Age and growth in the Indian major carp *Labeo rohita* (Cypriniformes: Cyprinidae) from tropical rivers of Ganga basin, India

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Abstract: Edad y crecimiento de la carpa mayor de la India *Labeo rohita* (Cypriniformes: Cyprinidae) de los ríos tropicales de la cuenca Ganga, India. *Labeo rohita* is a member of the Indian major carp species and originally an inhabitant of the Ganga river network in India. It is among the top ten aquaculture species of the world. Since there is a lack of information on the growth pattern of the wild populations of this species, this study aimed at evaluating the pattern of age and growth, to support the development of effective management plans. A total of 1 082 samples of *L. rohita* were obtained from May 2009 to July 2012 in six drainages of the Ganga basin. Scales of the fish were used to determine the age and growth by analyzing the annual rings growth. Out of six populations, a maximum 8+ age classes were recorded from two rivers (Betwa and Sharda). The back-calculated lengths at 8+ age class ranged from 86.22cm to 91.66cm. However, for the rest of rivers up to 7+ age classes were recorded. Among growth parameters, specific rate of length increase (C_l) and specific rate of weight increase (C_w) showed decreasing trend, and three distinct life stages of *L. rohita* were recorded based on growth constant data (C_{lt}). Analysis of variance (ANOVA) of the back-calculated length data set of six populations indicated a significant difference ($p<0.05$). All three populations showed significant variation in length attainment during 1+ and 3+ age groups, while two populations showed significant variation in length attainment during the 2+ and 7+ age classes. Additionally, analysis of age frequency at different length intervals indicated that with increase in age class, number of fish samples was reduced. Since the pattern of life history traits of *L. rohita* have not been attempted in the recent past; therefore, this study will guide fisheries biologists about the current stock structure of this fish across different spatial scale of the Ganga basin. Rev. Biol. Trop. 61 (4): 1955-1966. Epub 2013 December 01.

Keywords: *Labeo rohita*, back calculations, wild populations, Ganga basin, India.

The analysis of life history traits has been widely used by ichthyologists to differentiate among different species and different populations within a species; fortunately, this method continue to be used successfully (Ihssen et al., 1981). Studies of morphologic variation among populations still have an important role to play in stock identification, despite the advent of biochemical and molecular genetic techniques, which accumulate neutral genetic differences between groups (Mir, Sarkar, Dwivedi, Gusain & Jena, 2013). Studies on age and growth, maturity of commercially important fishes, provide baseline information that typically assists with the initial recognition and delineation of geographic regions that are representative of individual stocks (Pawson & Jennings, 1996) and is an almost essential prerequisite for successful stock identification (Griffiths, 1997). The use of such parameters is an efficient and cost-effective tool for stock identification, as these data are routinely collected for assessment and management purposes (Ihssen et al., 1981). Although the utility of these parameters

for stock identification appears to decrease with stock complexity, their applicability increases with the number and diversity of parameters examined (Begg & Waldman, 1999).

Among Indian fish species, age and growth aspects of the two major carps of India, *Cirrhinus mrigala* and *Catla catla* have been investigated previously (Khan & Siddiqui, 1973; Sarkar, Negi & Deepak, 2006; Mir et al., 2012). Nevertheless, there is a need of scientific information on age and growth profile of *L. rohita,* the most important carp in India. *L. rohita* (Hamilton, 1822) commonly known as 'Roho labeo' thrives in lakes, ponds and rivers in India and adjacent countries (Talwar & Jhingran, 1991). The natural resources of this fish extends from the network of the Ganga, the Sindh and the Brahmaputra river systems in the North, and the East and West coast river systems flowing through in the South and Central India. This species of fish grows up to 200cm size (Frimodt, 1995); however, a considerable decline in the overall size and species in natural waters (Mir et al., 2013) has been observed, and the species is now categorized as LC (Least Concern) as per IUCN (2012).

Recently, the National Bureau of Fish Genetic Resources (NBFGR), Lucknow, India, has started a flagship network programme on the stock identification of *L. rohita* (Lakra & Sarkar, 2010). Besides, to successfully develop and manage the population of *L. rohita* in natural waters of the Ganga basin, it is important to understand the current pattern of biological traits in natural habitats. Thus, this study was undertaken to provide information about the important life history attributes (age and growth) of *L. rohita,* and to compare these aspects among different rivers of the Ganga basin, that may support effective conservation and sustainable management actions for the stocks of *L. rohita* in the area.

