and these were located in the upland region of the country. Artisanal fisheries have developed, but little is known of the biology of the fish species thereof. This paper describes the abundance, reproductive pattern and breeding of common carp *C. carpio* (Cyprinidae), in Victoria, a recently impounded, deep, upland hydropower reservoir in Sri Lanka.

The common carp is a benthic omnivore, native to Central Asia. To optimize fish yield, two European strains of this species were introduced into the inland waters of Sri Lanka in 1915 (Fernando 1971). Reputed as a popular food fish and a highly culturable species with year round breeding under tropical and subtropical conditions, the common carp also plays an important role in polyculture systems in seasonal reservoirs and ponds of Sri Lanka (Chakrabarty 1982).

It is the only exotic carp species that is known to breed naturally in Victoria, one of the largest (2,270 ha) and deepest (D_{max}=102 m) hydroelectric reservoirs in Sri Lanka. Preliminary observations on the natural spawning pattern of this species in the Victoria reservoir have already been recorded (Nathanael and Edirisinghe 1998). In this paper, an attempt is made to identify environmental factors associated to its reproductive pattern and to focus attention on developing cost-effective propagation systems so as to eliminate the necessity of stocking reservoirs with fingerlings, thereby promoting sustainable fisheries.

Materials and Methods

The Victoria reservoir ($7^0$15' to $7^0$9'N; $80^0$39' to $80^0$48'E) is located 438 m above mean sea level in the central hill country of Sri Lanka. Its catchment and surface areas are 1891 km^2 and 23.7 km^2, respectively, and it has a capacity of 722 mcm at full supply level (De Silva 1992). Although the primary function of this reservoir is generation of hydroelectricity, fisheries is nevertheless an important secondary activity, that takes place throughout the year.

Abundance

Catch statistics were obtained by recording species specific fish yields of commercial gill-net catches from three different landing sites of the reservoir at weekly intervals during the period 1990 to 1998. During each interval, the catches of at least 15 fishers were taken into consideration. Using this data, the relative abundance and the mean CPUE ($kg \cdot craft^{-1} \cdot day^{-1}$) was computed annually for the study period.

Reproductive pattern

Seasonal variation in the mean monthly GSI, taken as the mean value of the ratio between gonad weight as a percentage of body weight was used

to determine the reproductive pattern. A sample of 50 common carp were collected monthly from May 1996 to April 1997 from commercial catches of the Victoria reservoir. The total length and weight of the fish were recorded. The fish were grouped into 5 cm length groups, dissected, and the gonads removed and weighed to the nearest 0.01 g. Correlation between the spawning cycle and the annual rainfall pattern was obtained using Spearman's rank correlation (Neave and Worthington 1992) for the female GSI, and the rainfall data collected each month for five different days. The overall correlation between the female GSI and the annual rainfall pattern during the period of investigation was also obtained using Spearman's rank correlation. For histological examination, gonad samples were randomly taken from individual length groups each month, processed in the usual manner (Pearse 1968), embedded in paraplast, sectioned at 6 µm and stained with Haematoxylin-Eosin.

During this period, rainfall data was obtained from the Headworks Division, Mahaweli Authority of Sri Lanka. Important water quality parameters such as water temperature, pH, total alkalinity, hardness, conductivity, and dissolved oxygen concentrations were analyzed from three randomly selected sampling sites using standard techniques (APHA 1989) during periods of peak spawning when there was a marked increase in the number of ripe females in the catches.

Spawning habitat

The nearshore littoral close to inflow areas of the reservoir is the favored habitat for common carp spawning. To study co-occurring fish species in the near-shore littoral, monthly fish samples were obtained from May to October 1998 from three randomly selected sites along a length of about 100 m using a cast net (1 cm stretched mesh) and a drag net (1 mm mesh size). The combined catch from all three sites were identified in the laboratory.

Duplicate water samples were collected monthly during the same period, at wadable depth, from the three different sites. Using standard techniques (APHA 1989) water quality parameters determined were temperature, pH, conductivity, hardness, nitrite, nitrate, total soluble phosphate, ammonia, calcium, and secchi disk transparency.

