European Journal of Biological Sciences 4 (4): 126-135, 2012
ISSN 2079-2085

DOI: 10.5829/idosi.ejbs.2012.4.4.6448

Pattern of Intrabasin Variation in Condition Factor, Relative Condition Factor and Form Factor of an Indian Major Carp, *Labeo rohita* (Hamilton-Buchanan, 1822) in the Ganges Basin, India

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Abstract: To test intrabasin variation of the condition factor, relative condition factor and form factor of a commercially important Indian Major Carp *Labeo rohita* (Hamilton-Buchanan 1822), a total of 1183 individuals were sampled in six rivers of the Ganges basin from January 2009 to December 2011. Condition factor (K) for male populations ranged from 1.20±0.28 - 1.51±0.17 while, in female ranged from 1.26±0.17 - 1.40±0.36. Significant variation of K was significantly in male populations of all the rivers ($p<0.05$) while, it was not significant in females ($p>0.05$). The variation in K with total length of fish showed distinct pattern of alignment. Relative condition coefficient (K_n) showed significant variations among different male populations and also with the total length of *L. rohita*. The UPGMA was employed to detect the population groups in males and females, which resulted in generation of five clusters for both sexes in six populations. For detecting shape variations of fish among different populations form factor has been deduced. Form factor ($a_{3.0}$) for males of six populations ranged from 0.004808-0.005404 and 0.004819-0.008669 for female stocks of six different rivers.

Key words: *Labeo rohita* · Relative Condition Factor · Form Factor · Variation · Ganges Basin · India

INTRODUCTION

Indian major carp, *L. rohita* commonly known as 'rohu' belongs to the family Cyprinidae, a warm water teleost, available in lakes, ponds, rivers and also confined to water bodies of India and adjacent countries [1]. The natural resources of this fish are primarily from the network of the Ganges River system, the Sindh and the Brahmaputra River systems in the north and the east coast and west coast river systems flowing through in the south and central India. It is a highly preferred carp and fetches high market prices. India is by far the largest producer of rohu and the total global aquaculture production peaked in 2009, at nearly 13, 50,000 tons [2]. The fish grows up to a maximum size of 200 cm [3]. However, there has been considerable decline in the overall size and species in the natural waters and the species is now categorized as LC (Least Concern) as per IUCN [4]. To successfully develop and manage the population in natural waters of the Ganges Basin, it is important to update the current growth pattern in natural habitat. Therefore, in India, NBFGR, Lucknow has been running a flagship network program on the stock identification of *L. rohita* using biological and molecular tools [5].

Fulton's condition factor is widely used in fisheries and fish biology studies. This factor is calculated from the relationship between the weight of a fish and its length, with the intention of describing the "condition" of that individual fish [6]. Different values of condition factor of a fish indicate the state of sexual maturity, the degree of food sources availability, age and sex of some species [7] and the system of environment [8]. In addition, the effect of environmental changes on fish species is also reflected through the score of fish condition factor. Condition factor provided information when comparing two or more

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populations living in certain feeding, density, climate and other conditions; when determining the period of gonadal maturation; and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source [9-11]. Relative condition factor can be used for comparing the observed weight of an individual with the mean weight for that length [6]. Relative weight is considered as management goal by fishery manager for monitoring status of fishes and for comparative growth studies. Relative weight is suitable index for comparing condition across populations and species [6]. For the evaluation of the significant changes in body shapes of fishes from different populations or species the form factor is an important tool [6]. Condition factor and relative condition factor of *Labeo* genus has been extensively investigated and reported [12-14]. The studies on *L. rohita* have been earlier investigated [15-17]. However, the information about condition factor, relative condition factor and form factor of *L. rohita* from Ganges Basin is negligible and fragmentary. Our study is the first attempt for evaluating the pattern of intrabasin variation in these factors and filling up the paucity of the information regarding growth of this fish over the decades for identifying different potential stocks.

MATERIALS AND METHODS

Sample Collection: Samples of *L. rohita* were collected randomly during January 2009 to December 2011 from six different drainages of the River Ganges Basin (70-88°30' East and 22°-31° North) including main channel. The GPS coordinates and the location of the selected sites on these rivers and the number of samples collected from each river is mentioned in Table 1. The samples were collected by using different types of fishing gears (cast net, drag net, gill net). Altogether 1183 specimens were collected and the required measurement of length and weight were taken at the site by using digital caliper (Mitutiya) and digital weighing machine (ACCULAB Sartorius Group) respectively. The length of the fish was taken from the tip of snout (mouth closed) to the extended tip of the caudal fin nearest 0.01mm and weighed to the nearest 0.01 gm (total weight). All the specimens were dissected at the site and the sexes were identified.

