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Biological parameters of the endangered fish *Chitala chitala* (Osteoglossiformes: Notopteridae) from some Indian rivers

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Abstract

Age, growth and maturity data of the freshwater feather back *Chitala chitala* (Hamilton-Buchanan, 1822) were collected from ten different geographical locations. Out of ten populations, maximum 6+ ages were recorded from four river basins namely river Bhagirathi, Koshi, Saryu and Ganga and the back calculated lengths at 6+ ages ranged from 1033.36–1073.63 mm. In rest of the locations, however, only 3+ age classes were recorded. Specific rate of linear growth (C_l) and specific rate of weight increase (C_w) showed decreases except in two locations. The specific rate of linear growth (C_l) and the specific rate of weight increase (C_w) increased at 3+ age class in the river Bhagirathi. Among other growth parameters, three distinct life stages of *C. chitala* were observed based on analysis of growth constant data. Analysis of variance (ANOVA) of the back-calculated length data of 10 populations indicated a significant difference ($p < 0.05$). Out of ten populations studied, six showed significant variation of growth in 1+ age class and two showed significant variation in 2+ to 6+ age classes. Length-weight relationship of the species from all the population was calculated and the coefficient of correlation (r) was at the significant level where the value of 'b' was almost 3 for all the locations studied. Male *C. chitala* attained maturity earlier (2+ age) whereas females matured at age 3+. The percentages of mature individuals also varied between river basins. Based on this study strategies can be proposed for sustainable exploitation of the species from wild populations.
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Keywords: *Chitala chitala*; 'Moi fish'; Age; Growth; Maturity; Conservation; India

1. Introduction

Endangered feather back *Chitala chitala* (Hamilton-Buchanan, 1822), commonly known as "moi", is widely distributed in all African and Asian countries including India, Pakistan, Bangladesh, Srilanka, Nepal, Thailand and Indonesia. It is a bony fish, belonging to the order Osteoglossiformes in the family Notopteridae and it bears very small cycloid scales. It constitutes an important component of riverine fisheries of India and is considered as one of the most commercially important and highly priced foods. It is also an aquarium fish. *C. chitala* has undergone heavy fishing pressure, leading to an alarming decline in natural populations. It deserves high conservation attention (Sarkar et al., 2006a). This species has been categorized as endangered (EN) in the Conservation Assessment and Management Plan (CAMP, 1998). Recently, it has been prioritized as a new candidate for fresh water aquaculture (Ayyappan et al., 2001). It was also evaluated in the NBFGR –NATP Workshop and has been listed as a prioritized fish as food, sport, aquarium, and highly priced cultivable fish (Ponniah and Sarkar, 2000) and declared as a State fish for Uttar Pradesh, India.

Studies on the age, growth and maturity of threatened and commercially important fishes are required for the management and conservation of fish population in natural water bodies. Though successful captive breeding protocol and larval rearing have been developed (Punia et al., 2006; Sarkar et al., 2006a,b), no work have been carried out on the age and growth pattern, length weight relationship and maturity of *C. chitala* from the wild population. Hence, the objectives of the present study are to evaluate the age and growth, length weight relations and maturity patterns of *C. chitala* from 10 population and to distinguish different stocks which may be helpful in conservation and management.

2. Material and methods

C. chitala was sampled during 2000 to 2004 from ten different populations of the river Ganga basin using various fishing

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Table 1
Details of different sampling locations of the river Ganga basin

S. no.	Riverine/locations	Number of samples	Latitude	Longitude
1	Ganga	40	24.53°N	88.10°E
2	Bhagirathi	40	24.05°N	88.06°E
3	Koshi	35	25.82°N	81. 26°E
4	Ghagra	25	26.75°N	81.99°E
5	Gomti	30	25.90°N	82.56°E
6	Samaspur bird Sanctuary (SBS)	25	25.97°N	81.67°E
7	Gerua (Katerniaght Wildlife Sanctuary)	25	28.21°N	81.25°E
8	Saryu	25	26.33°N	83.37°E
9	Sutluj	30	31.09°N	74.56°E
10	Yamuna	25	25.41°N	81.91°E

methods, drag nets, cast nets, gill nets of different mesh size. Scale samples were collected from ten different wild populations and the total number of samples along with other details of the locations are shown in Table 1. Three hundred individuals of *C. chitala* were collected and analyzed for age studies and a minimum 20 observations were taken for each population. To study age and growth, scales were removed from each fish, just below the dorsal fin and above the lateral line, washed in 5% KOH, and rinsed in distilled water. The scales were cleaned, dried and secured between two glass slides ($4 \times 4''$) for permanent storage and were examined under the stereo zoom microscope and the radius was measured with the help of ocular micrometer. The readings of the total radii and the number of the annuli along with their distance from the focus were noted in a standard proforma. Back-calculation was determined by the formula given by the Le Cren (1951).

$$L_n = L \times \frac{S_n}{S}$$

where L = total length (mm) of the fish at the time of scale removal, L_n = total length (mm) of the fish at the time of annulus "n" formation, S_n = scale radius (mm) from nucleus to the annulus "n", S = total radius (mm) of the scale.

