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Population structure and reproductive biology of a freshwater fish, *Labeo boggut* (Sykes, 1839), from two perennial rivers of Yamuna basin

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Summary

Population structure and reproductive biology of an important and less studied freshwater carp, *Labeo boggut* (Sykes, 1839), from two perennial rivers of Central India were studied between January 2008 and December 2009. Maximum three annual rings were found and used to assess growth data in samples representing 0 to 3+ year classes. LWR indicated positive allometric growth in males and females of both rivers. Asymptotic length (L_∞) and growth co-efficient (K) were 22.5 cm and 0.5 year^{-1} for the Betwa River; and 23.6 cm and 0.6 year^{-1} for the Ken River. Growth performance index (ø') was higher in the Ken than in the Betwa. Reproduction was between June and September and GSI of both sexes were maximal in mid-June, thereafter declining until September. Mean size at first sexual maturity was 12.2 cm (n = 12) for females and 13.2 cm (n = 8) for males in the Betwa, and 12.5 cm (n = 13) TL for females and 13.1 cm (n = 9) TL for males in the Ken. The exploitation level (E) and maximum allowable exploitation (E_{max}) limit of *L. boggut* was 0.23 and 0.36 in the Betwa, whereas it was 0.33 and 0.37 in the Ken. These presented biological traits and population characters of *L. boggut* from both rivers provide first basic information for use in future assessment and conservation planning.

Introduction

The Indian carp *Labeo boggut* (Syks, 1839) (Cyprinidae) is an economically important, bentho-pelagic fresh water species distributed throughout Central India northwards to the Cauvery River system, including Bangladesh and Pakistan (Talwar and Jhingran, 1991). With the exception of very preliminary information on breeding habits, sexual dimorphism, and fecundity of *L. boggut* (Misra, 1950; Job et al., 1955; Selvaraj et al., 1972), no current detailed international biological information is available on the general biology of this species. FiSAT has frequently used population parameter estimations of finfish and shellfish (Blaber et al., 1998; Amin et al., 2002), primarily because only length-frequency data was required.

Determination of fish age and growth has been commonly explored by scale analysis (Tandon et al., 1989; Desai and Srivastava, 1990; Tandon and Johal, 1993; Sarkar et al., 2008). The length–weight relationship has been used extensively in the analysis of fishery data due to technical difficulties and the time required to record weight in the field (Martin-Smith, 1996; Sinovcic et al., 2004; Froese, 2006) and is also widely used for conversion of the growth-in-length equation to growth-in-weight for stock assessment models (Wootton, 1990; Moutopoulos and Stergiou, 2002). In fish, the condition (K) factor reflects, through its variations, information on the physiological state of the fish in relation to its welfare. The K factor also provides information in comparing two populations living in specific conditions of feeding, density, climate, etc.; determining the period of gonadal maturation; and following up on the degree of feeding activity of a species to verify whether it is making good use of its source of food.

Effective management of any fishery requires considerable knowledge on population parameters such as age and growth and reproductive biology of the stock. The present paper aims to generate baseline data on the population structure and reproductive biology of a less-studied and economically important fish, *L. boggut,* in two important perennial rivers of the Yamuna basin that which will help in effective conservation planning for the development of this indigenous fishery. The present study area has been planned for use in countries having interlinking river systems (National Water Development Agency / Tech.III / 122 / 17 / 2005.V. http://www.nwda.gov.in, 2005), thus these comparative findings from two river populations may also serve as a basis for future conservation assessments of fish species.

Materials and methods

The River Betwa (N18°00′ E77°34′, 590 km length and discharge of 10 000 million m^3) and the River Ken (N24°41′ E079°54′, 427 km and 11 300 million m^3) are important perennial rivers of the Ganga basin. A total of 1674 *L. boggut* individuals were sampled from three sites on each river. Sampling in both rivers was done at random on alternate months between January 2008 and December 2009 (Fig. 1) by experimental daytime fishing (08:00–17:30 h) and at night (19:30–05:00 h). Fish sampling was in the channel .and near shoreline as per Bain and Knight (1996). Gear included cast nets (5–9 m radius, mesh size 1–5 cm), gill nets (length 30–75 m, mesh size 1–4 cm) and drag nets (with varying mesh sizes). After collection, specimens were preserved in 10% formalin solution, identified and measured. Total length (TL) of each fish was taken from the tip of the snout (mouth closed) to the extended tip of the caudal fin nearest 0.1-mm by digimatic caliper (Mitutiyo make) and weighed to the nearest 0.01 g (total weight, TW) with a digital weighing machine (ACCULAB Sartorious group). Data from the three stations in each river were pooled monthly and subsequently grouped into 1 cm intervals length-classes; length-frequency data were analyzed using the FiSAT software (Froese, 2006).