MATERIALS AND METHODS

Study area: The river Ganga basin is located 22°30'0'' - 31°30'0'' N - 73°30'0'' - 89°0'0'' E. Total drainage area exceeds 1 060 000km^2, the basin is the fifth largest in the world. The length of main channel from the traditional source of the Gangotri Glacier in India is 2 550km. The annual volume of water discharged by the Ganga is the fifth highest in the world, with a mean discharge rate of 18.7 x 10^{3}m^3/sec (Welcomme, 1985). The main sources of water in the basin are direct seasonal rainfall, mainly from the South-West and glacial and snowmelt during the summer (Chapman, 1995). The main channel of the Ganga begins at the confluence of Bhagirathi and Alaknanda, which descend from upper Himalayas to Devprayag (520m.a.s.l.) and receives a number of major tributaries. The Northern tributaries that enter on the left bank principally include Ghagra, Gomti, Buri Gandak and Kosi and Southern tributaries include Yamuna (Ken, Betwa), Son, Chambal, Tons, Kalisindh, Sharda and Damodar. Most of these tributaries are controlled by irrigation barrages and there are two major barrages across the main channel, one at Hardwar which abstracts much of the water at this point to irrigate the Doab area, and one at Farakka which diverts water down to Calcutta. All of these structures modify the flow of the river and may considerably influence fish distribution. Fish and fisheries are both important resources and activities in their own right, but also provide indicators of the overall impact of anthropogenic changes over the basin.

Sample collection: Samples of *L. rohita* were collected during May 2009 to July 2012 from six different rivers of the Ganga basin (Fig. 1). The GPS coordinates, implicating factors of the selected sites on these rivers, and the number of samples collected from each river is shown in Table 1. The samples were collected from the selected rivers (upstream, midstream and downstream) in the morning before the sunrise, by using cast nets (9m length, 9m breadth and 1/2cm mesh size) and drag nets (100m length, 20m breadth, 1⁄2cm mesh size), and also from the 18 landing centers present on these six rivers. Measurements on fish length and weight were taken; besides, fish were
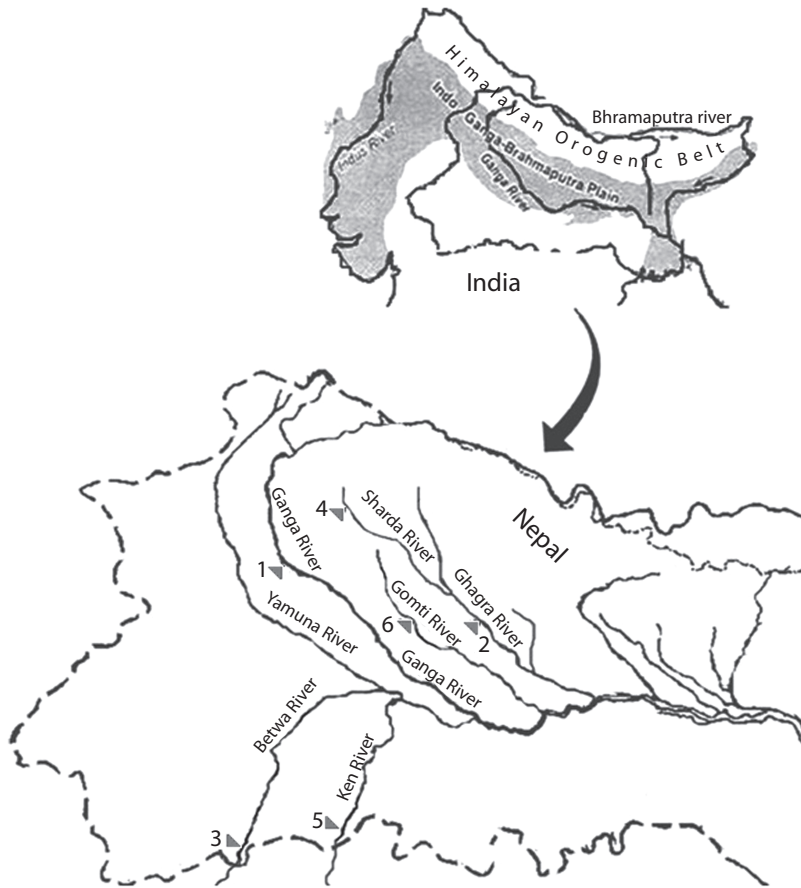
Fig. 1. Map showing the sampling locations of *Labeo rohita* on different rivers of Ganga basin.

dissected and sexes identified per collection site. Total length of each fish was taken from the tip of snout (mouth closed) to the extended tip of the caudal fin, nearest 0.01mm by digital caliper and weighed to the nearest 0.01g (total weight) (by digital weighing machine, ACCU-LAB Sartorius Group).

