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Biometric Characteristics based assessment of habitat suitability for the growth of a cold water cyprinid golden Mahseer (*Tor putitora*)

Bonika Pant, NN Pandey and RN Ram

Abstract
Uttarakhand state is blessed with a number of water bodies which harbour Golden mahseer having high ecological and economic importance. In this milieu, the present study investigated the patterns of length weight relationship and condition factor (K) of *Tor putitora* in different habitats. The sampling sites included two lotic, two lentic water body and one captive stock of the target fish *i.e.* River Kosi, River Saryu, Nanak Sagar, Lake Bhimtal and captive stock of DCFR Farm, Bhimtal. The results suggested that lotic systems had a remarkable larger size of Golden mahseer as compared to lentic ecosystems. Biometrics revealed that the fish of River Kosi had isometric growth pattern having growth coefficient of 3.013 and the condition factor of 1.45. River Saryu had highest the condition factor supporting the fact that lotic ecosystems provide a better and rather conducive habitat for the growth of Golden mahseer. Reservoir population had the least average size, *b* value and condition factor due to water abstraction and altered flow of the system. The value of condition factor is more than 0.5 in all the five populations thereby indicating a general well-being of the fish.

Keywords: Condition factor, golden mahseer, lentic, length- weight relationship, lotic

1. Introduction
The icy water bodies of the hilly state Uttarakhand harbour country's richest coldwater fish fauna including the world famous Golden mahseer, which is also recognized as the "*state fish*" in seven states of India. The most sought-after game fish for anglers across the world *Tor putitora*, is one of the twenty mega fishes of the world. Golden mahseer or Putitor mahseer or Himalayan mahseer, is an elusive and intelligent large cyprinid and the toughest among the fresh water sport fishes. Mahseers are considered as the bioindicators of healthy freshwater systems as these inhabit pristine untamed freshwaters equated with wilderness. An adult Golden mahseer is golden on the dorsal side of the body and fins are yellow-reddish. The fish is easily identified by their big scales and fatty lips with relatively powerful longer hair-like barbells (which are sensory organs in front of the mouth). The fish is carni-omnivore during migration and if size >46 cm fishes become piscivorous.
Biometrics is the technical word for measurements and calculations of the body of an organism. Weight of a fish is a unit function of growth and varies with the cube of length (Brown, 1957) [5]. Length-weight parameters of the same species may be different in the populations because of reproduction, feeding, swimming activities, stress factors and harvesting (Pervin and Mortuza, 2008) [26]. Different length and weight relationship of aquatic organisms are expressed due to the factors such as differences in food availability in lotic and lentic environmental conditions (Egbal *et al.* 2011) [6]. The mathematical relationship of length and weight can vary according to the environmental conditions and the availability of the food (Pervin and Mortuza, 2008) [26]. To understand the biology of a fish, the computed mathematical relationship between length and weight is very important. The relationship may be helpful as the weight of fish is the function of the length of the fish. The relationship helps to estimate the condition and growth of the fish like whether the growth of the fish is isometric or allometric (Le Cren, 1951; Tesch, 1971) [17, 30] by using the slope of regression (*b*). The other importance of length weight relationship is that it helps to make a proper exploitation and management of the species in their ecosystem (Anene, 2005).
The state of the fish in a particular water body can be calculated with the help of the condition factor. Condition factor (K) is calculated from the length and weight and it is used to estimate changes in condition of fish. K is a quantitative parameter of well-being of the fish and

determines present and future population success because of its influence on growth, reproduction and survival. The fish condition reflects recent biological and physical circumstances and fluctuates by interaction among physiological factors, feeding conditions and parasitic infections (Le-Cren, 1951) [17]. The condition factor can be affected by both internal components such as development of gonads, presence or absence of food and external components such as environmental conditions as well as the availability of food (Nikolsky, 1969).