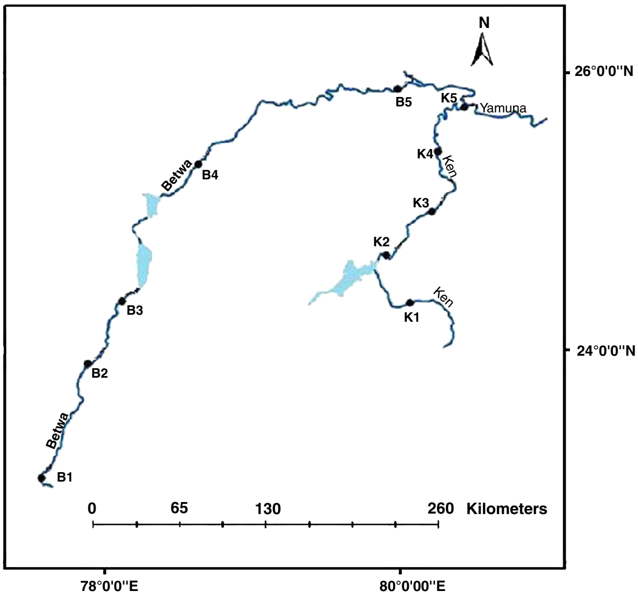

Fig. 1. Sampling stations of Betwa (B1–B5) and Ken rivers (K1–K5)

A total of 1674 specimen of *L. boggut* (845 fish samples from Betwa and 829 from Ken) were studied for age and growth. Scales (five from each side) were taken from the area between the lateral line and anterior edge of the dorsal fin, washed in 5% KOH, and rinsed in distilled water. The resulting slides were observed under a profile projector (Sipcon Profile Projector SP-400). The distance between the focus of the scale and each annulus was measured for back-calculation and growth rate analysis. Back-calculation was done using the described formula (Lee, 1920; Johal and Tandon, 1992; Sarkar et al., 2008). A chi-square (χ^2) test was used to determine whether sex ratio differed significantly from unity.

The length-weight relationship (LWR) of *L. boggut* was calculated applying the equation $\log W = \log a + b \log TL$, where a and b are the regression parameters (Froese, 2006). The coefficient of determination (r^2) was used as a quality indicator of the linear regression (Erguden and Goksu, 2010). Additionally, the 95% confidence limits of parameter b and the statistical significance level for r^2 were estimated. The condition factor (CF) was calculated using the equation: $K = 100*W/L^b$, where: W = weight of fish in grams, L = total length in cm, b = value obtained from the length-weight equation (Formula).

Population structure

In total, 845 *L. boggut* from the Betwa River and 829 from the Ken River were measured to study size-frequency distributions, which were plotted at 1-cm intervals for alternate months from January 2008 to December 2009. Bhattacharya's method, implemented from the FiSAT package (Froese, 2006), was used to identify the modes in the polymodal length-frequency distributions. Asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy Growth Formula (VBGF) were estimated using ELEFAN-I (Pauly and David, 1981). Estimated L_∞ and K were used to calculate the growth performance index (ø') (Pauly and Munro, 1984) using the equation:

$$\phi' = 2\log_{10}L_\alpha + \log_{10}K$$

Reproductive biology

The gonadosomatic index (GSI = gonads weight / total weight × 100, De Vlaming et al., 1982) was calculated for each sex. After dissection, gonads were measured to 0.001 g. According to the criteria proposed by Holden and Raitt (1975) and Bilgin and Çelik (2009), the maturity development stages were assigned as: (I) immature; (II) resting; (III) ripe; (IV) ripe and running; and (V) spent. First sexual maturity size was determined from the stage III criteria; gonad development was calculated for each size class. The proportion of mature fish by size was fitted to a logistic equation as described by King (1995): $P = 1/1 + \exp(a + b\,TL)$, where P is the predicted mature proportion, a and b the estimated coefficients of the logistic equation, and TL the total length. Size at sexual maturity (TL_{50}) corresponding to 0.5 sexually mature fish, was estimated as the negative ratio of the two coefficients [$TL_{50} = -(a/b)$].

Results

The scales of *L. boggut* are cycloid and distinguished by three sections: (i) the anterior embedded field, (ii) the posterior exposed and pigmented portion, and (iii) the two lateral portions, which were overlapped by the other scales.

Growth rate and sex composition

The appearance of growth rings on the scales of *L. boggut* in different year-classes showed on average little variation in either river (Table 1). Age group 3 in both rivers showed a higher growth rate over the previous age groups, a phenomenon referred to as growth compensation. Samples composed 541 females and 301 males in the Betwa River, and 557 females and 268 males in the Ken River. A total of 343 and 274 individuals were sexually indeterminate in the Betwa and Ken rivers, respectively, because they had very thin and transparent gonads. Throughout most of the year there was a predominance of females in both rivers except for December (Fig. 2). The sex ratio differed significantly from 1 : 1 (χ^2 = 15.325,

Table 1
Back-calculated lengths and growth rate of *Labeo* boggut

Age class	n	Average length (cm) at the time of capture	Back-calculated length		
			L1	L2	L3
Betwa River					
1+	245	10.8	10.200		
2+	230	15.3	9.9500	14.700	
3+	145	21.2	10.050	15.00	20.400
	620	15.73	10.050	14.850	20.400
SD			±0.258	±0.212	±0.00
Annual increment in length – C_L (cm)			10.050	4.8	5.55
Ken River					
1+	240	10.1	10		
2+	330	15.1	9.8	14.600	
3+	105	23.2	10	14.200	22.300
	670	16.13	9.93	14.400	22.300
SD			±0.115	±0.282	±0.00
Annual increment in length – C_L (cm)			9.93	4.47	7.9

n, sample size; L1, L2 & L3, back-calculated lengths at different age classes.