Specific rate of weight increase (C_w), specific rate of linear growth (C_l), growth constant (C_{lt}) and specific average size (h) were derived as per Chugunova (1963).

(i) Specific rate of linear growth

$$C_l = \frac{l_n - l_{n-1}}{l_n - 1} \times 100$$

(ii) Specific rate of weight increase

$$C_w \text{ or } C_g = \frac{W_n - W_{n-1}}{W_{n-1}} \times 100$$

(iii) Growth constant

$$C_{lt} = \frac{\log l_n - \log l_{n-1}}{0.4343} \frac{t_2 + t_1}{2}$$

The length–weight relationship based on the regression equation:

$$W = aL^b \text{ or } \log W = \log a + b \log L$$

where W = weight of the fish in grams, L = total length in mm, a = constant, b = equilibrium.

To test for possible significant differences in both slope and intercept, co-variance analysis was conducted. All the fishes were weighed (TW) with an electronic balance to the nearest 0.01 g. Total length of each fish was measured with slide calipers to the nearest 0.1 cm. The statistical significance level of r^2 was estimated and the parameters a and b were estimated by least square linear regression performed on the transformed equation.

2.1. Maturity stages

The seasonal changes in the gonadal developmental of *C. chitala* were studied and were distinguish into following categories according to Jhingran (1991).

Stage I – virgin
Stage II – developing
Stage III – maturing-I
Stage IV – maturing- II
Stage V – gravid
Stage VI – spawning
Stage VII – spent

2.2. Age at first maturity and sex ratio

C. chitala samples of the possible smallest size were collected with the on-set of maturity or sexually ripe specimens for the study of age at first maturity, which was computed. Fishes of different size groups were dissected and examined for the maturity stage during the peak breeding season (May–September). Stage IV–VI was considered as mature fishes. Very few species exhibit external sexual differences, so the sex was determined by examination of the gonad. The sex ratio was calculated for different locations.

Statistical analysis of data was done using statistical software SPSS Base 10.0 user's guide.