Propagation

Four replicate 2 m long "kakabans" with similar surface area were made using 25 cm long coconut fibers arranged as in a bottle brush using nylon thread. The "kakabans" were placed about 10 cm below water surface, prior to the onset of rain, and examined daily for the presence of eggs. The total number of eggs deposited on each "kakaban" was counted. The percentage fertility and hatchability were estimated by counting the number of unfertilized (opaque) eggs within 24 h of spawning and the number of unhatched eggs 96 h after spawning respectively, and determining the proportion of fertilized and hatched eggs

present on each 'kakaban". Fertility is expressed as a percentage of the number of fertilized eggs in proportion to the total number of eggs deposited, while hatchability is expressed as the number of hatched eggs as a percentage of the total number of fertilized eggs.

Results

Fishing was prohibited since the impoundment of this reservoir in 1984 up to the end of 1988. The reservoir has been stocked from its year of impoundment up to 1990 as follows: tilapia 151,350 comprising 10% *O. mossambicus,* 80% *O. niloticus,* and 10% *T. rendalli*; common carp (*C. carpio*) 125, 250; rohu (*L. rohita*) 170,400; bighead carp (*Aristichthys nobilis*) 69, 725; mrigal 13,850; silver carp (*Hypophthalmichthys molitrix*) 30,100 (Edirisinghe 1997). Withdrawal of state patronage for inland fisheries in Sri Lanka in July 1990 resulted to a complete cessation of all fish stocking programs. In the Victoria reservoir, fish stocking was not implemented over a six year period. Thereafter, only sporadic stocking with a small number of *O. niloticus* and common carp fingerlings has been carried out.

Abundance

The catchability of common carp in this reservoir is second only to cichlids represented by the colonization of three different species *O. mossambicus*, *O. niloticus* and *Tilapia rendalli* (Edirisinghe et al. 1990).

Figure 1a shows fluctuations in catch composition (by weight) of the commercial fishery since 1990. The relative abundance of common carp increased by 33.5% from 1990 to 1998, with a corresponding increase in CPUE (Fig. 1b), in spite of the cessation of stocking (during the period 1990 until the end of 1996), indicating successful natural recruitment to the fishery.

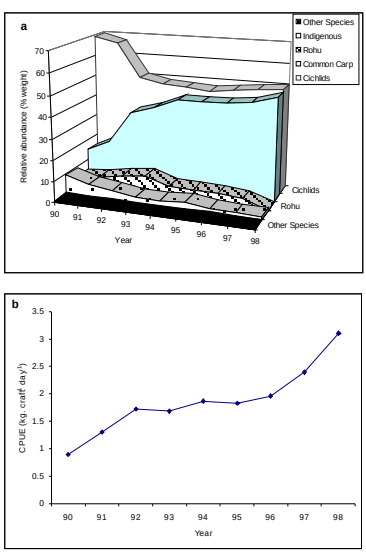

Fig. 1a. Fluctuation of catch composition (by weight). Indigenous species include only the three main constituent species *Tor khudree*, *O. bimaculatus* and *P. sarana*. Other species-miscellaneous exotic and indigenous species netted occasionally. (b) Fluctuation of mean CPUE of common carp during the period 1990 to 1998.

Reproductive pattern

The mean monthly surface water temperature that ranged from 24.4 to 28.9^{0}C during the study period appears to favor year round spawning of common carp in the Victoria reservoir. The overall gonad maturation and spawning pattern are significantly correlated to rainfall (Spearman's rank correlation r_s=0.5638; $p < 0.05$)) and varies widely, ranging from 7.1 mm to 261.0 mm during the study period (Fig. 2b).

Histological observations complement the observation that the breeding pattern is correlated to rainfall. Immature individuals were abundant in the catches during July and August when rainfall was very low. Figure 3a shows previtellogenic oocytes from an immature ovary collected in August, whereas figure 3b is an immature testis collected during the same period. Fish in spawning condition were frequently netted soon after the onset of monsoonal rains in October. Figure 3c is a mature oocyte with peripheral vacuoles and yolk granules where the nucleus has begun migrating towards the membrane prior to germinal vesicle breakdown and subsequent spawning while figure 3d is the testis of a ripe male also collected in October, with large numbers of mature inactive spermatozoa filling the ampullae.

Water quality parameters recorded during peak spawning viz. temperature (24.4 to 26.0^{0}C), pH (6.9 to 8.1), total alkalinity (39 to 79 mg·l^{-1}), total hardness (44 to 72 mg·l^{-1}) conductivity (53 to 70 µs·cm^{-1}) and dissolved oxygen (4.4 to 6.5 mg·l^{-1}) indicate optimum requirements for common carp breeding in this reservoir.