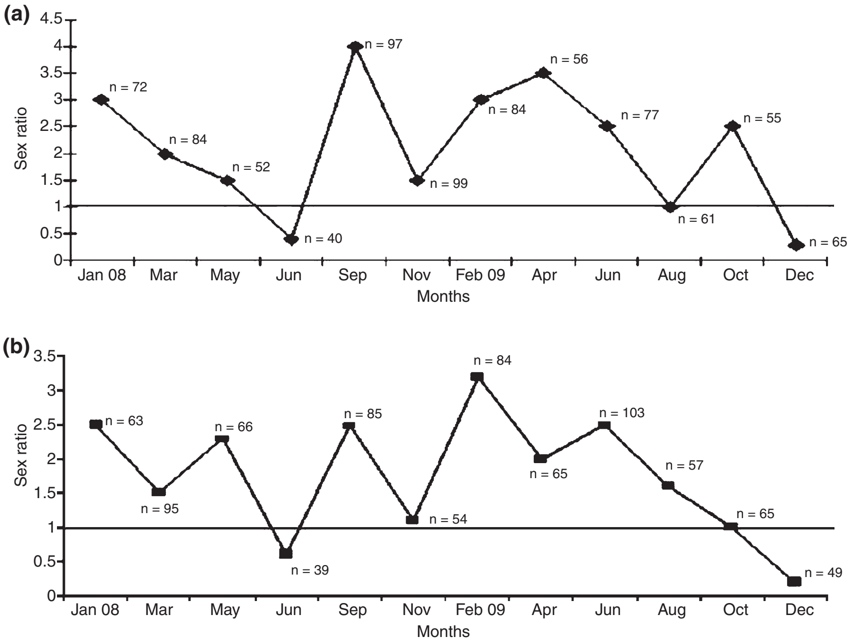

Fig. 2. Monthly variation in mean values of *Labeo boggut* sex ratio sampled from rivers (A) Betwa and (B) Ken. Straight line = 1 : 1 ratio; n = monthly sample size

$P < 0.001$ in the Betwa; and $\chi^2 = 14.112$, $P < 0.001$ in the Ken), as shown in Fig. 2.

Length-weight relation

Length-weight relationships of male and female *L. boggut* from the Betwa and Ken rivers are presented in Table 2. Both sexes showed positive allometric growth in each river. All relationships were highly significant ($P < 0.001$), with values of $r > 0.95$. When the specific gravity of a fish remains unchanged and retains the same shape during its lifetime, it grows isometrically, and the length value of exponent b would be exactly 3.0.

Condition factor

The female condition factor (K) ranged from 0.96 (±0.11) to 1.20 (±0.04) and 0.99 (±0.02) to 1.6 (±0.13), and for males from 0.83 (±0.13) to 1.05 (±0.09) and 0.88 (±0.05) to 1.20 (±0.14) in the rivers Betwa and Ken, respectively (Table 2). The condition factor decreased in both sexes at the start of the spawning period due to very high metabolic rates.

Table 2
L. boggut descriptive statistics and estimated parameters of length-weight relationships ($W = aL^b$) collected from two perennial tributaries of Yamuna basin

				Total length (cm)		$W = aL^b$						
Season	River	Sex	n	Min	Max	10^a	b	SE (b)	95% CI of a	95% CI of b	R^2	K
Summer	Betwa	M	80	9.00	19.00	0.006	3.162	0.029	−2.193 to −2.265	3.175 to 3.183	0.972	0.83 ± 0.13
		F	106	9.10	22.00	0.0063	3.182	0.014	−2.188 to −2.197	3.160 to 3.165	0.975	0.96 ± 0.11
		B	290	9.00	22.00	0.0063	3.162	0.018	−2.187 to −2.198	3.159 to 3.189	0.975	0.92 ± 0.19
	Ken	M	100	9.00	19.00	0.0046	3.243	0.012	−2.324 to −2.336	3.250 to 3.259	0.973	0.88 ± 0.05
		F	120	10.00	22.50	0.0048	3.257	0.022	−2.311 to −2.320	3.239 to 3.245	0.976	0.99 ± 0.02
		B	280	9.00	22.50	0.0050	3.223	0.028	−2.389 to −2.395	3.220 to 3.227	0.975	0.95 ± 0.08
Monsoon	Betwa	M	54	10.40	20.10	0.0047	3.290	0.027	−2.315 to −2.321	3.285 to 3.293	0.974	1.05 ± 0.09
		F	95	10.00	21.80	0.0045	3.300	0.013	−2.339 to −2.345	3.297 to 3.306	0.978	1.20 ± 0.04
		B	284	10.00	21.80	0.0060	3.253	0.022	−2.289 to −2.292	3.249 to 3.255	0.976	1.14 ± 0.10
	Ken	M	88	11.90	20.00	0.0045	3.364	0.017	−2.592 to −2.612	3.487 to 3.492	0.975	1.20 ± 0.14
		F	94	11.20	23.50	0.0026	3.290	0.018	−2.552 to −2.579	3.453 to 3.460	0.975	1.60 ± 0.13
		B	253	11.20	23.00	0.0030	3.372	0.018	−2.518 to −2.525	3.418 to 3.423	0.976	1.25 ± 0.18
Winter	Betwa	M	80	10.50	18.90	0.0047	3.224	0.025	−2.319 to −2.328	3.221 to 3.227	0.951	0.99 ± 0.02
		F	110	11.20	22.00	0.0043	3.249	0.065	−2.352 to −2.364	3.241 to 3.251	0.956	1.02 ± 0.12
		B	271	10.50	22.00	0.0055	3.156	0.046	−2.251 to −2.258	3.151 to 3.158	0.955	1.00 ± 0.06
	Ken	M	68	10.00	20.10	0.0036	3.322	0.034	−2.436 to −2.441	3.319 to 3.325	0.950	1.02 ± 0.01
		F	112	10.60	23.00	0.0023	3.355	0.028	−2.598 to −2.621	3.460 to 3.466	0.956	1.10 ± 0.02
		B	296	10.00	23.00	0.0028	3.399	0.023	−2.536 to −2.542	3.395 to 3.400	0.952	1.07 ± 0.02

M, male; F, female; B, both; a, Intercept; 10^a, anti log of Intercept; b, Slope; r^2, Coefficient of determination; K, Condition factor.