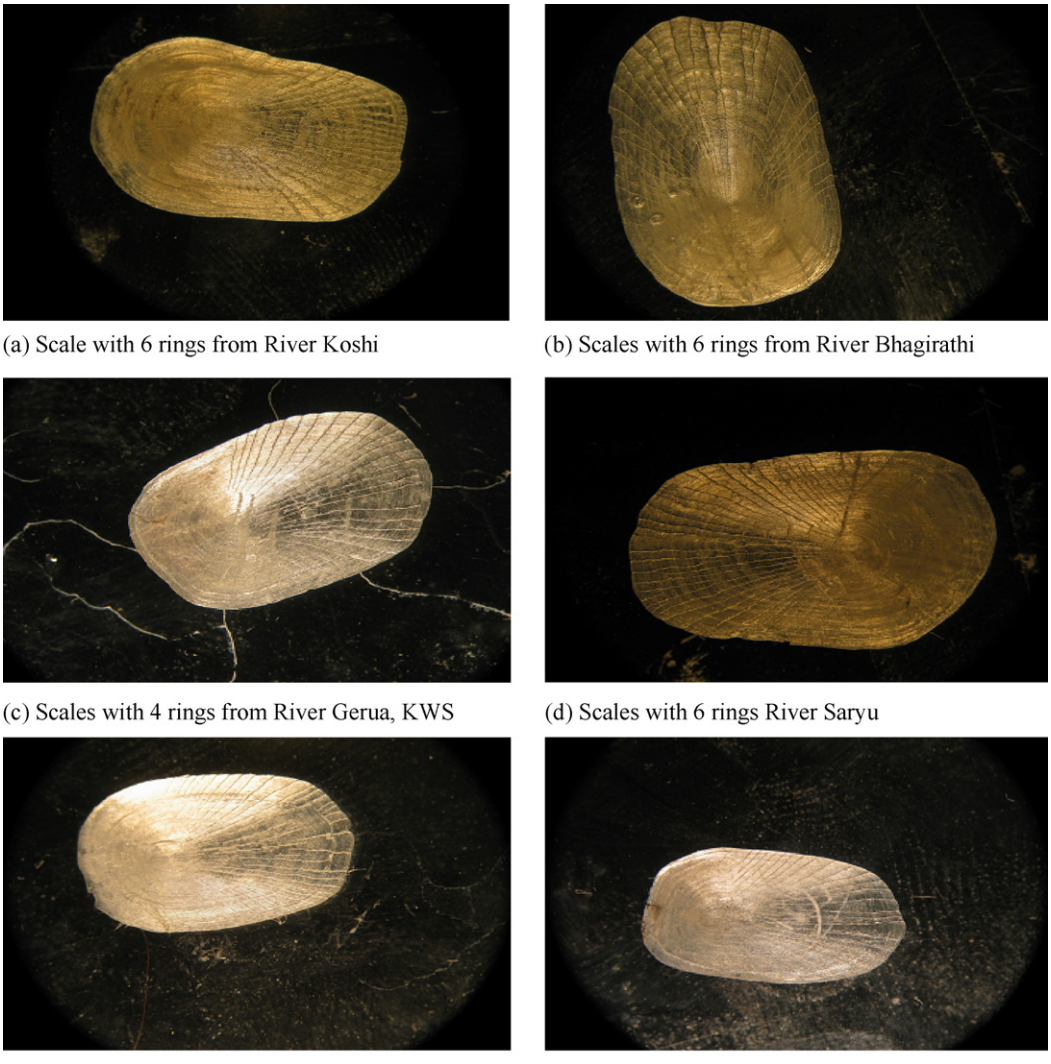
3. Results

The scale of *C. chitala* is cycloid, and shows true, false and larval marks suitable for age determination. The central part of the scale (focus) is the initiation of the growth. In *C. chitala* true marks (annulii) are defined by light bands in the form of grooves extending around the scale. The focus was located near the anterior field. A ridge-like structure radiates from the nucleus towards the margin. The structure of the scale of *C. chitala* at various ages is shown in Fig. 1.

3.1. Growth rate

Growth rate of individual fish was analyzed by back- calculation methods and the back-calculated lengths (L) in each age from different populations are presented in Table 2. A maximum 6+ age classes were recognized from Bhagirathi river, river Kosi (Bihar), river Saryu and river Ganga (Kanpur) while only 3+ age classes were observed in the other locations (river Ganga, Rajmahal), river Gomti, river Satluj). The model length ranged from 338.5–627.27 (1+ age class), 473.1–763.76 (2+ age class), 621.33–855.74 (3+ age class), 897.46–992.1 (4+ age class), 1030–1062.73 (5+ age class) and 1033.36–1073.63 (6+ age class), respectively. The analysis of the back-calculated results indicated wide variations in length in the first year (1+) for all populations. The maximum growth in first year age was observed in river Kosi (Bihar) followed by river Saryu, river Bhagirathi, river Gerua, KWS and river Gomti.

On the basis of above results the annual rate of growth (h) over the years was calculated for different locations. Maximum average growth indicated higher values for the river Ganga Rajmahal (284.73 mm) followed by river Gerua, KWS (252.70 mm), river Yamuna (246.84 mm), river Sutluj (230.35 mm) and SBS (227.92 mm) while minimum growth increment was observed in river Koshi (212.76 mm), Gomti (207.11 mm), river Ganga,



(a) Scale with 6 rings from River Koshi

(b) Scales with 6 rings from River Bhagirathi

(c) Scales with 4 rings from River Gerua, KWS

(d) Scales with 6 rings River Saryu

(e) Scales with 4 rings from River Ganga

(f) Scales with 3 rings from River Satluj

Fig. 1. Scales of *Chitala chitala* collected from different rivers of India.

Table 2
Comparison of back calculated length of *C. chitala* from different river basin of India ($Ø_h$ value of index of species average size)