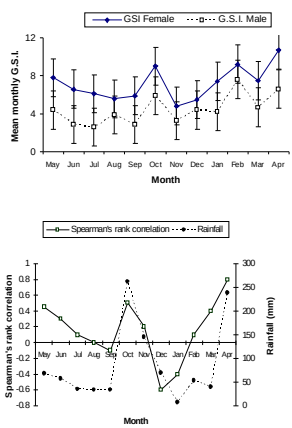

Fig. 2a. Seasonal variation in male and female GSI. Vertical lines indicate standard error.(b) Rainfall pattern and corresponding fluctuations of Spearman's rank correlation (monthly female GSI and rainfall) during the study period.

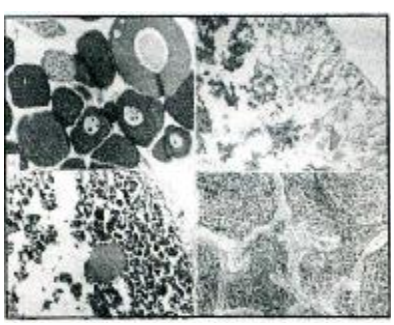

Fig. 3. Previtellogenic oocytes from an immature ovary (a) and an immature testis (b) collected in August; mature oocyte (c) and ripe testis (d) collected prior to spawning in October.

Spawning habitat

Sixteen co-occurring fish species were identified in the near-shore littoral close to an inflow area, the favored spawning habitat of common carp. Among these species were three exotics, *O. mossambicus*, *O. niloticus* and *T. rendalli*, and the estuarine transplant *Etroplus suratensis*. Indigenous species were predominated by minor cyprinids *viz. Amblypharyngodon melettinus, Puntius filamentosus, P. chola, P. dorsalis, Danio malabaricus, Rasbora daniconius, Esomus thermoicos* and *Garra ceylonensis*. Other indigenous species present were the catfishes *Heteropneustes fossilis, Mystus vittatus, Ompok bimaculatus*, the bar-eyed goby *Glossogobius giuris*, and the Mahseer *Tor khudree*.

Table 1 summarizes some important physicochemical parameters of the near-shore littoral close to the inflow. These parameters indicate desirable limits for growth of common carp.

Propagation

High percentage fertilization and hatchability of eggs (Table 2) indicate that appropriate systems could be developed under natural conditions for

Table 1. Water quality of three near-shore sampling sites close to an inflow area of the Victoria reservoir. (May to October 1998)

Water parameters	Statistics	Sampling site		
		1	2	3
Temperature (°C)	Mean	27.9	27.5	28.4
	SE	± 0.4	± 0.3	± 0.5
	Range	24.3-30.0	25.8-29.0	24.9-31.1
pH	Mean	7.0	6.9	7.2
	SE	± 0.1	± 0.1	± 0.2
	Range	6.5-7.4	6.3-7.2	6.9-7.9
Conductivity µs ^{25}	Mean	83.0	65.1	78.2
	SE	± 7.3	± 2.6	± 5.3
	Range	49.0-144.3	51.0-84.8	49.1-110.3
Hardness mg·l^{-1}	Mean	41.2	38.4	50.4
	SE	± 1.2	± 3.8	± 1.8
	Range	22-70	36-51	39-63
Nitrite mg·l^{-1}	Mean	0.03	0.01	0.01
	SE	± 0.01	± 0.001	± 0.001
	Range	0.01-0.13	0.01-0.02	0.01-0.03
Nitrate mg·l^{-1}	Mean	3.6	4.2	4.1
	SE	± 0.6	± 0.2	± 0.4
	Range	0.9-3.5	3.0-5.7	1.0-6.6
Total soluble phosphate mg·l^{-1}	Mean	1.1	1.6	2.5
	SE	± 0.2	± 0.3	± 0.4
	Range	0.1-2.8	0.3-3.9	1.0-6.6
Ammonia mg·l^{-1}	Mean	0.9	0.8	0.3
	SE	± 0.3	± 0.1	± 0.1
	Range	0.2-3.2	0.4-2.0	0.1-0.8
Calcium ppm	Mean	2.4	3.1	3.4
	SE	± 0.2	± 0.3	± 0.1
	Range	1.3-4.4	1.2-5.1	3.1-4.0
Secchi depth cm	Mean	90.4	109.4	119.0
	SE	± 4.4	± 5.4	± 8.2
	Range	66-115	83-150	85-189

the propagation of common carp. Eggs hatched 48 to 72 h after spawning. Regular washing and sun-drying of "kakabans" were essential since the quality of the substrate on which egg deposition takes place was found to be particularly important.