Methodology

Condition Factor: Index of well being or condition of fish is measured by the unit called condition factor (K) calculated by using Fulton [18] type condition factor of the form:

$$K = W*10^2/L^3$$

where,
K: condition factor,
W: weight of fish in grams
L: total length of fish in mm.

K calculated for individual fish was pooled year-wise, river-wise and sex-wise.

Relative Condition Factor: The relative condition factor (K_n) compensates for changes in form or condition with increase in length and was calculated using LeCren [19] & Froese [6]:

$$K_n = W/aL^b$$

where,
W = Observed weight in grams,
L = length of fish in mm

For relative condition factor relative weight was calculated by the formula:

$$W_{rm} = 100*W/a_m L^{bm} \text{Froese [6]}$$

where W_{rm} is relative weight, W observed weight in grams, a_m = geometric mean of intercept *a*, b_m is mean of slope *b* and L is the length of fish in mm.

Table 1: Sample size and the GPS coordinates of the samplings sites and land use pattern of *Labeo rohita*

Rivers (Sites)	Sample size	Latitude (^{0}N)	Longitude (^{0}E)	Land use pattern
Ganges (Narora)	273	28^{0}4'14"	78^{0}44'54"	Atomic Power Plant, Dams, temples, Semi-urban, agriculture, domestic sewage
Ghagra (Faizabad)	146	26^{0}75'	81^{0}99'	Semi-urban, agriculture, domestic sewage
Betwa (Bhojpur)	162	23^{0}45'39"	78^{0}14' 93"	Small dams, water lifting pumps, new road construction activities, industrial discharge, temples, rural, agriculture
Sharda (Palia)	160	22^0 49' 60"	75^0 47' 60"	Rural area, buffer zone (PA) agriculture activities, Forest
Ken (Patan)	197	24^{0}41" 40"	79^{0}54' 95"	Rural area, buffer zone (PA) agriculture activities, Forest
Gomti (Lucknow)	245	26^{0}52'22"	80^{0}54'58"	Urban, barrage, domestic sewage, beverage, distillery industry, temple in the river bank

Form Factor: The slope of log *a* vs *b* can be used to estimate for a given LWR the value that coefficient *a* would have if exponent *b* were 3. This value ($a_{3.0}$) can be interpreted as a form factor of the species or population. For this species the form factor ($a_{3.0}$) was calculated according to Froese [6]

$$a_{3.0} = 10^{\log a - s\,(b-3)}$$

where *a* and *b* are the coefficient of LWRs and *s* is the regression slope of log *a* vs *b*.

Variations in the condition factor (K), relative condition factor (K_n) and form factor ($a_{3.0}$) were described among different geographical locations. The significance of the K and K_n were assessed by analysis of variance (ANOVA) and the values for each river were tested by t-test to verify its significance level between males and females among the six rivers. All the statistical analysis was done by using SPSS 10.0 and Excel 2007.

RESULTS

Variation in Condition Factor (K): The sample size, length range and mean K±SD values are given in table 2. The results indicated that there were significant difference among the condition factor of male populations of all the rivers ($p<0.05$). None of the rivers showed any significant difference in female populations ($p>0.05$). The value of K ranged from 1.20-1.51 for males. The minimum K was noticed for River Betwa (1.20±0.28) and highest value in River Ghagra (1.51±0.17). In female populations the value of K was lowest for Rivers Ganga and Gomti (1.26) and highest for River Ghagra (1.40).

The variations in K with total length (mm) of fish in male populations of all the rivers are given in figure 1. In River Ghagra five phases of variation are easily distinguished. In phase 1, K significantly increased from 1.35 at a length class of 300-380 mm to 1.54 at a length class of 380-460 mm. In phase II, it decreased from 1.54 (380-460 mm) to 1.49 at a length class of 460-540 mm. In phase III, it again increased from 1.49 (460-540 mm) to 1.67 at a length class of 540-620 mm. In phase IV, there was a decline from 1.67 (540-620 mm) to 1.58 at a length interval of 700-780 mm and at final phase it increased from 1.58 (540-620 mm) to a highest value of 1.70 at a length interval of 780-860 mm. In River Betwa variation was observed in three phases, in phase I the K increased from 0.98 at a total length interval of 280-360 mm to 1.48 at a length interval of 600-680 mm, in phase II it showed slight increase from 1.48 to 1.52 at a length of 760-840 mm and then declined again to 1.48 at a length of 840-920 mm. For River Sharda K ranged from 1.21-1.44 at the respective length intervals of 440-520 mm and 600-680 mm. For River Ken K increased from 1.07 at length of 310-390 mm to 1.31 at a length interval of 550-630 mm and then finally decreased to 1.24 at a length of 630-710 mm. In River Ganges four phases are clearly noticed, in phase I K increased from 0.96 at a length class of 160-240 mm to 1.20 at a length of 320-400 mm. In phase II it decreased from 1.20 to 1.12 at a length class of 480-560 mm. In phase III the value increased from 1.12 to highest value of 1.58 at a length interval of 720-800 mm and at final phase it decreased from 1.58 to 1.29 at a length of 880-960 mm. In River Gomti the lowest K (1.20) was observed at al length interval of 260-340 while highest K (1.48) at a total length of 660-740 mm.