Location	Back calculated length						
	L_1	L_2	L_3	L_4	L_5	L_6	$Ø_h$
Bhagirathi	481.96 ± 73.39[a] (357.4–562.4)	593.1 ± 71.88[a] (507.4–683.3)	718.38 ± 90.31 (648.1–820.25)	932.32 ± 1.98[a] (930.15–934.15)	1040.63 ± 0.85[a] (1041–1041.5)	1073.63 ± 1.46[a] (1072–1072.3)	178.7
Ganga (Rajmahal)	353.54 ± 117.78 (267.6–487.8)	552.86 ± 38.85 (512.9–605.5)	706.27 ± 10.02 (696.71–716.7)	NS	284.73		
Koshi (Bihar)	627.27 ± 66.50 (392.86–745.02)	763.76 ± 36.64[a] (553.58–876.8)	855.74 ± 46.82 (808.75–983.22)	992.1 ± 40.3 (941.0–1036.4)	1062.7 ± 12.8 (1051.1–1076.5)	1060.9 ± 13.6	212.76
Gomti	392.53 ± 23.80[b] (329.7–564.5)	564.06 ± 24.51 (523.7–598.1)	621.33 ± 3.53 (620–625.3)	NS	NS	NS	207.11
Satluj	380.03 ± 45.63[a] (345.25–490.1)	514.56 ± 42.14 (463.8–567)	691.05 ± 50.68 (638.4–739.5)	NS	NS	NS	230.35
Saryu	484.06 ± 4.50[b, c] (480.8–489.2)	715.3 ± 0.66 (715–715.1)	871.86 ± 1.81 (870.8–873.8)	980.6 ± 2.32[a] (980.1–983.1)	1056.35 ± 1.82 (1050–1056.95)	1057.71 ± 1.03	178.28
KWS (Katraniaghat)	467 ± 160.23 (330.1–649.1)	618.36 ± 76.71 (491.2–871.4)	762.17 ± 119.04 (627.7–854.1)	NS	NS	NS	252.70
SBS (Samaspur Bird Sanctuary)	338.5 ± 7.9[c] (330.6–346.4)	473.1 ± 2.59 (470.5–476.5)	683.76 ± 3.40 (680.7–683.7)	NS	NS	NS	227.92
Ganga (Kanpur)	346.42 ± 19.09[c] (315.61–326.5)	501.30 ± 44.71 (462.82–477.1)	735.33 ± 38.80 (696.11–773.7)	897.46 ± 6.49 (900–902.7)	1030.26 ± 1.62[a] (1030–1031.7)	1033.36 ± 2.15[a] (1130–1130.95)	188.49
Yamuna	355.16 ± 22.71[c] (332.4–377.82)	544.54 ± 22.06 (515.14–568.3)	742.08 ± 10.08 (730.8–750.24)	NS	NS	NS	246.84

Values in parenthesis indicate range. Superscript letters a, b, c indicate significant difference at $p<0.05$. $L_1, \ldots, L_6$ represents back calculated length of each year. NS, no samples available.

Kanpur (188.49 mm), river Bhagirathi (178.72 mm) and river Saryu (176.28). The growth decreased with increasing age except Bhagirathi, Sutluj, Kanpur (Ganga) and river Yamuna and SBS. In these sites growth was suddenly increased at 4+ age class in Bhagirathi samples and 3+ age class of Sutlej, Ganga (Kanpur), river Yamuna and SBS.

An analysis of variance was used to detect significant difference between the locations. ANOVA were carried out by using observed back-calculated length data of each year (L1, L2, L3, L4, L5 and L6) of 10 different populations (Table 2). Significant interspecific variation ($p<0.05$) was recorded in length between the locations. Out of 10 populations, six showed significant variation in 1+ age group whereas only two showed significant variation within different locations in 2+ to 6+ age group. No significant variation was observed in 3+ age class (Table 2).

Analysis of back-calculated length of 1+ age class indicated significant variation for some of the population. River Bhagirathi (481.96 mm) showed significant difference with river Satluj (380.03 mm). Similarly river Gomti (392.53 mm) was significantly distinct from river Saryu (484.06 mm). There was also a significant variation between river Saryu (484.06 mm) with river Ganga, Kanpur (346.42 mm) and river Yamuna, (355.16 mm). Out of 10-location only two populations, in river Bhagirathi (593.1 mm) and river Koshi (763.76 mm), showed significant variation within locations in 2+ age group. No significant variation was observed in 3+ age group.

The variation of different growth parameters is presented in Fig. 2. Specific rate of linear growth (C_l) and specific rate of weight increase (C_w) decreased of all population except Bhagirathi and SBS samples. In the river Bhagirathi C_l (21.4) and C_w (104.8) were increased at 3+ age group. However in the samples of Samaspur C_l (30.3) were increased at 2+ age class. Based on the analysis it was concluded that C_l exhibited higher values for the population of river Bhagirathi (42.45) followed by KWS (32.69) and Yamuna (33.26), and minimum for Punjab (24.29) in 1+ age group. Similarly, in 2+ age group the value should be maximum for Ganga (Kanpur) and minimum for River Koshi (Bihar) (17.32). But the value shows much differences in 5+ age group as maximum as 8.77 for Kanpur and minimum as 2.60 for Bhagirathi.