Analysis of age and growth by scale preparation and reading techniques: To study age and growth, four to five scales of each fish were taken, from the area below the posterior margin of the dorsal fin, and two scale rows above the lateral line from each fish, by using a scalpel. After collection, the scales were washed with 5% KOH and rinsed in distilled water. Scales were cleaned and

mounted dry between two glass slides (4 x 4") for permanent storage and studied under profile projector (Sipcon made) at appropriate magnification. To avoid any biases, scale reading was performed by same person every time. The true mark or annuli (defined by light bands in the form of grooves and extending around the scale) were included in the age determination; whereas, false annuli (or marks formed due to unfavorable condition like unavailability of natural food, environmental alteration leading to cessation of growth), were excluded from the analysis. The total radius of the scale (S) and scale radius from nucleus to the annulus (S_n) were measured using K25d-img software connected to the profile projector. Growth patterns were determined using size at age data

Rivers (Sites)	Latitude (°N)	Longitude (°E)	Implicating factors
Ganga (Narora)	28°12'12"	78°23'33"	Atomic power plant, Dams, temples, Semi-urban, agriculture, domestic sewage
Ghagra (Faizabad)	25°45'55"	84°38'14"	Semi-urban, agriculture, domestic sewage
Betwa (Bhojpur)	24°08'54"	76°30'35"	Small dams, water lifting pumps, new road construction activities, industrial discharge, temples, rural, agriculture
Sharda (Palia)	22°49'47"	75°45'59"	Rural area, buffer zone (Preserved Area) agriculture activities, Forest
Ken (Patan)	23°17"04"	79°41'27"	Rural area, buffer zone (Preserved Area) agriculture activities, Forest
Gomti (Lucknow)	26°52'24"	80°55'42"	Urban, barrage, domestic sewage, beverage, distillery industry, temple in the river bank

from counts of inner layer in scales. Since scales have been found very convenient and authentic in use for age and growth (Khan & Khan, 2009), the following formula given by Bagenal & Tesch (1978) have been used for back calculation based on the scale readings as:

$L_n - a = S_n/S (L-a)$
Where, a=correction factor
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 linear growth (C_l), Specific rate of weight increase (C_w), Growth constant (C_{lt}) and specific average size (h) were derived as per Chugunova (1963).

Specific rate of linear growth (C_l):

$C_l = L_n - L_{n-1}/L_{n-1} *100$
Where L_n=Mean computed total length of fish at ultimate years of life
L_{n-1}=Mean computed total length of fish at penultimate years of life.
Specific rate of weight increase (C_w):
$C_w = W_n - W_{n-1}/W_{n-1} *100$

Where W_n=Mean computed total weight of fish at ultimate years of life.
W_n-1=Mean computed total weight of fish at penultimate years of life.
Growth constant (C_{lt}):
$C_{lt} = \log L_n - \log L_{n-1}/0.4343*t_2 + t_1/2$

t_2 and t_1 are time intervals between ultimate and penultimate age groups and the value of $t_2 + t_1/2$ is equal to 1.5. Here age groups were defined as the beginning and end of a year group and denoted as 1, 2, 3 and so on.

An analysis of variance was carried out to detect significant difference of six different populations by using back-calculated length data of each year (L1 to L8). The statistical analysis was carried by using ORIGIN 6.1, SPSS 12.0 and EXCEL 2007.