Table 2: Descriptive statistics of Fulton's condition factor (K), Relative condition factor (Kn) and Form factor (a_3.0) of *L. rohita* from six different rivers of Ganges Basin

Rivers	Sex	N	Length range (mm)	Fulton's condition factor (K) Min.-Max.	Mean ± SD	95% CI	Relative condition factor (Kn) Min.-Max.	Mean± SD	95% CI	Form factor (a_3. 0)
Ganges	M	137	308-920	0.74-2.00	1.27 ±0.26^{d}	1.22-1.30	0.07-3.91	1.28±0.98^{a}	1.13-1.35	0.004830
	F	136	160-900	0.73-2.00	1.26 ±0.23	1.23-1.30	0.28-3.80	1.21±0.85	1.16-1.28	0.004819
Ghagra	M	77	305-800	1.22-2.08	1.51 ±0.17^{a,b,c,d,e}	1.46-1.53	0.37-3.39	1.39±0.74	1.32-1.42	0.005404
	F	69	160-850	0.88-2.14	1.40 ±0.36	1.27-1.46	0.09-4.14	1.13±1.05	1.10-1.24	0.005071
Betwa	M	86	280-870	0.81-1.97	1.20 ±0.28^{a,f,g}	1.15-1.26	0.20-3.15	1.59±0.87	1.42-1.63	0.004808
	F	76	308-920	0.85-1.97	1.35 ±0.25	1.29-1.41	0.23-3.65	1.51±0.87	1.43-1.61	0.004920
Sharda	M	89	280-850	0.97-1.75	1.32 ±0.17^{b,l,g,h}	1.28-1.36	0.27-3.40	1.79±0.92	1.67-1.82	0.004977
	F	71	290-940	0.87-1.83	1.35 ±0.20	1.30-1.39	0.27-3.89	1.12±0.89	1.09-1.18	0.005223
Ken	M	112	310-710	0.79-1.56	1.20 ±0.15^{c,f,h,i}	1.17-1.23	0.24-1.91	0.89±0.44^{a}	0.79-1.02	0.004819
	F	85	160-870	0.74-2.86	1.30 ±0.35	1.23-1.38	0.07-3.27	1.21±0.85	1.12-1.43	0.004875
Gomti	M	125	265-880	0.87-1.89	1.31 ±0.21^{e,l,g,i}	1.27-1.35	9.25-3.46	0.99±0.74	0.84-1.21	0.004897
	F	120	265-810	0.99-1.75	1.26 ±0.17	1.23-1.30	0.45-3.33	1.23±0.65	1.12-1.73	0.008669

Superscript *a* to *i* represent the value of significance (P<0.05) for male (M) and female (F) populations