Population structure

The annual size frequency distribution obtained from alternate monthly samples showed exploited sizes to be between 9.5–21.5 cm in the Betwa and 10.5–22.5 cm in the Ken, with the bulk between 12.5–18.5 cm for Betwa and 10.5–20.5 cm in the Ken. Monthly size frequency distributions identified the modal lengths with cohorts in the different months (Fig. 3). The length-frequency distribution over 12 months suggested that the population consisted of a maximum of three and four age groups, respectively, for the River Betwa and River Ken, with mean values of 10.46, 16.82 and 19.1 cm for Betwa and 12.2, and 15.1, 16.67 and 21.67 cm TL for the Ken. River Betwa recruitment took place in March–April and May–June, and in the Ken in February–April and June–September, displaying a modal recruit size between 9.5–10.5 cm TL in Betwa, and 10.5–12.5 cm in the Ken (Fig. 3).

Growth parameters

Observed vs predicted maximum lengths (L_{max}) of *L. boggut* were 21.50 and 22.65 cm in the Betwa, and 22.50 and 23.23 cm in the Ken (Fig. 4). The range of the 95% confidence interval for maximum length was 21.95–23.35 cm and 22.64–23.82 cm for the rivers Betwa and Ken, respectively. The ELEFAN-I program estimated asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy Growth Formula (VBGF) for *L. boggut* as 22.58 cm and 0.53 year^{-1} for River Betwa, and 23.63 cm and 0.610 year^{-1} for the River Ken. The computed

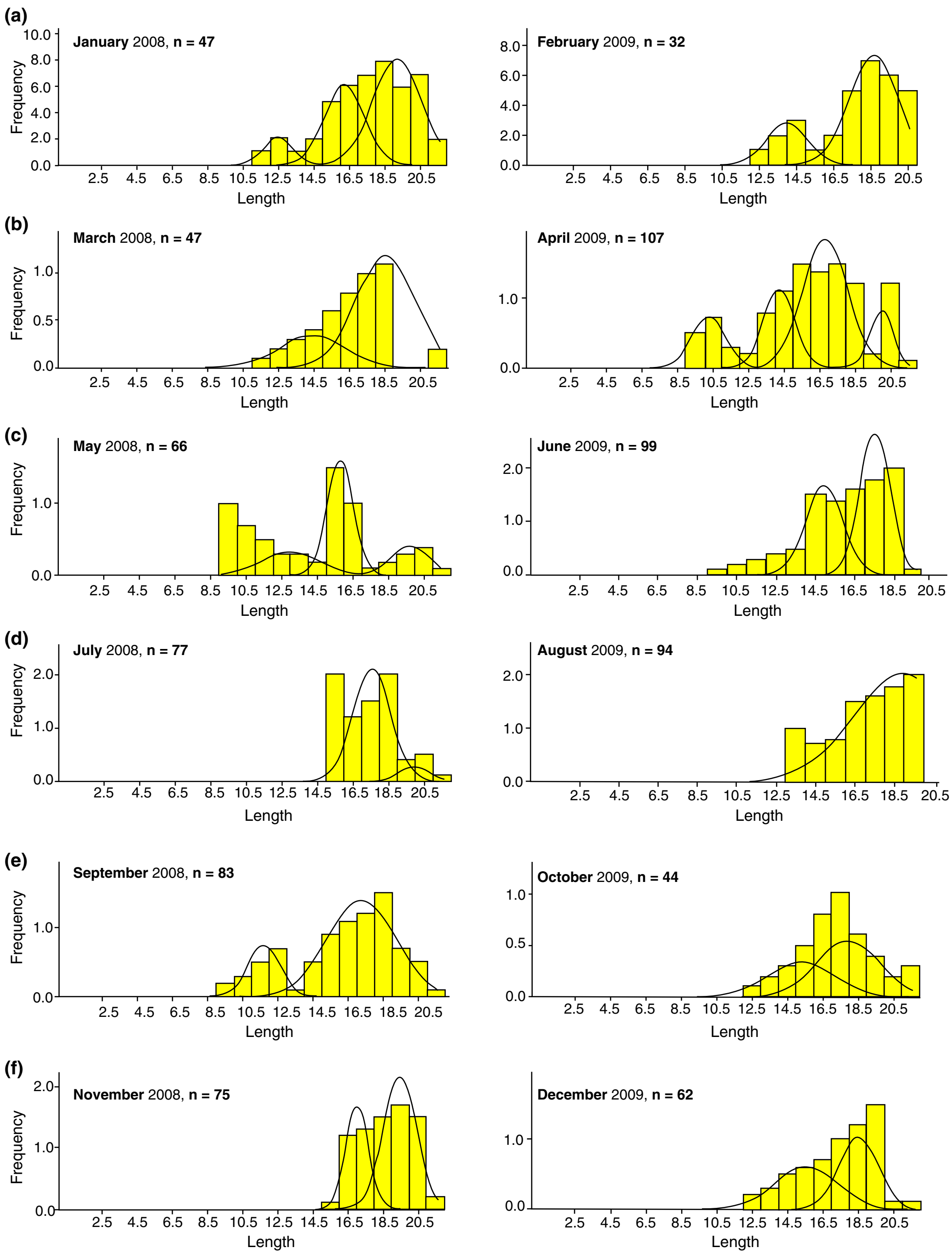

Fig. 3. Monthly length size distribution histograms of *Labeo boggut* in Betwa (a–f) and Ken (g–l) rivers