RESULTS

A total of 1 082 fishes were collected. The scales of *L. rohita* were cycloid and were distinguished into true ring, false ring and larval marks besides radii. Annual growth rings were clearer and sharper in scales thereby producing lesser errors in age estimation (Fig. 2). The focus, which represents the initiation of growth in scales, is located near the anterior field of the scale; while, the larval marks appear in the first year age class and are situated not far from
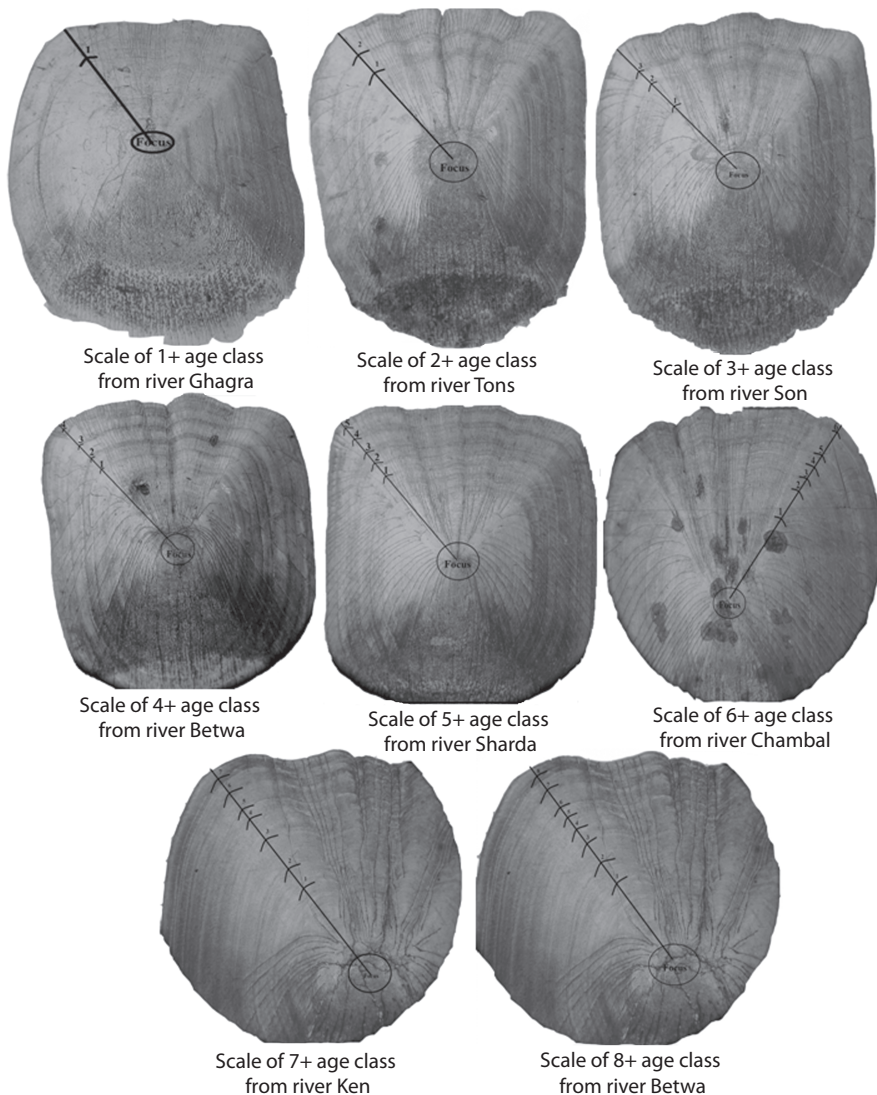
Fig. 2. Scales of *Labeo rohita* showing different age classes from six rivers of Ganga basin in India.

the focus. Marks presumed to be annuli were counted under the profile projector.

Age and growth: Growth rate of *L. rohita* was analyzed by back-calculation methods, and the back-calculated lengths (L_n) of each age from the different populations are presented in Table 2. From our results, we established up to a total of 8+ age class (the age class

is the maximum length attainment in certain age group as detected through the back calculation method).

In this study, a maximum 8+ age class was recorded from river Betwa and Sharda. The back-calculated length for 1+ age class was highest in river Sharda and lowest in Ganga, and for 8+ age class it was highest in river

TABLE 2

Comparative pattern of growth rate of *L. rohita* from six different rivers of Ganga basin, India

Location	N	Back - calculated lengths (cm)								$\emptyset_h$
		L1±SD (Range)	L2±SD (Range)	L3±SD (Range)	L4±SD (Range)	L5±SD (Range)	L6±SD (Range)	L7±SD (Range)	L8±SD (Range)	
Ganga	189	28.55±8.84[a] (24.85-33.78)	43.62±11.01[a] (40.44-51.32)	55.45±11.26[a] (51.72-60.12)	64.55±11.32 (60.84-66.90)	72.65±12.65 (67.64-74.33)	76.55±10.23 (74.55-77.67)	82.22±13.44[a] (78.88-85.56)	NS	117.46
Ghagra	159	28.98±7.01[b] (25.22-34.16)	44.18±9.22 (41.22-52.44)	56.32±10.62[b] (52.52-61.20)	65.58±9.14 (61.66-67.89)	73.62±12.72 (68.86-75.89)	77.55±11.32 (75.25-83.04)	83.53±10.33 (81.24-85.91)	NS	129.25
Betwa	192	31.25±6.22 (26.55-35.76)	46.14±10.82 (42.50-53.20)	58.74±9.59[a] (52.38-60.42)	65.78±10.67 (60.56-68.54)	73.04±13.78 (69.75-75.76)	77.65±13.43 (75.82-81.32)	84.12±12.48 / 88.64. ±62.24 (82.32-86.76) / (86.22-90.45)	88.64 ±13.24 (86.22-90.45) / (86.22-90.45)	110.80
Sharda	190	32.54±8.84[a, b] (27.35-36.86)	47.33±9.24[a] (43.58-54.72)	59.56±10.67[a, b] (53.40-61.66)	66.86±11.77 (61.56-69.46)	74.34±9.12 (70.55-77.88)	78.94±12.34 (76.63-83.23)	85.58±12.80[a] / (82.43-88.65) (82.43-88.6.50)	89.88±13.33 (87.28-91.66)	128.40
Ken	175	29.80±8.03 (25.32-34.18)	44.65±11.27 (41.45-52.40)	56.50±8.17 (51.28-59.65)	65.87±8.51 (59.24-67.42)	73.84±10.4 (68.94-74.94)	76.73±10.68 (75.45-89.36)	84.95±11.49 (80.23-84.54)	NS	173.67
Gomti	177	29.84±7.01 (25.38-34.77)	44.60±12.91 (41.46-52.36)	56.48±6.73 (52.29-61.17)	65.65±11.39 (61.88-67.89)	73.69±11.45 (68.66-75.35)	77.58±12.26[b] (75.48-78.66)	83.65±10.55[a] (79.76-86.68)	NS	119.50