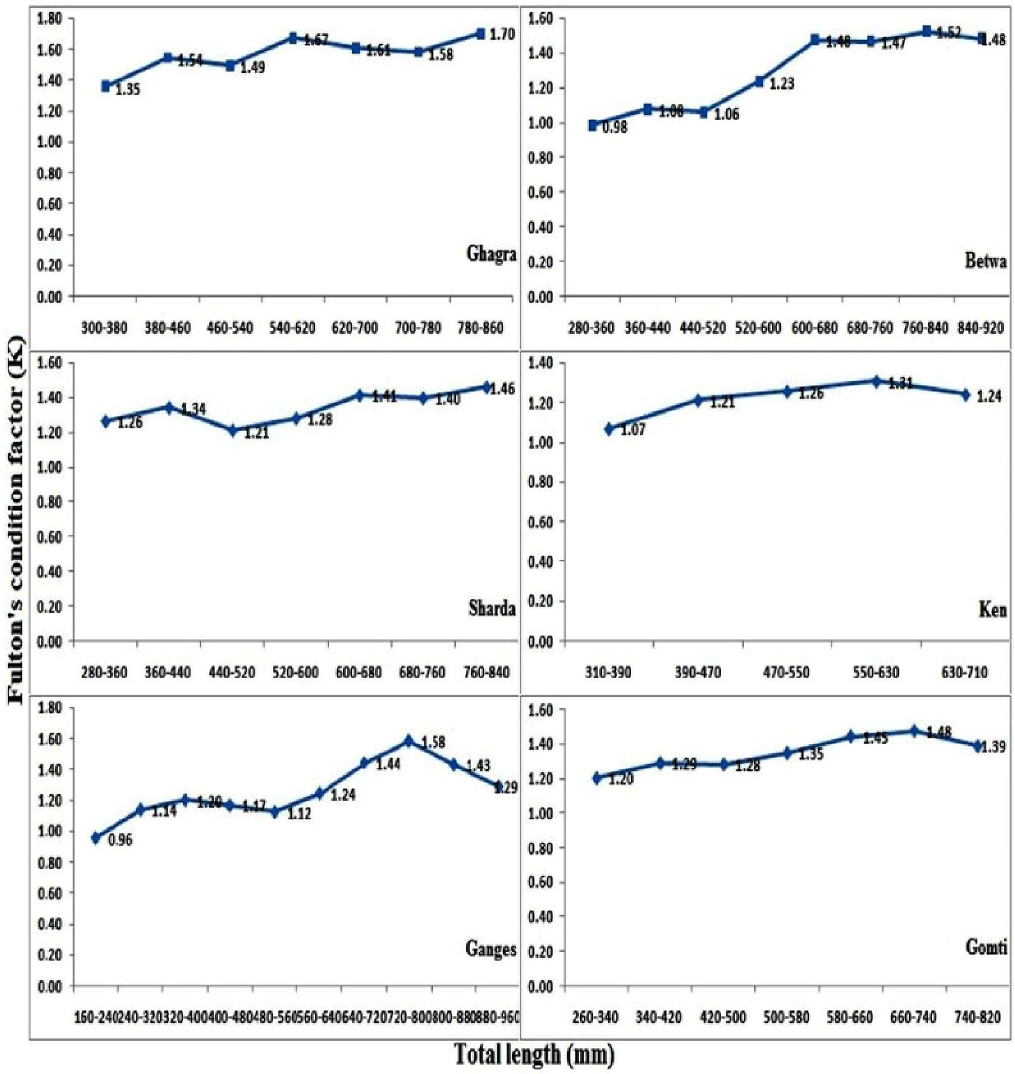

Fig. 1: Variation of condition factor (K) with the total length (mm) of male population of *L. rohita* for six populations from January 2009 to December 2011

In female populations the K values were plotted against the total length (mm) (Figure 2). The variation of K in Ghagra showed three phases, it first increased from 1.09 to 1.41 then declined to 1.16 and again increased to 1.93 at 1.60-240 mm, 240-320 mm, 400-480 mm and 800-880 respectively. For River Betwa the value increased from 1.03 to 1.63 and then decreased to 1.51 at different length intervals. For River Sharda K showed lowest value at 290-370 mm (K = 1.23) and highest value at 610-790 mm (K = 1.48), the value of K noticed for River Ken ranged from 0.96-1.55 at 160-240 mm and 640-720 mm respectively. In River Ganges K ranged from 1.15-1.61 at 300-380 mm and 700-780 mm respectively. In River Gomti K ranged from 1.17-1.61 at 460-540 mm and 780-860 mm respectively.

Variation in Relative Condition Factor (K_n): The mean K_n±SD values are given in table 2. The results indicated that there were significant difference between the K_n values of male populations in Rivers Ken and Ganges ($p<0.05$). In female populations none of the rivers showed any significant differences ($p>0.05$). K_n ranged from 0.89-1.79 for males. The minimum value was noticed for River Ken (0.89±0.44) and highest for River Sharda (1.79±0.92) and in case of female populations K_n was lowest for River Sharda (1.12) and highest for River Betwa (1.51).

The variation of relative condition factor with total length of fish in male populations of all the rivers is given in figure 3. In River Ghagra the K_n varies from 0.53 at a length interval of 300-380 mm to 3.34 at 780-860 mm. River Betwa showed the same variation as River Ghagra,