The specific rate of weight increase (C_w) was maximum for river Bhagirathi (246) followed by KWS (230), river Saryu (200) and river Satluj (130.7) while it was minimum for river Ganga Kanpur (71.48) followed by river Ganga Rajmahal (63.48) and river Koshi (56.3) as shown in Fig. 3a. Similarly, in 2+ age group the value was maximum for SBS (84.21) and minimum for river Koshi, Bihar (43.37). The value shows many differences in 6+ age class as maximum as 24.72 for river Ganga, Kanpur and minimum as 8.87 for river Bhagirathi. The value of index of population weight growth intensity (ϕ Cw) of *C. chitala* was maximum for river Bhagirathi (131.98) followed by KWS (154), river Satluj (103.65), river Saryu (84.8) and SBS (77.3) and minimum for river Ganga Rajmahal (57.3) Kanpur (49.09) and river Koshi (37.6).

The values of growth characteristics (Clth) are useful to determine the period, where the first year ends and the second phase

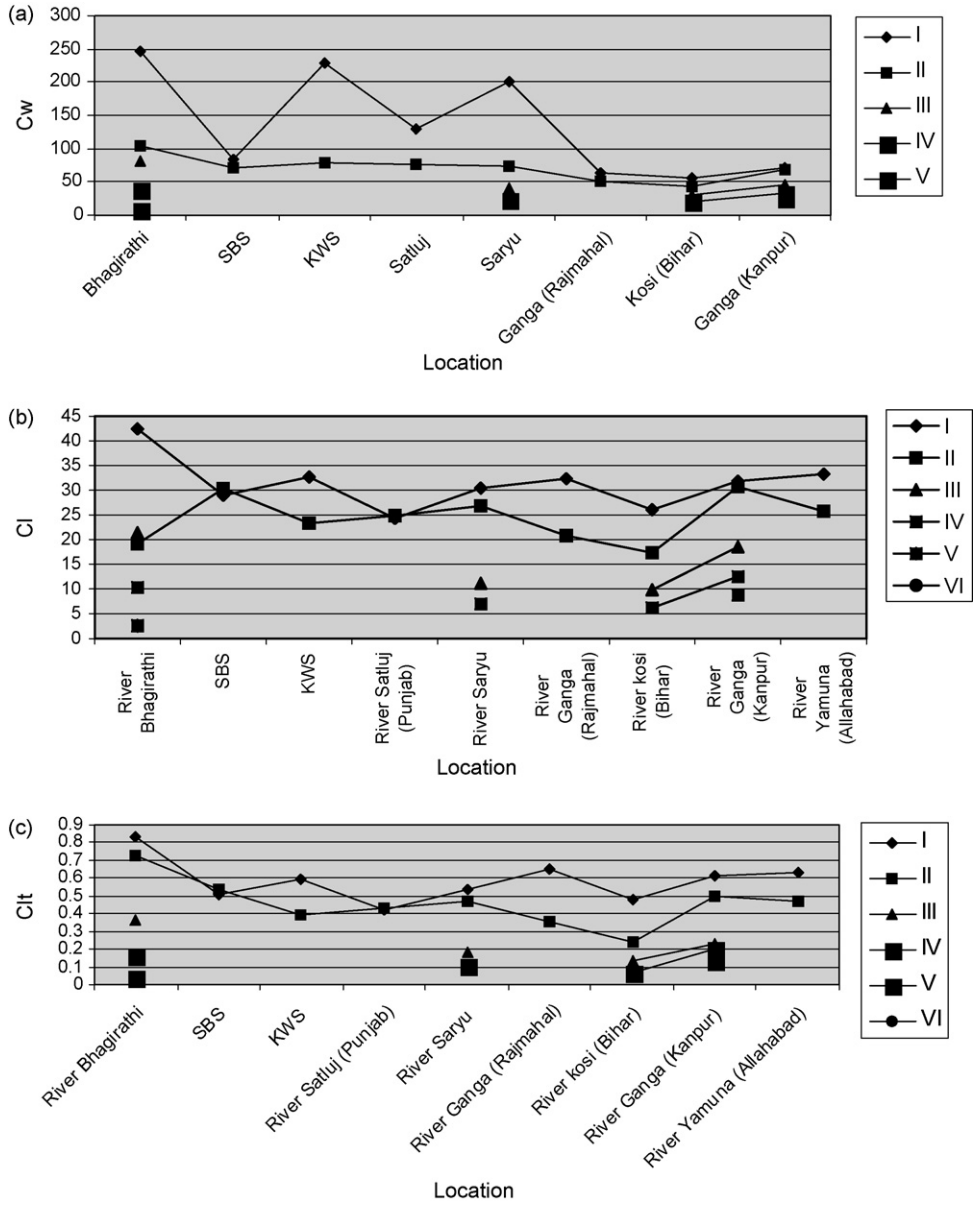


Fig. 2. Variation of different growth parameters of *C. chitala*. C_w, specific rate of weight increase; C_l, specific rate of linear growth; Clt, growth constant.