The study of biometrics of fish has numerous practical applications in fisheries resource management for rational exploitation and management of the fish species (Anene, 2005). The sampling sites for the comparative study included two lotic, two lentic and one farmed stock of Golden mahseer. River Kosi is one of the major rivers of Uttarakhand, originating from the middle Himalaya village Budhha Peenath, Kausani in district Almora. The river flows in the central part of District Almora and continuing to western part of Nainital, the river enter the plains in Ramnagar. River Saryu/Sarju rises in the north of the Bageshwar district at Sarmool and receives Punger River and Lahor River from the left and right respectively and then flows through the city of Bageshwar (Aggarwal and Agrawal, 1995).The shoe shaped lake Bhimtal is a very unique and beautiful lake of Uttarakhand which is the largest in the Kumaun region. Bhimtal Lake situated at 1370 m above sea level not only forms a major drainage reservoir but is also the source of water for domestic and irrigation purposes. Nanak Sagar Reservoir is situated in latitude 28º45' N, longitude 79º45' E and the major purpose of the dam is to provide irrigation and drinking water to the nearby places. Farm raised stock was also collected for the analysis of results in captive conditions from the fish farm of Directorate of Coldwater Fisheries Research, Bhimtal, District Nainital. The aim of the study includes comparative study of length- weight relationship and condition factor of Golden mahseer collected from the selected habitats.

Materials and Methods

Sampling sites

The sampling design for exploratory studies involved obtaining representative samples from the entire geographical range to investigate the pattern of variations and potential for mixing. The length weight relationship can be obtained from the length and weight measurements of the fishes from a sample of fish taken at a given time (Wootton, 1990).

River Kosi

The sampling was performed from two sites of the river. The first sampling site was Kosi, Almora at the elevation of 1,642m above sea level (5,387 ft) and from the coordinates 29˚38'N and 79˚37' E, located prior the Kosi barrage and collection of fishes was done with the help of local fishermen. The second sampling site was the small town Ramnagar, District Nainital at the elevation of 345m above sea level (1,132 ft). The fishes were sampled with the help of local fisherman who catch the fishes to sell in the local market.

River Saryu

Samples of Golden Mahseer were collected from two sites- Bageshwar and Pancheshwar. The first sampling site was near Saryu bridge (near National Highway 309A), Bageshwar at the coordinates 29º 50' N and 79º46' E and at the elevation of 1,004 m asl (3,294 ft), before the confluence of Saryu with Gomti, near the ancient temple Bagnath. The second site was at 29º26' N and 80º14' E near Pancheshwar bridge, Pancheshwar. Sampling was performed during daytime with the help of local fishermen.

Lake Bhimtal

The sampling was performed during early morning hours with the help of local fishermen from Bhimtal Lake (29°20′ N, 79°33′ E). The lake Bhimtal is divided into three zones as per its physico- geographical position. The length and width of the lake is 1.8 km and 0.4 km respectively and has a maximum depth of 26.5 m.

Nanak Sagar Reservoir

The sampling site was in Sitarganj, District U. S. Nagar where the gears are fixed in afternoon or evening by the fishermen. Samples were collected after the harvest was hauled at the local collection centre during morning.

Captive Stock from Fish Farm

The farmed stock was collected from the Fish farm of Directorate of Coldwater Fisheries Research, Bhimtal. The premiere institute was established in 1987 and has a well built up infrastructure with a flow through mahseer hatchery and cemented ponds. The sampling was performed from the ponds with the help of fishermen of the institute at the coordinates of 29˚21'N and 79˚33'E.

Fishing Gears Used

Considering the depth and type of the water body, different kinds of fishing gears were used during the present study. In the shallow waters of River Kosi cast net was used to catch the fish along with bait fishing. Early morning sampling was done using gill net in Lake Bhimtal for the collection of specimens. Generally, this net is set in the evening and removed in the following morning. Drag net was operated in the fish farm of DCFR at Bhimtal. It is operated by dragging the net using manpower and fishes are trapped in a particular place.