Superscript letters **a**, **b**=indicate significant differences at p<0.05, **L1** to **L8**=back calculated length of each year, **NS**=no samples available, **N**=number of samples, **SD**=standard deviation, $\emptyset_h$=value of index of species average size.

Betwa and lowest in river Sharda. The analysis of the back-calculated results indicated variation at different age classes among the studied populations (Fig. 3).

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 Ken (173.67) followed by river Ghagra, Sharda, Gomti and Ganga, while minimum growth increment was observed in river Betwa (110.80). The growth decreased with increasing age except river Betwa, Ganga, Sharda and Gomti, where growth suddenly increased at 5+ age class of river Betwa and Sharda and 7+ age class of river Betwa, Ganga, Sharda and Gomti. In order to detect population groups of *L. rohita* with similar growth patterns, we employed Bray-Curtis distance and the unweighted pair-group method using arithmetic averages (UPGMA) in our application of a hierarchical cluster analysis to six rivers × six length at-age (one to six years) matrix. The six populations resolved into two groups (Fig. 4) (by decreasing order of growth rate):
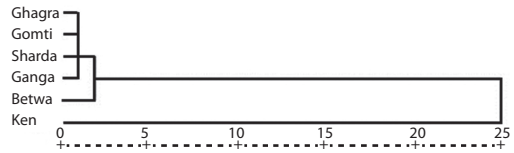

Fig. 4. UPGMA dendrogram representing lengths-at-age distances among six populations of *L. rohita* from Ganga basin.

group one included river Ken that supported the population with the highest growth rate in the study area; group two, comprised river Sharda, Ganga, Betwa, Gomti and Ghagra.

An analysis of variance was used to detect significant differences between the locations. ANOVA was carried out by using observed
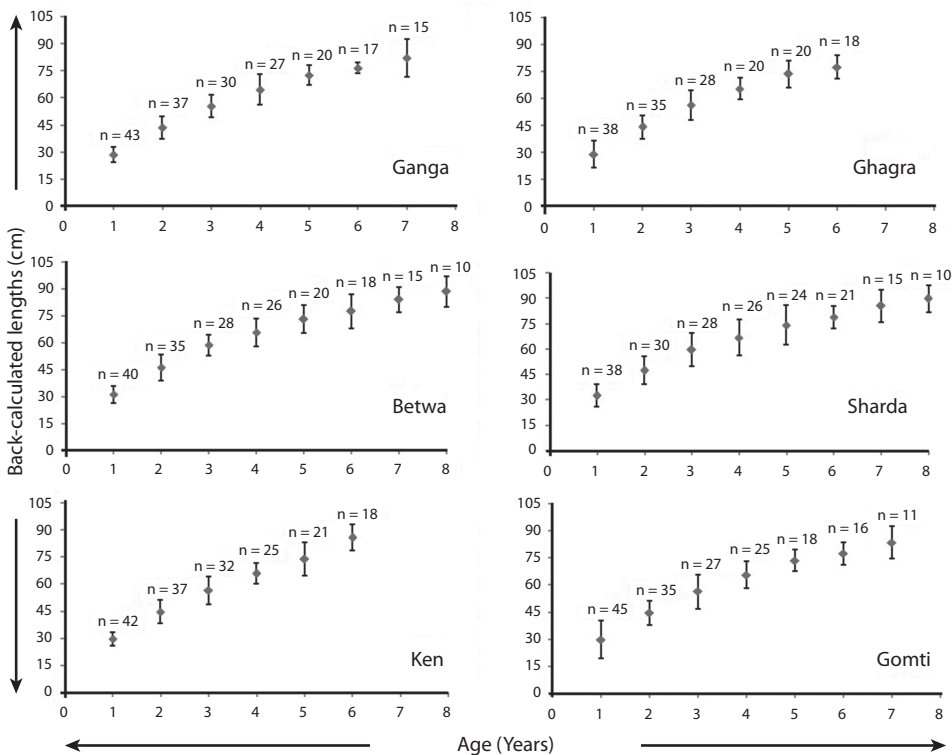

Fig. 3. Back-calculated lengths-at-age (mm) mean values (±SD) of *Labeo rohita* populations in the studied rivers of Ganga basin, India.