begins. Growth constants are helpful to determine the periods of life span of the fish. The results of the present study clearly indicate that C. *chitala* from the river Bhagirathi enter the second period of the life after 3rd and 4th years, respectively (Table 2). The other locations show only first life span upto 3+ age in these locations samples were not obtained beyond age 3+. The analysis of growth constant indicated maximum 3-life phases from river Bhagirathi and Ganga (Kanpur). Thus, growth parameters like average value of specific rate of linear growth and the index of population weight growth intensity were the indicators of overall level of competition (inter- and intraspecific) whereas the index of species average size indicates the overall growth of a particular species.

In the present study, length weight relationship of pooled data (male & female) from ten different geographical locations indicated that the value of '*b*' was almost 3 (Fig. 3). The highest '*b*' value was obtained from the river Satluj (4.10), with regression coefficient $r = 0.92$. The lowest '*b*' value was obtained from river Gomti (2.37), with value $r = 0.88$.

3.2. Maturity size and age

We found that in male *C. chitala*, minimum size at first maturity was attained at a mean length of 620 ± 40.4 mm length from the river Sutluj, whereas maximum size at first maturity (810 ± 52.98) was recorded from the river Saryu. However, in females minimum size at first maturity (755 ± 35.36) was observed from Ganga river (Kanpur) and maximum (910 ± 23.23) from Saryu river (Table 3). In all the studied populations, male *C. chitala* matured earlier (2+) and in females, maturity was recorded at age 3+. The comparative analysis of data indicated that overall maturity percentage in males was