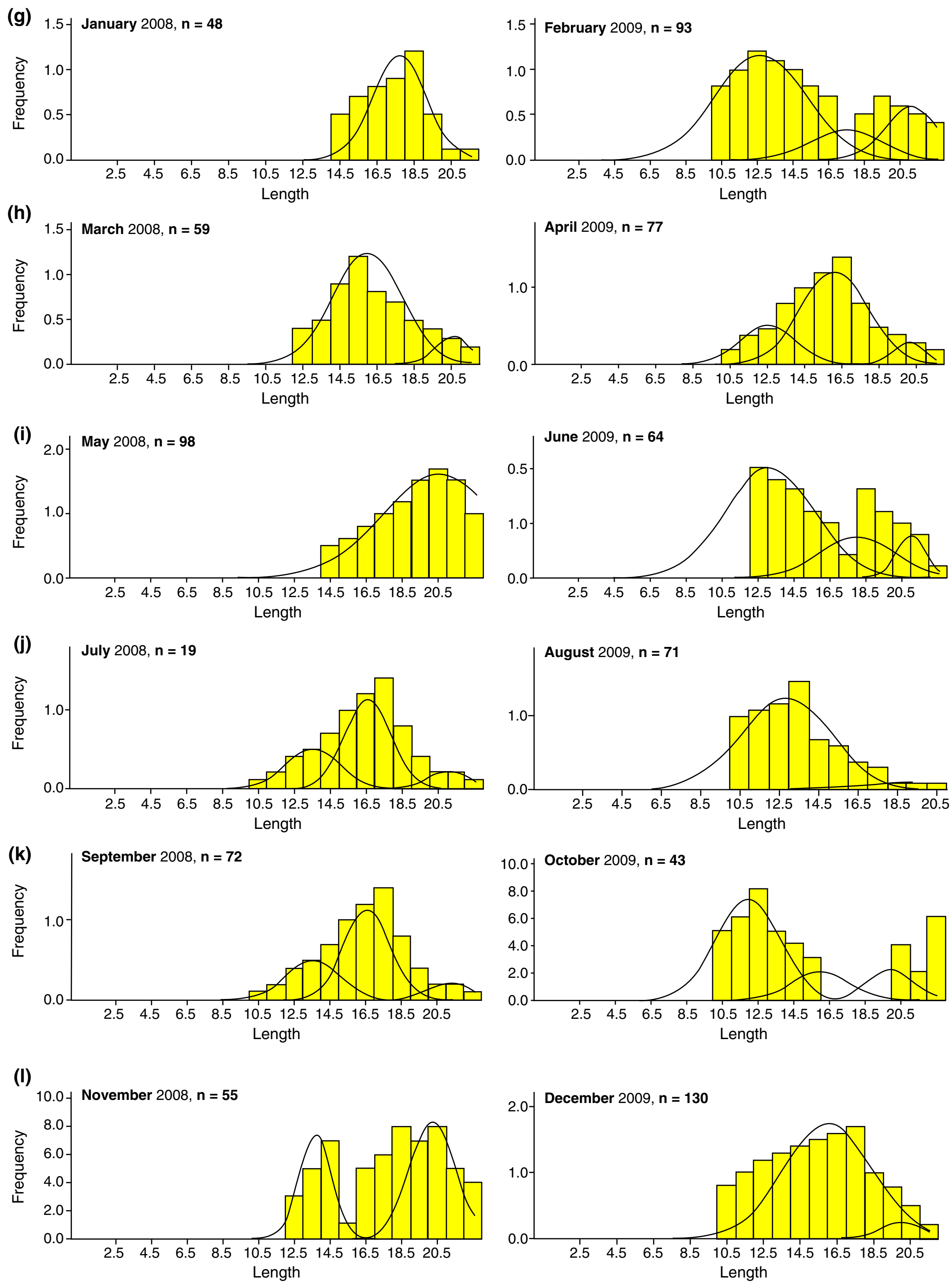

Fig. 3. Continued

growth curve with these parameters is superimposed over the restructured length distribution in Fig. 5. The calculated growth performance index (ø') of *L. boggut* in the River Ken (2.53) was higher than for the Betwa (2.43).