Fish specimen collection

Live specimens of the fish *Tor putitora* were collected by fishing or from commercial catches from the wild. Intact fishes were collected and their total length and total weight was recorded. A total of 133 intact individuals representative of the splendid *T. putitora* were collected from all sites throughout the sampling period. Fish specimens were collected using simple random sampling without replacement from five populations for the study from March 2017 to June 2018. The species was identified by following standard taxonomic keys *viz.* Fish base (Froese and Pauly, 2015) [9]; Fishbase. (*http://www.fishbase.org*); FAO Fact/Identification Sheets. Length of fish was taken with a marked ruler and a balance was used to know the weight of collected samples.

Length-weight relationship

Study of length-weight relationship of a fish establishes the mathematical relationship between the two variables- length and weight, and helps in assessing the variations from the expected weight for the known length groups. Length of fish was taken with a marked ruler and a sophisticated balance was used to know the weight of collected samples. The length-weight relationship of Golden mahseer was worked out

as per the cube law (Le Cren, 1951) [17].

$$W = a L^b$$

Where, W=Weight of fish (g), '*a*' is the regression intercept, L is total length of fish (cm) and '*b*' is the slope of regression (Tesch, 1971) [30]. Deviation of b value from isometric value of 3 was tested with student *t* test. *t* value was calculated as follows: $t = (b - 3)/S_b$. Where, S_b is the standard error of *b*.

Fulton's Condition Factor (K)

The relationship between weight and length differs within a species according to the body shape inherited and the robustness (condition) of individual fish. Condition factor is a numerical index to compare weight and length in particular samples under standard conditions (Ricker 1975). The value of K was calculated following Froese (2006) [8]:

$$K = 100 \times (W/ L^{3})$$

Where, W is total body weight of fish measured in grams, L is the total length of fish measured in centimetres. 100 factor is used to bring the condition factor close to unity.

Results and Discussion

Length-weight measurement

The fishes were subjected to measurement of total body length and total body weight. The mean length and mean weight of the specimens of Golden mahseer (*Tor putitora*) collected from the lotic ecosystem, River Kosi were 29 cm and 204.23 g respectively. Specimens of River Saryu had a mean body length of 21.27 cm and mean body weight 137.8 g. The samples of the fish collected from Lake Bhimtal had 20.64 cm mean body length and 125.30 g mean body weight respectively. The fishes of Reservoir Nanak Sagar had a mean body length and mean body weight of 19.25 and 120.53 g respectively. The farmed stock of DCFR, Bhimtal had a mean body length of 30.42 cm and mean body weight of 207.85 g. The results stated that lotic systems had a remarkable larger size of Golden mahseer as compared to lentic ecosystems. Among both the running water bodies River Kosi harboured larger fishes than Saryu River and among the stagnant waters, Lake Bhimtal had bigger sized fish than the reservoir. The results are in consonance with the findings of Mustafa (1978) [20] who studied various length groups of *Esomus danricus* and reported that fishes dwelling in running water have rapid growth compared to the fishes inhabiting stagnant water. The largest size of fishes were at the farm or the artificial habitat which supported the reports of Arabaci *et al*, (2010) [3] who stated that farmed fishes live in captivity with fixed periodic feeding and easily available food thus the foraging is different from that of wild fishes. The wild fishes have to search the food and a significant energy is lost during the process in comparison to captive stocks. The results are in accordance to Sen *et al.* (2011) [28], who found that wild individuals can be characterized by a more elongated body shape while studying *Decapterus russelli* from coastal India. Grigorakis *et al.* (2002) [11] studied wild Seabream and reported relatively lower body height and more spindle-shaped body than in cultured Seabream.

Length-weight relationship

The study of length-weight relationship is treated as an important tool for understanding the condition of fish where the weight is measured in gram and length in centimetres. When the relationship is expressed, the exponent value (*b*) sometimes deviates in different ecosystems from the basic value 3 due to most fishes changing shapes or forms while growing (Martin, 1949) [19]. The length-weight relationship of *Tor putitora* collected from River Kosi, Lake Bhimtal and farmed stock are presented in Table-1 and Figures 1 to 5 respectively.