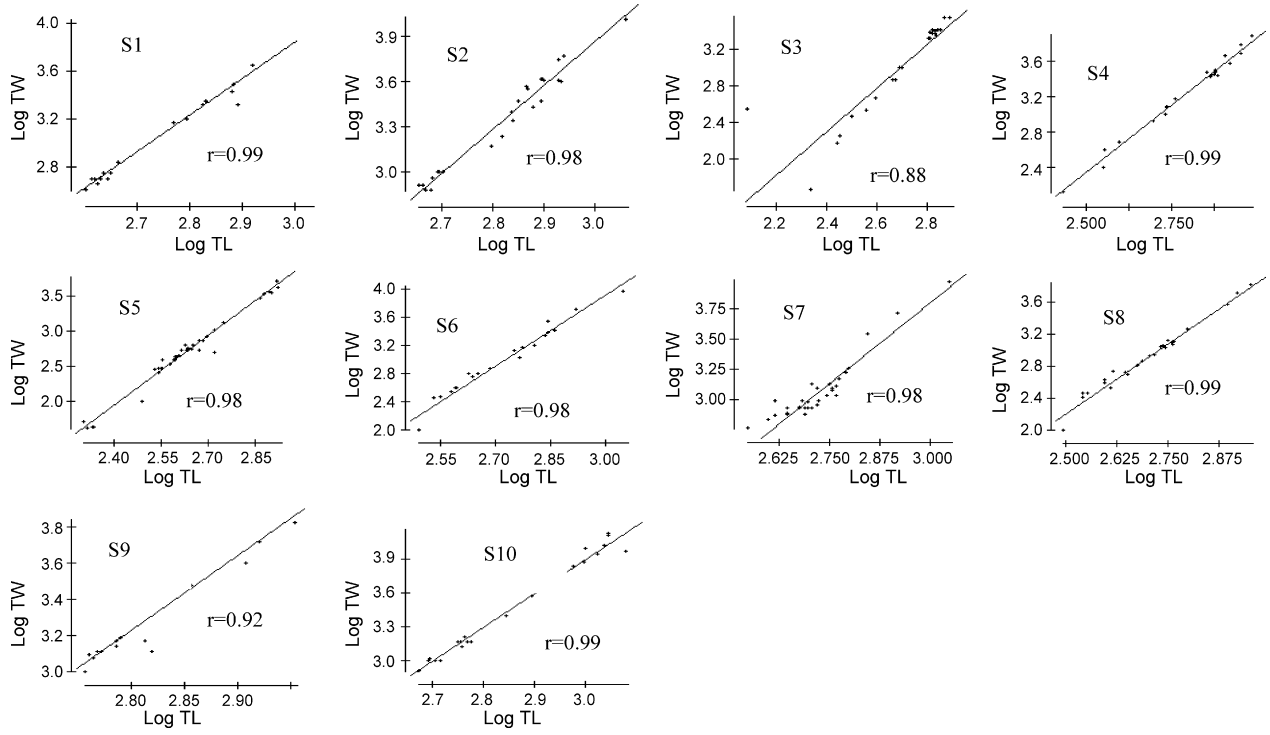


Fig. 3. Length–weight relationship of *C. chitala* from different river basin of India. S1: river Bhagirathi, S2: river Ganga (Rajmahal), S3: river Kosi., S4: river Gomti, S5: river Satluj, S6: river Saryu, S7: river Gerua, Katraniaghat Sanctuary, S8: SBS, S9: river Ganga (Kanpur), S10: river Yamuna.

highest (73.3%) in Yamuna river followed by river Gerua, KWS (72.7%) and lowest (50.0%) in Gomti river population (Table 4, Fig. 4). However, the percentage of maturity in females was higher (65.4%) in river Gerua, KWS and minimum (40.9%) in Ganga river. No maturity was recorded in 1+ age in males and 1+ to 2+ age classes in females.

4. Discussion

This is the first report on the age structure and growth pattern of *C. chitala* from different river basins of India. The results of the age and growth indicate that the length attainment in the successive years varied in different river basins. Lower growth increment was recorded for the samples of for river Satluj, river Ganga (Rajmahal) whereas population of river Koshi (Bihar) showed higher length followed by river Saryu, river Bhagirathi, river Gerua, KWS and river Gomti. river Yamuna, river Ganga (Kanpur) and SBS. As expected the mean back calculated length was higher in the first year when fish attained 627.27 mm (river Kosi). Maximum individuals were recorded with age classes 1+, followed by age classes 2+ and 3+ respectively, which might be due to unsustainable fishing pressure in the riverine system. Among different growth parameters, the specific rate of linear growth (C_l) and specific rate of weight growth of ten populations exhibited sharp decreasing trend. The level of C_l and C_w declined with increase in age classes (Fig. 2a and b). The results of the present study corroborate findings of Johal and Tandon (1992), Tandon and Johal (1993) and Tandon et al. (1993) on *Catla catla* (Hamilton), *Labeo rohita* (Hamilton) and *Tor putitora* (Hamilton), respectively. Abbas and Siddiqui (1987) also

Table 3
Age and size at first maturity of *C. chitala* from different river basin of India

Location	*N*	Size at first maturity (mm)		Age at maturity	
		Male	Female	Male	Female
Bhagirathi river	66	735.5 ± 48.89	797.5 ± 53.03	2+	3+
Ganga river (Rajmahal)	42	712 ± 37.00	782.5 ± 28.65	2+	3+
Koshi river	53	675 ± 35.35	865.2 ± 45.76	2+	3+
Gomti river	44	665 ± 32.21	805 ± 36.51	2+	3+
Satluj river	54	620 ± 40.40	810 ± 43.32	3+	3+
Saryu river	59	810 ± 52.98	910 ± 23.23	2+	3+
KWS (Katraniaghat)	48	675 ± 35.35	860 ± 55.5	3+	3+
SBS (lake)	36	675 ± 41.32	790 ± 45.32	2+	3+
Ganga river (Kanpur)	29	688 ± 26.48	755 ± 35.36	2+	3+
Yamuna river	34	690 ± 36.53	775 ± 42.52	2+	3+

Table 4
Sex wise percentage of maturity in successive age classes of *C. chitala* from different river basin

Locations	% of maturity											
	Male						Female					
	1+	2+	3+	4+	5+	6+	1+	2+	3+	4+	5+	6+
Bhagirathi river	–	57.14	89	93	100	100	–	–	51.6	88	100	100
Ganga river (Rajmahal)	–	72.0	98	–	–	–	–	–	52.9	–	–	–
Koshi river	–	67.74	85	99	100	100	–	–	40.9	75	94	100
Gomti river	–	50.0	91	–	–	–	–	–	41.6	–	–	–
Satluj river	–	60.0	78	–	–	–	–	–	34.48	–	–	–
Saryu river	–	54.54	79	95	100	100	–	–	46.15	70	99	100
KWS (Katraniaghat)	–	72.7	89	–	–	–	–	–	65.4	–	–	–
SBS (Samaspur)	–	63.62	71	–	–	–	–	–	57.14	–	–	–
Ganga river (Kanpur)	–	60.0	77	96	100	100	–	–	50.0	85	100	100
Yamuna river	–	73.3	89	–	–	–	–	–	57.89	–	–	–

reported that specific growth rate decreased with the increasing age and size of fish.