Reproduction

Male and female *L. boggut* with ripe gonads were recorded from January to December, but were most abundant in June and July. Ripe and running (stage IV) males were observed in May and June, especially in June; and for females in May–July, especially in July. Spent (stage V) males were mainly recorded in August and September, and females mainly from September to October (Fig. 6). Monthly variation of the gonadosomatic index (GSI) (Fig. 7) ranged between 8.9–34 and 7.2–36 in females, whereas it was 0.8–4.8 and 0.81–4.2 in males of the rivers Betwa and Ken, respectively. Average GSI of females was 19.9, and 2.6 in males. GSI values exhibited a similar trend in both sexes, with a maximum in mid-June then declining until September (Fig. 7). The spawning season thus

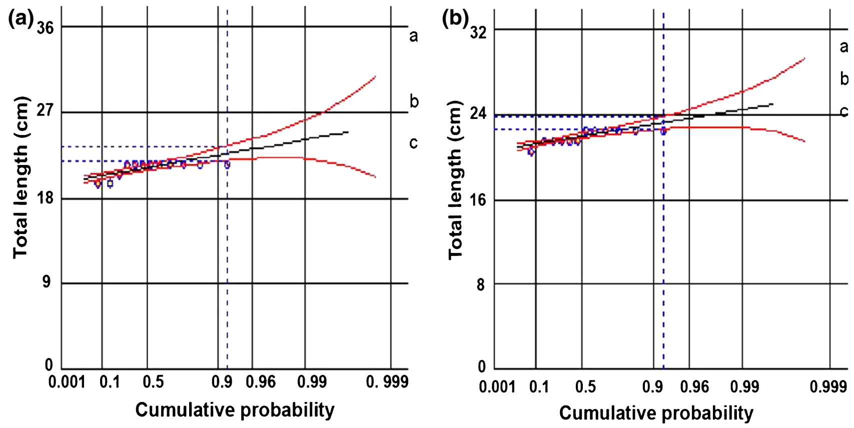

Fig. 4. Predicted maximum total length of *Labeo boggut* from (a) Betwa and (b) Ken rivers based on extreme value theory (Formacion et al., 1991). Predicted maximum length and 95% confidence interval obtained from intersection of overall maximum length with lines b, a and c, respectively

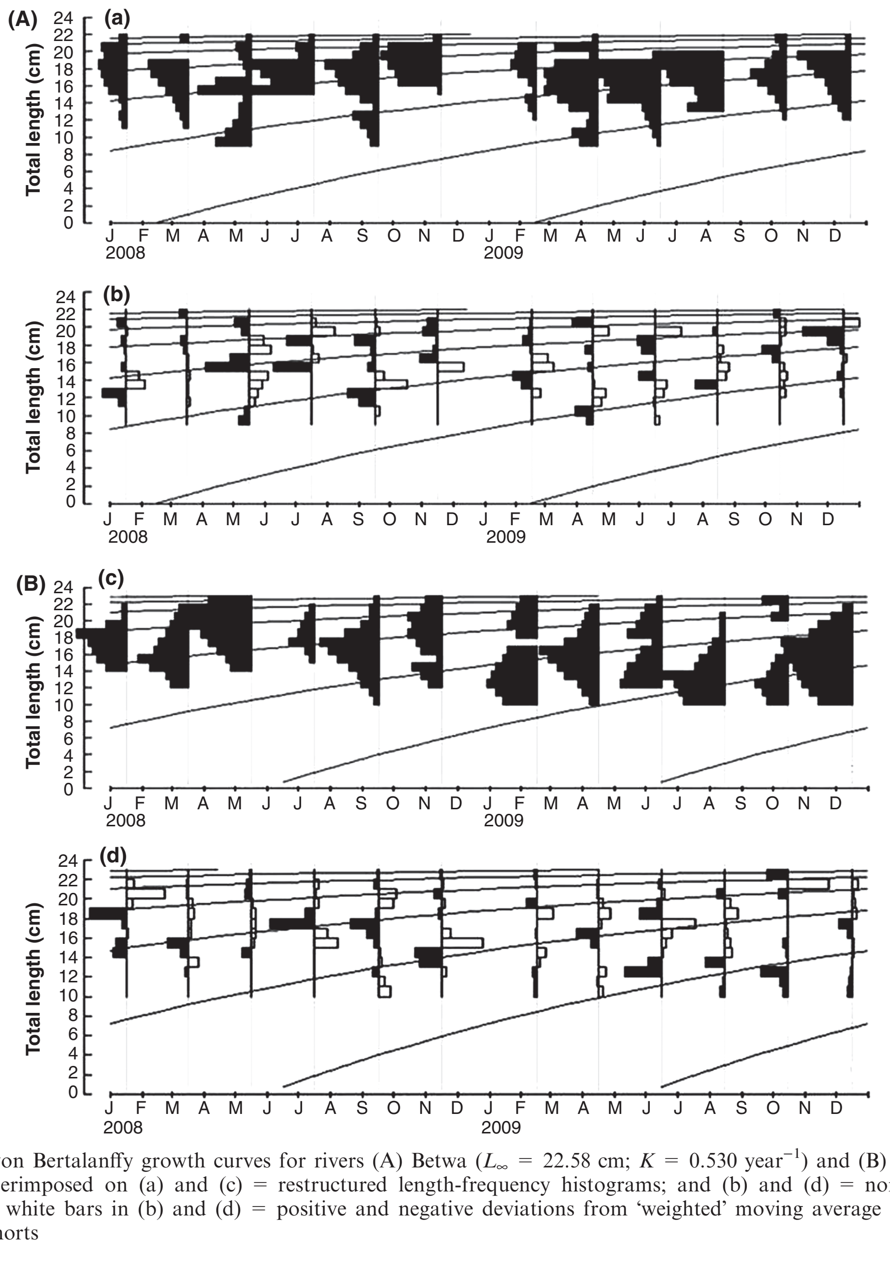

Fig. 5. *Labeo boggut* von Bertalanffy growth curves for rivers (A) Betwa (L_∞ = 22.58 cm; K = 0.530 year^{-1}) and (B) Ken (L_∞ = 23.63 cm; K = 0.610 year^{-1}) superimposed on (a) and (c) = restructured length-frequency histograms; and (b) and (d) = normal length frequency histograms. Black and white bars in (b) and (d) = positive and negative deviations from 'weighted' moving average of three length classes representing pseudocohorts