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back-calculated length data of each year (L1 to L8) of six different populations (Table 2). Significant interspecific variation was recorded in length among locations. Out of six populations, three showed significant variation in 1+ and 3+ age group whereas, only two showed significant variation within different locations in 2+ and 7+ age class. Analysis of back-calculated length of 1+ age class indicated significant variation for some of the population. River Sharda showed significant difference with river Ganga and river Ghagra. There was also a significant variation between river Sharda and river Ganga at 2+ age class. At 3+ age class, river Sharda showed significant difference with river Ganga and river Ghagra. Significant variation was observed between river Sharda and river Ganga at 7+ age class, non-significant variation was observed 4+, 5+, 6+ and 8+ age class.

Among growth parameters, specific rate of linear growth (C_l) and specific rate of weight increase (C_w) decreased for all populations. However, C_l increased at 5+ and 7+ age class in river Betwa and Sharda whereas, C_w increased at 7+age class in river Betwa. Based on this analysis it was concluded that C_l exhibited higher values for the population of river Sharda followed Betwa, Gomti, Ken, Ghagra and Ganga at 1+ age class. At 7+ age groups, it was maximum for river Sharda and minimum for river Betwa. Similar pattern of variation was also observed at rest of the age classes (Fig. 5A, B).The index of population weight intensity ($\emptyset C_w$) of *L. rohita* was maximum for river Ken (170.50) followed by river Ghagra (160.25), river Sharda (133.43), river Betwa (99.71), river Ganga (97.67) and river Gomti (93.30).

The growth characteristics (C_{lth}) are useful to determine the period, where the first year ends and the second phase begins. Growth constants (C_{lt}) are useful to determine the periods of life span of the fish. The results of the present study clearly indicate that *L. rohita* enters second period of life after third year in all the studied rivers (Fig. 5C).The analysis of the growth constant indicated maximum three life phases from all the studied rivers except river Ken where two life phases were observed. Additionally, the percentage of age frequency was estimated at different total length intervals among six populations, and it was observed that with an increase in fish total length, the higher age classes declined, and with smaller length intervals, lower age classes were importantly present (Fig. 6).

DISCUSSION

The present study reported the age and growth composition from six different populations of *L. rohita* in Ganga basin, and showed considerable intra-basin variations. We have observed that the growth increment in terms of length attainment in the successive years varied in different rivers. Lower growth increment was recorded for the samples of river Betwa, whereas population of river Ken showed higher length increment. The results of the present study corroborated the previous findings of Sarkar et al. (2006).