In the samples of river Bhagirathi, the growth suddenly increased at 3+ age indicating that the fish might be exposed to favorable environment conditions after 2+ age group. Although, in the river Bhagirathi the fishes were recorded up to 6+ age, but no individuals were more than 3+ ages from rest of the locations and this phenomena may be related to environmental degradation. The value of growth constant is important to understand the periods of life in the life span of fish. In *C. chitala* three phases of life was observed based on the values of growth constant which also corroborates the studies of Khan (1972) and Singh (1990) who reported three phases of life of in Indian Major Carps from riverine population of Aligarh and Jaisamand Lake, India. According to Yablokov (1986) the average value of growth characteristics can be used to separate populations of the same species or conspecific population. Balon (1974) observed the high value of index of species average size in *Cyprinus carpio* from pond population and of index of population weight growth intensity from the river population. The present observations reveal that the wild population of *C. chitala* shows variations in growth from one population to another and accordingly fisheries strategy could be made for conservation and sustainable utilization.

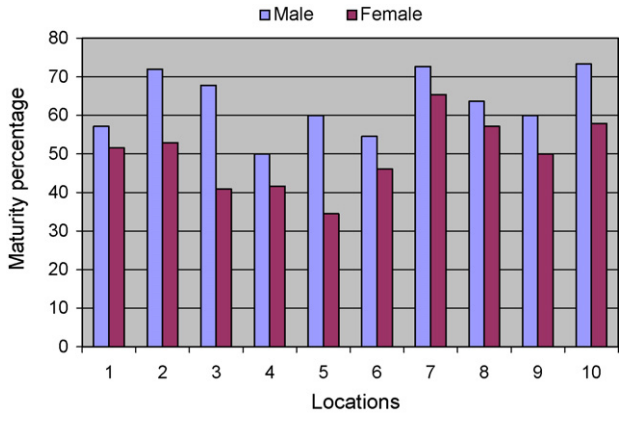


Fig. 4. Comparative maturity percentage of male and female at 2+ and 3+ age classes of *Chitala chitala*. River basin: 1. Bhagirathi (WB), 2. Ganga (Rajmahal), 3. Koshi (Bihar), 4. Gomti, 5. Satluj (Punjab), 6. Saryu, 7. KWS (Katraniaghat), 8. SBS (Samaspur Bird Sanctuary), 9. Ganga (Kanpur), 10. Yamuna river.

In the present study the variations observed in *L–W* relationship of *C. chitala* from different population may be attributed to the variations in the different habitats on which their biology depends. Allen (1938) reported that in an ideal fish, which maintains a constant shape, the slope value '*n*' or '*b*', will be 3. However, Hile (1936) suggested that it may vary between 2.5 and 4.0. The general expectation is that the weight increases as the cube of length (Lagler, 1952; Rounsfell and Everhart, 1953).

In *C. chitala*, it is difficult to determine sex externally even when the fish is fully matured because the size of gonad in both sexes is small. In the present study the size at maturity and maturity percentage varied in males and females across different river basins studied. Our study also showed that the male *C. chitala* attained maturity a year earlier than females, which may be attributed to the faster growth of males than females. Sarkar et al. (2006a,b) reported successful captive breeding of *C. chitala* at a minimum size of 600 mm for male and 700 mm female, respectively which supports the present data sets. Chondar (1999) reported that *C. chitala* attains *maturity* in the third year of life, male being sometimes at the later part of the second year. Taeshita et al. (1998) reported that in *P. aurantiacus*, minimum size at maturity for males was less than that of females.

5. Conclusion

This study shows a well-defined growth pattern in different river basins/locations and new information has been generated on age pattern and reproductive parameters of *C. chitala*. The study has provided basic information on the other important biological attributes and would be useful for fishery biologist to impose adequate regulations for sustainable fishery management and conservation of the endangered fish. It is evident that wild populations of *C. chitala* show variations in age profile from one population to another. The study could help in identifying the base populations for selective breeding and conserving genetic diversity in future. Evidently, fisheries strategy could be made for conservation of river fishes.

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