Discussion

The common carp is a highly adaptable species found in still and running waters from the cold temperate zone to the tropics. An optimum temperature between 18 to 24°C is required for natural reproduction (FAO 1985). It is the only exotic carp species that has been successful in establishing breeding populations in Sri Lanka, and now occurs in many headwater streams above an elevation of 1,500 m (Fernando and Indrasena 1969, Pethiyagoda 1994). It also forms a significant proportion of the catch in hill country reservoirs such as Kotmale (Silva 1991), Castlereagh and Mausakelle.

The spawning pattern of common carp varies according to climate. In tropical and subtropical regions carp usually mature during their first year and may spawn several times within a given year, whereas in temperate regions, maturation usually takes between 3 to 4 years, with spawning occurring only once a year during late spring.

Natural spawning of common carp is influenced by two different types of environmental cues, basic factors (i.e. water temperature, dissolved oxygen content and light intensity) and stimulatory factors (i.e. specific weather conditions, the presence of the opposite sex or grassy vegetation, and rainfall or flooding) (Horvath 1985). During the final stage before spawning, eggs within the ovary remain dormant, in a state of ripeness (gravid), until appropriate environmental cues appear (Horvath 1985). In carp species, final maturation and spawning could occur within a 24 h period after cues mandatory for spawning are present, and this probably explains the steep rise in the GSI during such periods. If these cues do not appear within a certain period, gonadal atresia or resorption of a portion of the vitellogenic oocytes takes place.

The Victoria reservoir has been constructed mainly for hydropower generation. Although fisheries was not an item in the development plan it has subsequently been developed into a productive subsidiary enterprise with an annual production of 166.2 metric tons, which is equivalent to 70 $kg \cdot ha^{-1}$ (De Silva 1992). The findings obtained during the

Table 2. Number of eggs deposited and the fertility and hatchability rates on "kakabans"made of coconut fiber under natural conditions.

Replicate	No: of eggs deposited	Fertilization (%)	Hatchability (%)
1	4,985	96	92
2	13,265	90	76
3	10,276	91	79
4	7,903	94	86
Mean ± SD	9,107 ± 3,516	92.8 ± 2.8	83.3 ± 7.2

present investigation indicate that common carp contributes significantly to this fishery.

The onset of monsoon and inter-monsoonal rains appear to initiate peak breeding of common carp in the Victoria reservoir. Horvath (1985) reports that a water temperature of 25^0C is best for growth and oocyte development, with an optimum dissolved oxygen concentration varying from 5 to 10 $mg \cdot l^{-1}$ (FAO 1985) and a pH value between 4.4 to 10.4 (Sifa and Senlin 1995). The water quality parameters recorded during peak breeding in this study fall well within the required limits.

An initial study (Wijewardena 1998) on the development of lake-based hatcheries for common carp, using breeding hapas and "kakabans" made of water hyacinth *Eichornia crassipes* through community-based management, has shown that this approach is technically, economically and environmentally viable under prevailing Sri Lankan reservoir conditions.

During periods of acute drawdown in reservoirs, silt deposition on fish eggs is known to increase fish mortality and thus decrease reproductive success (Ploskey 1981). Frequent drawdown also minimizes the amount of submerged littoral vegetation available for spawning, which means that natural propagation systems should be introduced only when hydrological conditions in the reservoir are favorable. The findings of the present investigation indicate the possibility of installing "kakabans" in reservoir inflow areas with a gentle flow of water to stimulate spawning, prior to the onset of rain as a viable option for producing fingerlings by natural propagation in the future. "Kakabans" suspended on bamboo frames would be best suited for reservoirs such as the Victoria, with extensive fluctuations in water level. The "kakabans" with newly spawned eggs could then be transferred to coves or floating net cages, where newly hatched fry could be cultured to fingerling size before release into the reservoir.