The growth pattern in *L. rohita* showed increase in the populations of river Betwa, Sharda, Ganga and Gomti at certain age classes, indicating that the fish might have been exposed to favorable environmental conditions at these stages of life. In rivers Betwa and Sharda, the fishes were recorded up to 8+ ages whereas up to 7+ age recorded in Ganga and Gomti, which are quite closer to the maximum reported age of 10 years (Khan & Jhingran, 1975). The higher growth performance index in river Ken might be due to low competition, high productivity and better ecological conditions (Lakra, Sarkar, Dubey, Sani & Pandey, 2011). Sarkar et al. (2006) reported the analysis of the age structure of *L. rohita* in river Ganga and indicated that the number of older individuals tended to decrease which might be due to unsustainable exploitation of the resources, and the migration of the fishes away from the reaches that eventually dry out in order to find refuge in deeper habitats (Oliveira, Ferreira & Ferreira, 2002).
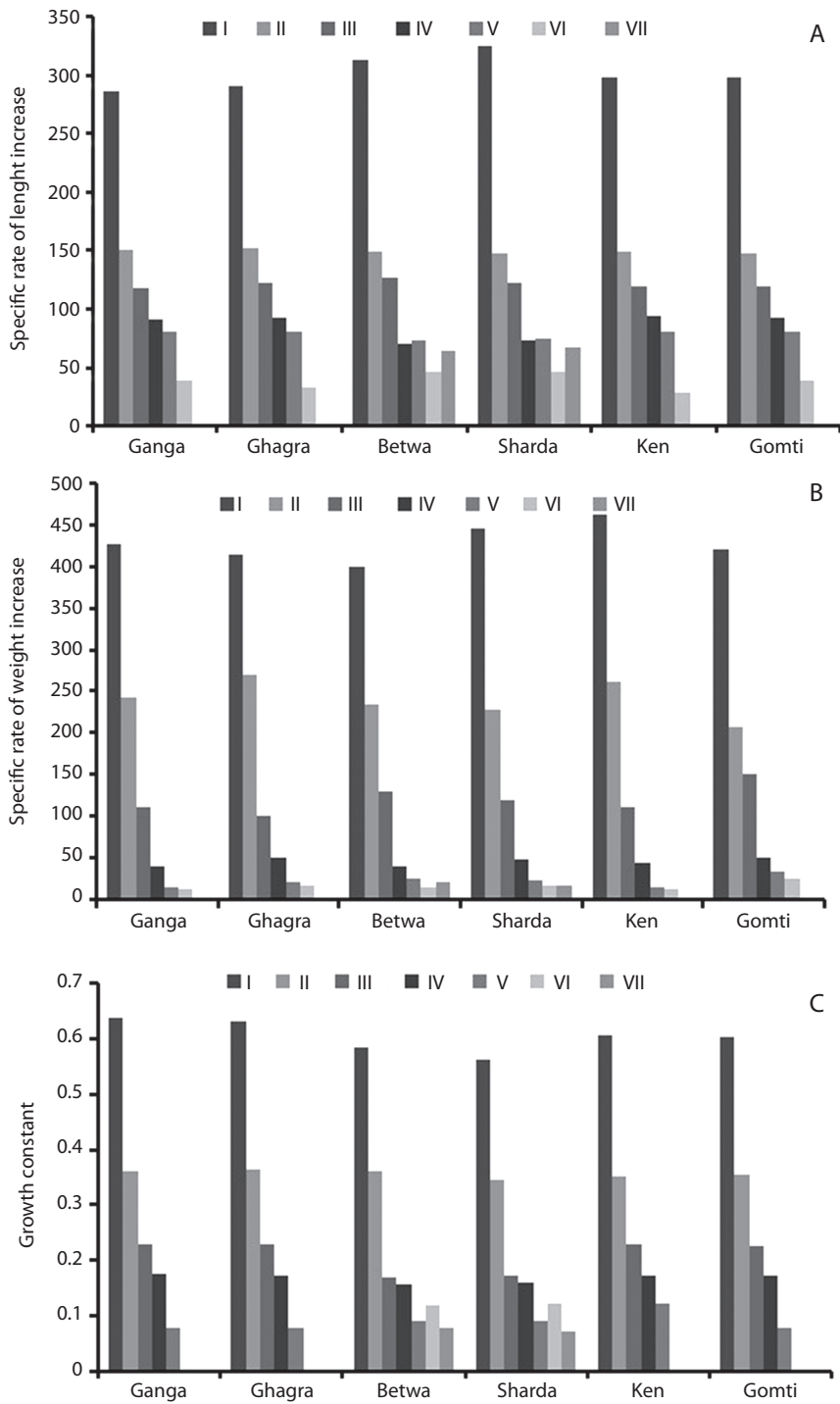
Fig. 5. A., B., C. Variation in different growth parameters of *Labeo rohita*; C_l: specific rate of linear growth; C_W: specific rate of weight increase; C_{lt}: growth constant.
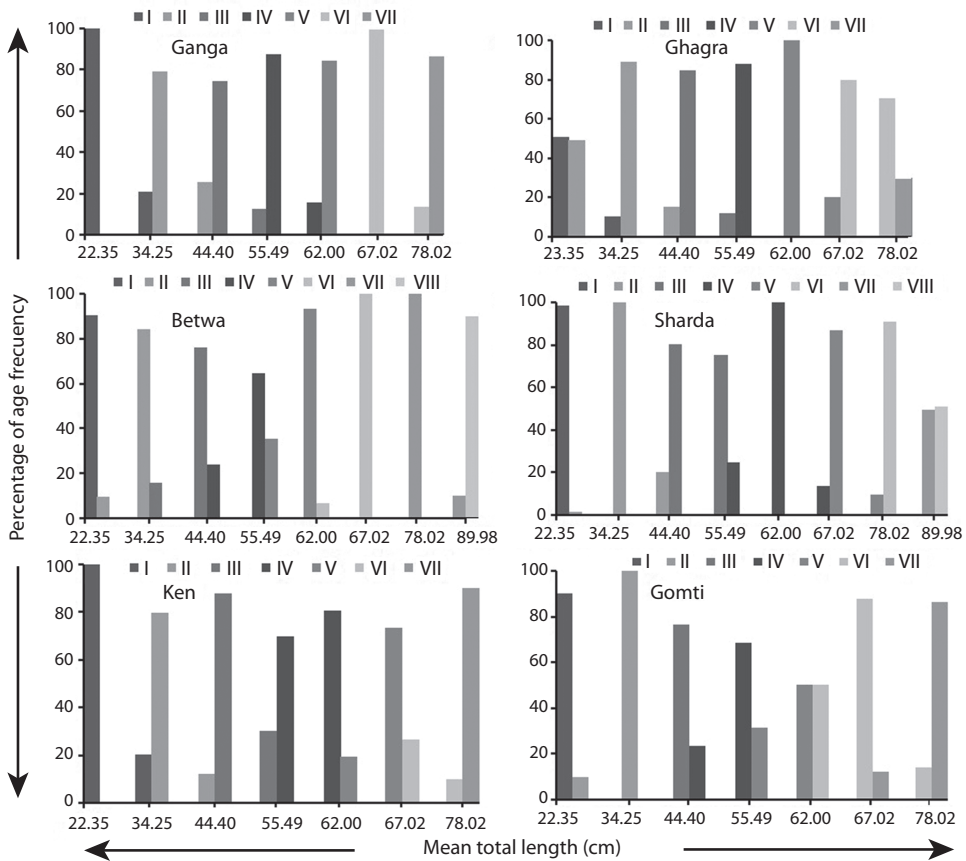
Fig. 6. Percentage of age frequency of *Labeo rohita* in six drainages of Ganga basin in India.