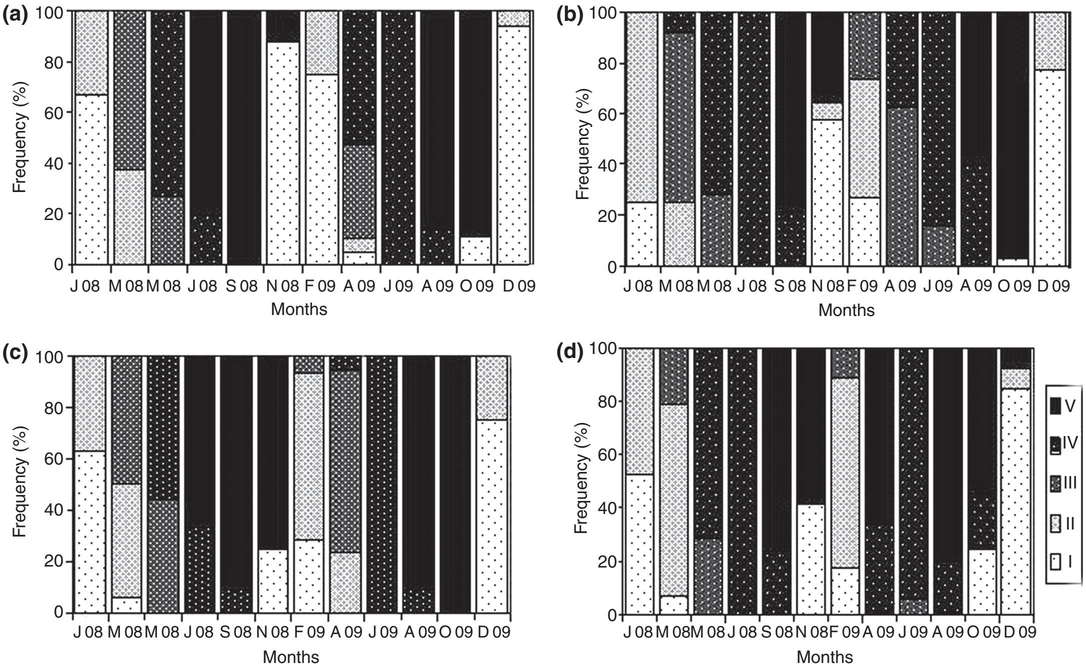

Fig. 6. Relative composition of maturity stages in *Labeo boggut* cohorts sampled in two perennial tributaries of the Ganga River, January 2008 (J 08) to December 2009 (D 09); data grouped bi-monthly: Betwa River (a = males; b = females) and Ken River (c = males; d = females). Total sample size (n): Betwa = 310 males, 386 females; Ken = 302 males, 350 females)

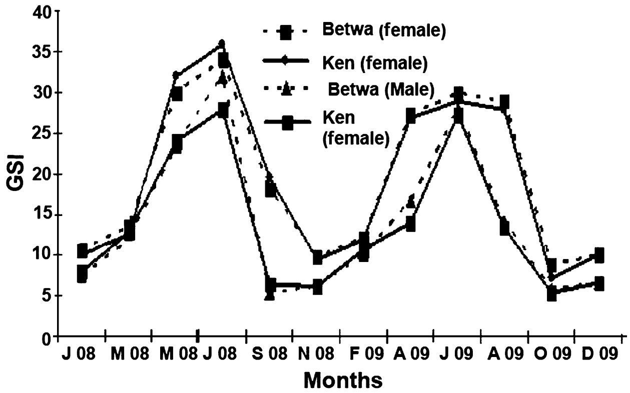

Fig. 7. Seasonal variation of gonadosomatic indexes (GSI) for female and male *Labeo boggut* from rivers Betwa and Ken, January 2008 (J 08) to December 2009 (D 09)

extends from June to September. During the study period, 182 of 317 females and 96 of 185 males collected from Betwa River and 184 of 326 females and 123 of 229 males sample collected from the Ken River were found to be sexually mature. The relationship between total length (TL) and the proportion of adult males and females of the Betwa and Ken was calculated as $P = 1/1\ (3.22 - 2.32)$ TL and $P = 1/1\ (3.24 - 2.3)$ TL; $P = 1/1\ (3.34 - 2.79)$ TL and $P = 1/1(3.41 - 2.5)$ TL, respectively. From this, the estimated size for 50% sexual maturity (TL_{50}) was 12.2 and 12.5 cm for females and 13.2 and 13.1 cm for males, of the Betwa and Ken, respectively (Fig. 8).