Future progress towards developing cost-effective natural propagation systems for common carp in deep perennial reservoirs such as the Victoria will depend on the choice of appropriate management strategies and the availability of adequate resources for carrying out further research, which in turn, could have a major impact on the productivity and sustainability of this fishery.

Acknowledgments

The financial support given by the Council for Agricultural Research Policy (Grant no: 12/319/242) is gratefully acknowledged. We also wish to thank Mr. S.G.K. Nawaratne, Engineer, Headworks and Administrative Operations and Maintenance Office, Digana, for the rainfall data and Mr. M.A. Navaratne of the Department of Veterinary Medicine and Animal Science, University of Peradeniya for the technical assistance. This paper was presented at the Fifth Asian Fisheries Forum, Chiang Mai, Thailand.

References

APHA. 1989. Standard methods for the examination of water and waste water. American Public Health Association, Washington, D.C.

Chakrabarty, R.D. 1982. Polyculture-principles and practices. Journal of Inland Fisheries. 1: 30-40.

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

De Silva, K.H.G.M. 1992. Limnology and fishery of three recently impounded reservoirs in Sri Lanka. In: Reservoirs of Asia. Proceedings of the 2nd Asian reservoir fisheries workshop in Hangzhou. China. (ed. S.S. De Silva) pp. 12-22. IDRC. Ottawa. Canada.

Edirisinghe, U. 1997. A case study on reservoir fisheries management: gill net fishery in a hill country deep reservoir-Victoria reservoir. Sri Lanka Journal of Agricultural Sciences 34: 155-165.

Edirisinghe, U., N. Sirisena and R.M.S. Bandara. 1990 Catchability of the common carp *Cyprinus carpio* by gillnetting in the Victoria reservoir (Abstract) Proc. Sri Lanka Assoc. for the Advancement of Science 46: (1) 51

FAO. 1985. Common carp. Part 1. Mass production of eggs and early fry. Food and Agriculture Organization, Rome. Training Series 8: 87 pp.

Fernando, C.H. 1971. The role of introduced fish in fish production in Ceylon's freshwaters. In: The scientific management of animal and plant communities for conservation. (ed. E. Duffey and A.S. Watts) pp. 295-310. Blackwell Scientific Publications, Oxford.

Fernando, C.H. and H.H.A. Indrasena. 1969. The freshwater fisheries of Ceylon. Bulletin of the Fisheries Research Station. Ceylon. 20 (2): 101-134.

Horvath, L. 1985. Egg development (oogenesis) in the common carp (*C. carpio*). In: Recent Advances in Aquaculture. (ed. J.F. Muir and R.J. Roberts) 2: pp 32-77 Croom Helm, London.

Nathanael, S. and U. Edirisinghe. 1998. The natural spawning cycle of the common carp (*C. carpio*) in the Victoria reservoir. Sri Lanka Journal of Aquatic Sciences. 3: 85-95.

Neave, H.R. and P.L. Worthington. 1992. Distribution-free tests. Routledge, New York.

Pearse, A.G.E. 1968. Histochemistry: theoretical and applied. J. and A. Churchill. London.

Pethiyagoda, R. 1994. Threats to the indigenous freshwater fishes of Sri Lanka and remarks on their conservation. Hydrobiologia. 285:189-201.

Ploskey, G.R. 1981. Factors affecting fish production and fish quality in new reservoirs with guidance on timber clearing, basin preparation, and filling. Fish and Wildlife Service, National Reservoir Research Program, U.S. Department of the Interior, for the U.S. Army Engineer Waterways Experiment Station. Vicksburg, Massachussets. Technical Report E 81-111.

Sifa, L. and X. Senlin. 1995. Culture and capture of fish in Chinese reservoirs. International Development Research Centre, Ottawa, Canada, and Southbound Sdn. Bhd. Penang, Malaysia.

Silva, E.I.L. 1991. Limnology and fish yields of newly built standing water bodies in the Mahaweli River Basin, Sri Lanka. Verhandlungen Internationale Vereingung für Theoretische und Angewandt Limnologie 24: 1425-1429.

Wijewardena, H.M.S.L. 1998. Formulation of a strategy to develop lake-based hatcheries in Sri Lanka. M. Sc. Dissertation. Asian Institute of Technology. Bangkok, Thailand.

Manuscript received 29 June 2001; Accepted 10 August 2001