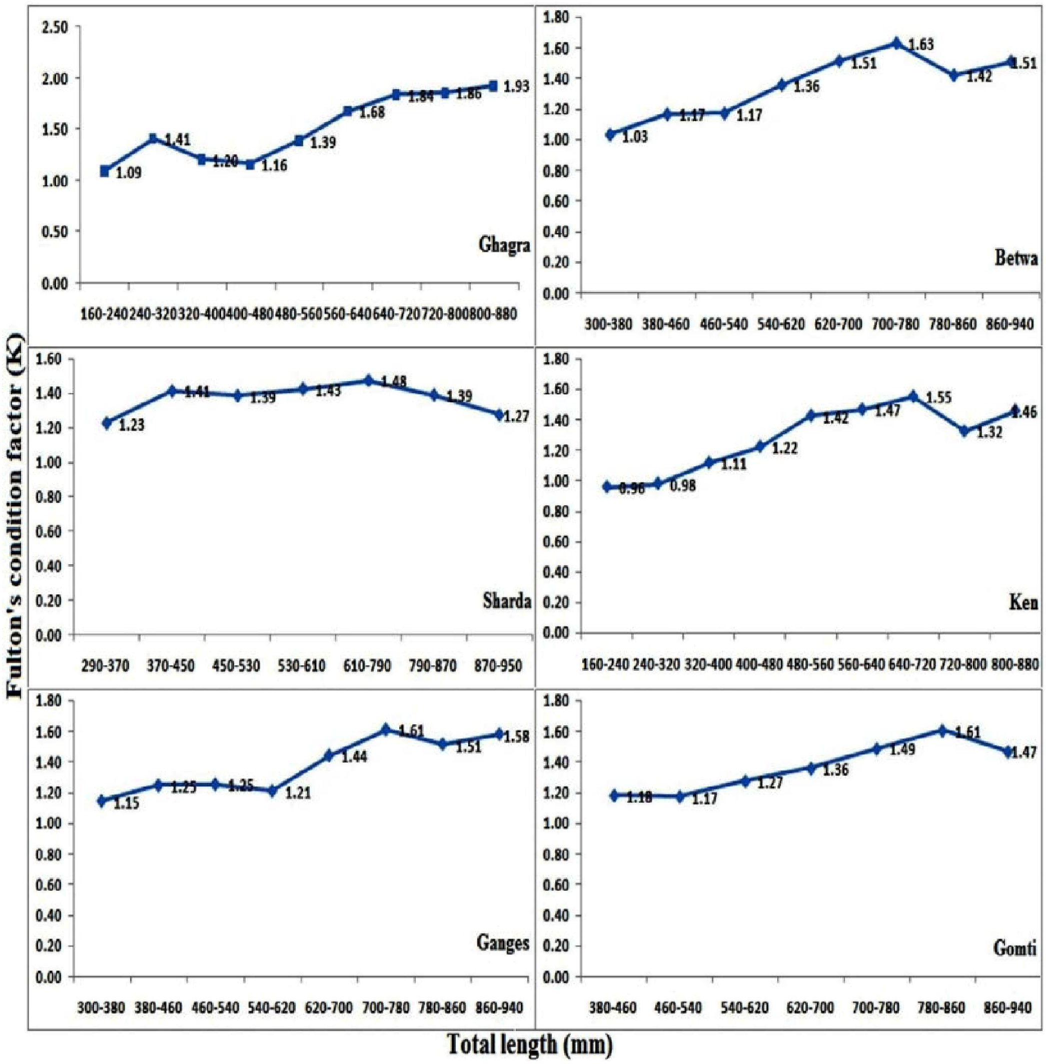

Fig. 2: Variation of condition factor (K) with the total length (mm) of female population of *L. rohita* for six populations from January 2009 to December 2011

the lowest K (0.30) was recorded at 280-360 mm and the highest value (3.12) at 840-920 mm. In River Sharda two phases are formed, in phase I K_n decreased from 0.82 (280-360 mm) to 0.48 at 360-440 mm of total length interval, in phase II it increased from 0.48 to 3.01 at a length interval of 760-840 mm. For River Ken the value increase from 0.72 at a total length of 310-390 mm to 1.07 at a length interval of 470-550 mm then decreased to 0.84 at a length of 550-630 mm and finally the value increased from 0.84 to 0.93 at a length of 840-920 mm. River Ganges showed zigzag type of variation in K_n, in phase I the value from 0.37 (160-240 mm) to 2.30 (400-480 mm), in II phase it decreased to 1.09 at 560-640 mm length interval, phase III showed increased value from 1.09 to 1.33, phase IV indicated a sudden decrease to 0.57 and then again increased to 1.79 at 800-880 mm length interval and finally decreased to 1.53 at final length interval. In River Gomti K_n it increased from 0.53 (260-340 mm) to a highest value of 1.91 at a length interval of 500-580 mm, it decreased from 1.91 to 1.27 but showed a slight increase at a length interval of 660-740 mm.