Discussion

The sex ratio study on *L. boggut* showed a deviation from 1 : 1, with the presence of more females in most months. Similar results were observed by Selvaraj et al. (1972) in *L. boggut* and Weyl and Booth (1999) in *L. cylindricus*. The predominance of males during December in both rivers might have been due to their faster growth; similar results were reported by Nikolsky (1956) and Singh (1994). Furthermore, an unequal sex ratio in *L. boggut* populations may result from physiological mechanisms as well as physical factors such as interspecific sex physiology, differential migration or habitat ethology between sexes and sex-linked tolerance of the environment.

The growth coefficient *b* generally lies between 2.5 and 3.5 (Carlander, 1977); the relation is said to be isometric when equal to 3, as reported for most fish (Quinn and Deriso, 1999). In the present study all LWRs indicated positive allometric growth in both sexes from both rivers. However, all allometric coefficients (*b*) estimated in the present study were within the expected range (Froese, 2006). Due to the absence of data on LWRs of *L. boggut*, the present results could not be compared with other *L. boggut* LWR studies. Similar positive allometric growth was reported by Sarkar et al. (2009) and Sani et al. (2010) for *Chitala chitala* and *C. mrigala* in India, and for major carp by both Pet et al. (1996) in Sri Lanka and Ahmed et al. (2003) in Bangladesh. The seasonal average value of '*b*' in the River Ken was found to be greater than in River Betwa. In both rivers it was maximum in the monsoon season and lowest in summer. Length–weight relationships in fishes are affected by a number of other factors including gonad maturity, sex, diet and stomach fullness, health and preservation techniques (Bagenal and Tesch, 1978; Olim and Borges, 2006).

The condition factor of *L. boggut* in both rivers shows a decrease at the start of the spawning period due to very high metabolic rates. Usually there is a gradual increase in condition factor during the reproductive period (monsoon) with normalization immediately afterward, possibly due to the state of gonadal development based on the consumption of fat reserves during the spawning period; similar observations were reported by Martins-Juras (1980) and Gomiero and Braga (2005).

The higher value of asymptotic length of *L. boggut* in River Ken than in River Betwa may be due to better feeding and

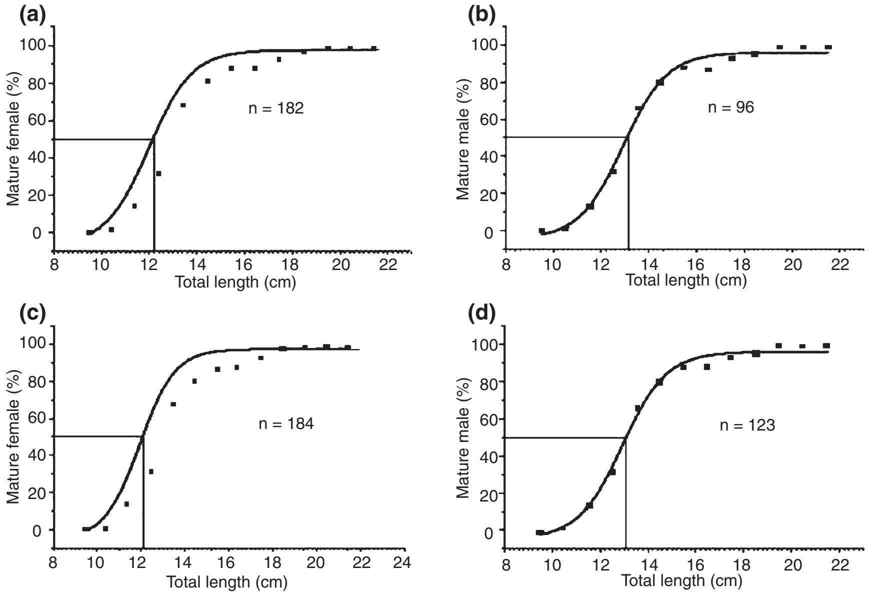

Fig. 8. Sexual maturity curves of male and female *Labeo boggut* sampled from rivers Betwa (a,b) and Ken (c,d), n = sample size

habitat conditions. These findings agree with those of Azadi et al. (1997) in *G. chapra* and *G. manminna* from Kaptai Lake. Rather similar values of L_∞ estimated by ELEFAN-I and Wetherall Plot methods were also obtained by Azadi et al. (1997) in *Gudusia chapra* and *Gonialosa manminna*, and Suresh et al. (2006) in *Macrognathus pancalus*.

The change in GSI and magnitude of adult specimens with ripe ovaries indicates that the spawning season of *L. boggut* is June to September. Selvaraj et al. (1972) reported a similar spawning period trend for *L. boggut* in Panna, India. The values of GSI presented herein are in agreement with those of *L. boggut* and other minor carps reported by Selvaraj et al. (1972) and Siddiqui et al. (1976). Current results on age at first sexual maturity shows that the *L. boggut* attains maturity in the first year of life, just like other carps reported by Alikunhi (1950); Alikunhi and Rao (1951); Selvaraj et al. (1972). Difference in the length at first maturity arises because the sexual maturity is a function of the size and may be influenced by the abundance and seasonal availability of food, temperature, photoperiod and other environmental factors in various localities (King, 1995).

The present study shows a well-defined growth pattern, population structure and reproductive biology of *L. boggut* in two perennial rivers of Central India, but which will likely be altered in the near future due to river interlinking. It is predicted that the present ecological conditions will be changed after river alteration, which may further modify the reproductive strategies and population characters of *L. boggut* stocks. Therefore, this baseline information on the different biological and population traits of this less-studied fish should be useful for comparisons in the context of change/loss and also to effect good conservation and restoration planning.

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