The growth constant is important to understand the periods of life in the life span of fish. In *L. rohita* three phases of life were observed based on growth constant which also corroborates the studies of Singh (1990) who reported three phases of life in Indian major carps from riverine population of Aligarh and Jaisamand Lake, India. According to Yablokov (1986), the average growth characteristics can be used to separate populations of the same species or conspecific population. The present observations revealed that the wild populations of *L. rohita* showed variation in growth from one population to another, and fisheries strategy could be made accordingly for conservation and sustainable utilization.

The information derived from this study can be used to describe stock boundaries at a range of spatial scales that may assist in directing future studies to refine stock structure using other techniques. This study showed a well-defined growth pattern from different geographical locations and important information has been generated on the age pattern of *L. rohita*. It is evident that wild populations of *L. rohita* showed variations in age profile from one population to another. Therefore, special conservation measures may be taken up to improve the current situation and steps should be taken by the conservation agencies towards the stock enhancement of higher age classes. The present study will therefore be useful for the fishery biologists and conservation agencies

for successful development, management, production and conservation. The work presented here is part of the ongoing programme titled Outreach activity of fish genetic stocks.

RESUMEN

Labeo rohita es de las principales especies de carpas hindúes y originalmente un habitante de la red del río Ganges en la India. Se encuentra en la lista de las diez especies principales de la acuacultura mundial. Puesto que no hay información sobre el patrón de crecimiento de las poblaciones silvestres de esta especie, este estudio tuvo como objetivo evaluar el patrón de edad y crecimiento para apoyar el desarrollo de planes de gestión eficaces. Un total de 1 082 muestras de *L. rohita* se obtuvieron en el periodo de mayo 2009 a Julio 2012, en seis desembocaduras de la cuenca del río Ganges. Las mediciones de los peces fueron utilizadas para determinar la edad y el crecimiento mediante el análisis de los anillos de crecimiento anuales. De las seis poblaciones, se registró un máximo de categoría de edad 8+ en dos ríos (Betwa y Sharda). Las longitudes de retrocálculo en la edad 8+ variaron entre 86.22-91.66cm. De los parámetros de crecimiento, la tasa específica de aumento de longitud (C_l) y la tasa específica de aumento de peso (C_w) mostraron una tendencia decreciente, y basado en los datos constantes de crecimiento (C_{lt}) se registraron distintas fases del ciclo de vida de *L. rohita*. El análisis de variancia (ANOVA) de los datos de longitud de retrocálculo de seis poblaciones indicó una diferencia significativa (p<0.05). Las tres poblaciones mostraron una variación significativa en la obtención de la longitud durante los grupos de edad 1+ y 3+, mientras que dos poblaciones mostraron una variación significativa en lograr la longitud durante los tipos de edades 2+ y 7+. Además, el análisis de la frecuencia de la edad en diferentes intervalos de longitude indicó que, con el aumento de la categoría de la edad, se redujo el número de muestras de peces. Dado que el patrón de rasgos de la historia de la vida de L. rohita no se ha tratado en el pasado reciente, este estudio será una guía para los biológos de peces acerca de la actual estructura de la población de estos peces en diferentes escalas espaciales de la cuenca del Ganges.

Palabras clave: *Labeo rohita*, retrocálculos, poblaciones silvestres, cuenca del Ganges, India.

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