For female populations the K_n was plotted against the total length (mm) (Figure 4). River Ghagra showed a constant increase in K_n from 0.13 at a length interval of 160-240 mm to 3.95 at a total length of 800-880 mm. In River Betwa the variation in K_n was overt in four phases, in phase I it increased from 0.64 (300-380 mm) to 1.75 at a total length of 380-460 mm, in phase II it decreased to 0.54 at 540-620 mm length range, in phase III it again increased

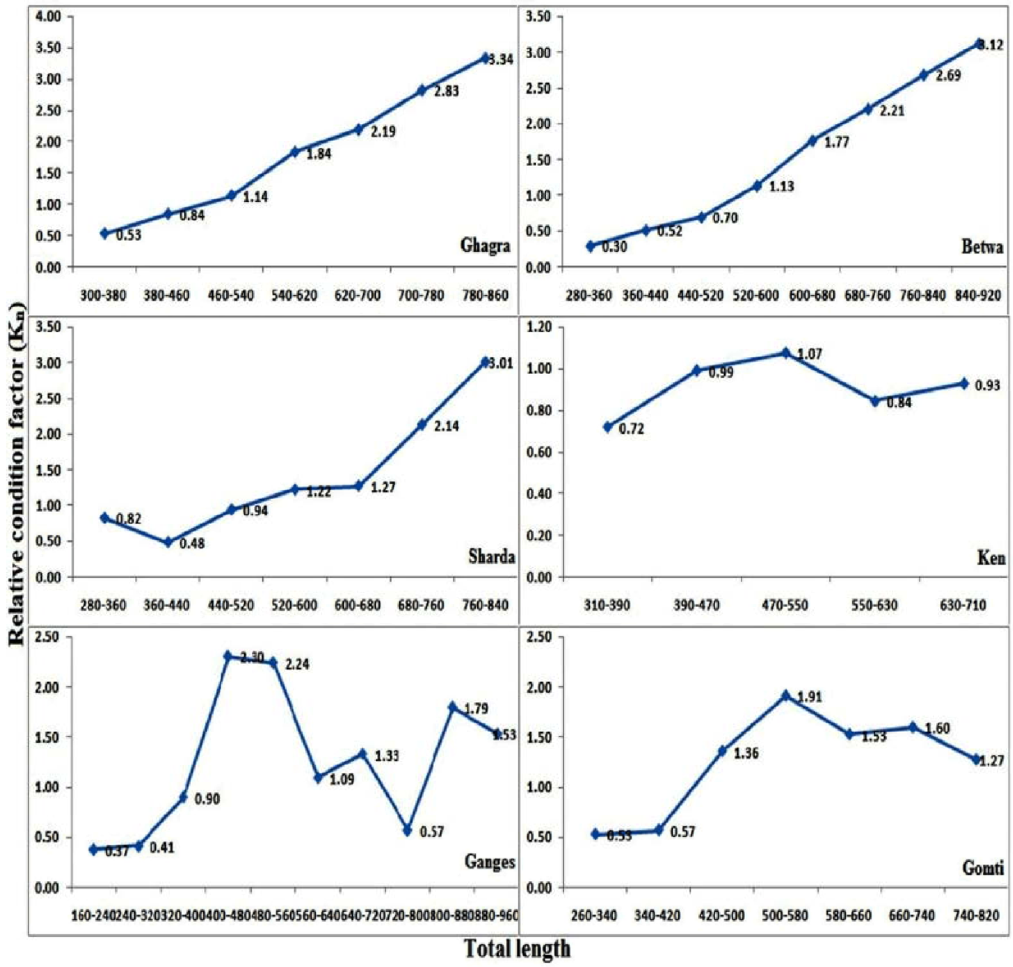

Fig. 3: Variation of relative condition factor (Kn) with the total length (mm) of male population of *L. rohita* for six populations from January 2009 to December 2011

to a highest value of 2.81 at a length interval of 780-860 mm and in last phase it decreased to 2.06 at a length interval of 860-940 mm. For River Sharda K_n decrease from 1.78 at first length interval of 290-370 mm to 0.40 at an length interval of 870-950 mm. River Ken showed a zigzag variation in K_n, it was highest (K_n = 2.26) at 240-320 mm and lowest (0.29) at 800-880 mm of length interval. In River Ganges the variation in K_n indicated three peaks one at 380-460 mm where it was highest (2.20), the second peak was at 460-540 mm at which the value was 2.04 and the final peak is at 620-700 mm where the observed K_n was 1.38, the lowest K_n (0.51) was noticed at 780-860 mm. In River Gomti it increased from 0.96 at a length of 380-460 mm to 1.70 at 540-620 mm length, afterward it decreased to 1.05 at total length range of 780-860 and finally it increased to 2.39 at a length interval of 860-940 mm.

In order to detect population groups of *L. rohita* with similar growth pattern we employed unweighted pair group method using arithmetic averages (UPGMA) in our application of hierarchical cluster analysis of six rivers on the basis of average condition factors of males and females separately. The six populations resolved into five clusters in both males and females (Figure 5). In case of males, group 1 included Rivers Gomti and Ghagra, group 2 comprised Betwa, group 3 included Ken, group 4 Ganga and fifth group included River Sharda, similar type of pattern was observed in case of female populations with a slight reshuffling of groups.

The plot of log *a* vs *b* showed expansion of some of the points around the trend line, with the correlation coefficient r^2 = 0.83 (Figure 6). The form factor ranged from 0.004808-0.005404 for male population of Betwa and Ghagra respectively and 0.004819-0.008669 in case of female populations of Ganges and Gomti respectively.

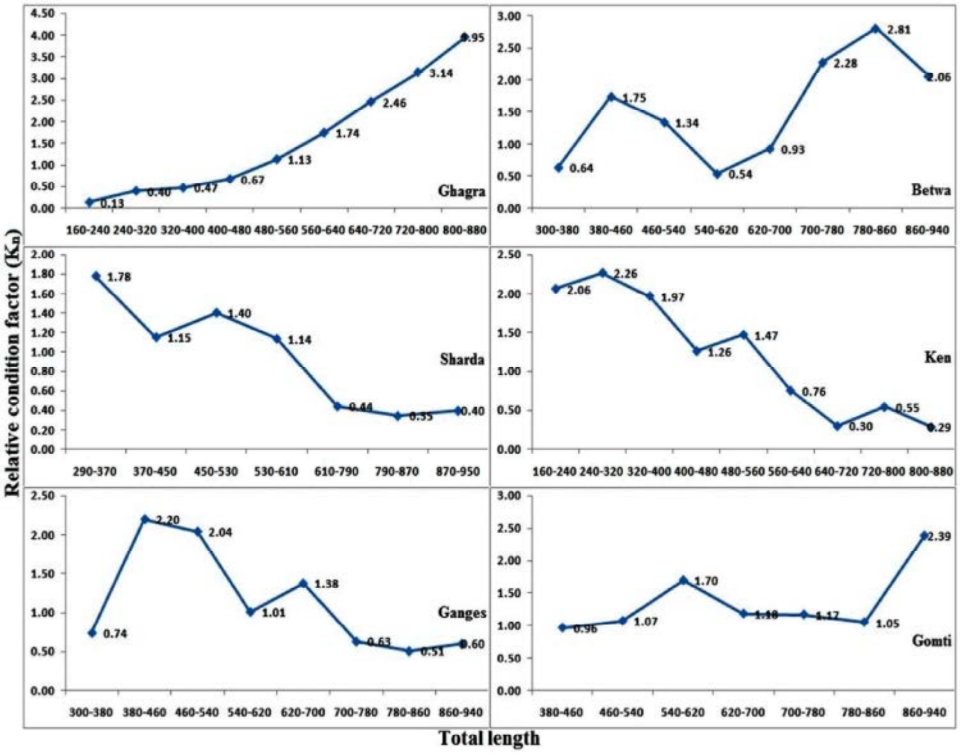

Fig. 4: Variation of relative condition factor (Kn) with the total length (mm) of female population of *L. rohita* from January 2009 to December 2011

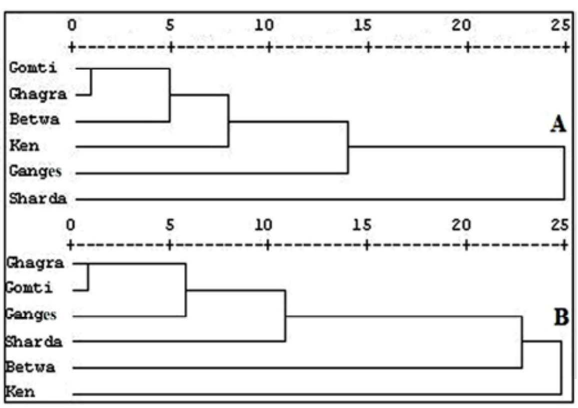

Fig. 5: UPGMA Dendrograms representing average linkages among different six populations of *L. rohita* by using square Euclidean distances on average condition factors for males (A) and females (B)

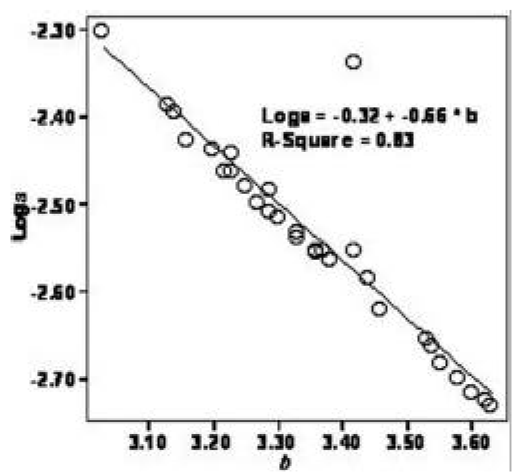

Fig. 6: Plot of log a over b for length-weight relationship of *L. rohita* from Ganges River basin for estimation of form factor

DISCUSSION

The studies on intrabasin variation in growth and other life history parameters of fishes in wild habitat have not been investigated thoroughly for decades, but in recent years, comparative work on these parameters has been done from different parts of the world for different species [20, 21]. For *L. rohita* this is the first comparative study on the condition factor, relative condition factor and form factor in the six drainages of the Ganges Basin, which could serve as a tool for providing insight into growth strategies of the populations.

These attributes were previously available for only the ponds, hatcheries, Lakes and a few rivers [13, 16, 17] information provided here is new for the other tributaries of the Ganges River Basin. The mean K of *L. rohita* varied significantly for almost all the populations. River Ghagra showed highest K for both male and female populations and lowest values were noticed in Rivers Ken and Betwa for males and Ganges and Gomti for females. For rest of the rivers it showed significantly lower variation which may be attributed to the dissimilar food availability and other human interruptions [22]. The variation of condition factor with total length of the fish showed higher values after 50% of maturity was attained in the fish, usually at a total length of 450 mm above for both males and females [23], but some of the populations like Ghagra, Sharda, Ganges and Gomti showed significantly higher values at lower length intervals also. LeCren [19] reported that environmental factors, food supply and parasitism have great influence on the health of the fish. The differences in condition factors on different length intervals and among different rivers could be attributed to low feeding intensity and degeneration of ovaries during winter and high feeding intensity and full development of ovaries at the maturity periods.

In this study, a significant variation in relative condition factor (K_n) among different rivers was noticed, which showed highest value for River Sharda and Betwa in case of male and female populations respectively. This may be due to the dissimilar food availability and random seasonal collection of the samples throughout the year [22]. K_n showed fluctuation in all size groups of male and female populations during the present investigation. Similar observations were reported by Azadi and Naser [24] for *Labeo bata*. For male population of Rivers Ghagra, Betwa and Sharda the smaller size fishes showed lower K_n which consistently increased with increase in length of fish. Similar observations were reported by Chatterjee *et al*. [13] and Sarkar *et al*. [16] in *L. rohita*. In Rivers Ken, Ganges and Gomti, condition factor increased above 400 mm of total length, which is the 50% maturity size of this fish and then again showed decline when spawning period was over [23]. This may be due to increase in the weight of the fish due to gonadal maturation and sufficient availability of food [13]. For females of Rivers Ghagra, Betwa, Ganges and Gomti smaller size fishes showed lower K_n. Similar type of result was reported by Reddy and Rao [25] in several freshwater carps. In females of Rivers Sharda and Ken, smaller size groups showed higher K_n. Similar observations were recorded by Raizada and Raizada [26] in case of *Cirrhinus mrigala* and suggested that high K_n values in smaller immature samples may be due to its high feeding intensity for rapid growth.

Additionally, the hierarchical cluster analysis of six populations based on average condition factor values for male and female populations of *L. rohita* generated five clusters in males and females. In both sexes, Rivers Gomti and Ghagra were placed in one group, this may be due to similar land use pattern and smaller distance between the two rivers and the rest of rivers were placed in separate individual groups. This may be attributed to their separate land use pattern, some of the rivers fall into the buffer zones and some have severe human interruptions [25].

With regard to the form factors, those of the studied populations fell within the confidence limit of the elongated body shape [6] as the study areas are rivers, this may explain why the form factor for the fish belonged to this body shape. He also pointed out that if several length-weight relationships are available for a species, then a plot of *a* over *b* will form a straight line which can be used to detect outliers. However, due to the large expansion of the points around the trend line accompanied by decreased correlation coefficient (<0.85), exclusions of outliers were not possible. This can be interpreted as a large variety in the coefficient (*a* and *b* of LWR).

Keeping in view the great importance of Indian major carps as food fish and having fast growth, we investigated the pattern of intrabasin variation in these factors for one of the important major carp *L. rohita* within this basin for filling up the paucity of the information regarding growth of this fish over the decades and identifying the different potential stocks. Data derived from these parameters can be used to describe stock boundaries at a range of spatial scales that may assist in directing future studies to refine stock structures. In order to confirm our findings, we suggest the use of a more sensitive condition index, such as RNA/DNA content, lipid content [27, 28] and otolith fingerprinting over a wider range of specimens.

ACKNOWLEDGEMENTS

The authors are grateful to the Director NBFGR, Lucknow, for providing necessary facilities. Thanks are due to the Indian Council of Agricultural Research, New Delhi for financial support to carry out this work.

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