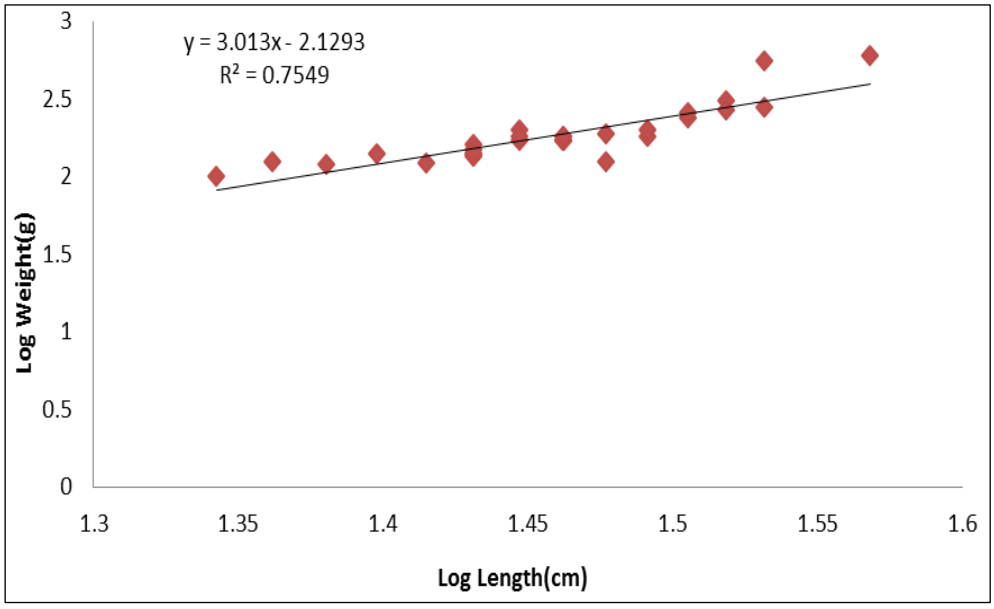

Fig 1: Length weight relationship of *Tor putitora* individuals collected from River Kosi

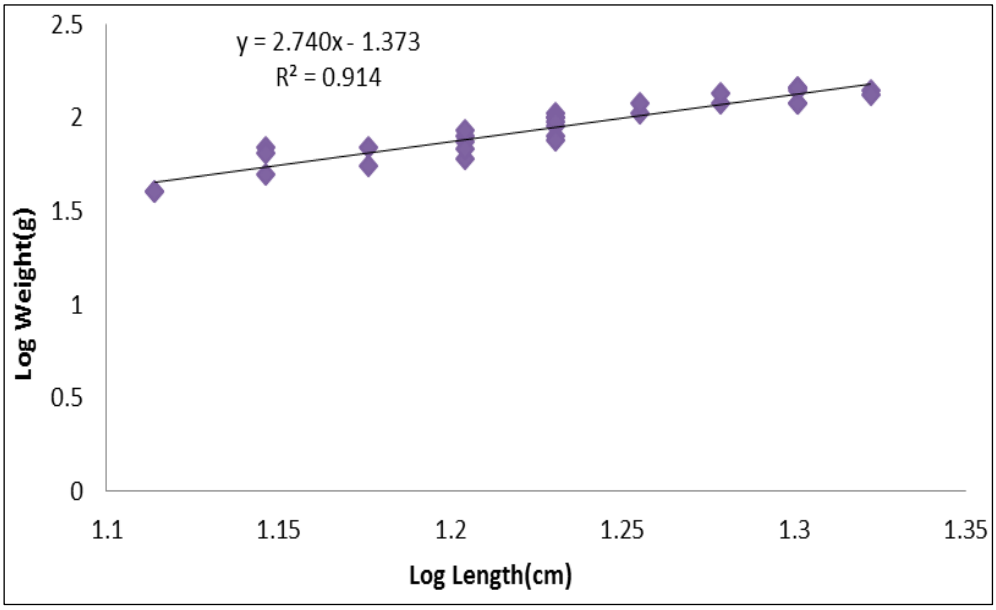

Fig 2: Length weight relationship of *Tor putitora* individuals collected from River Saryu

The values of *b* ranged from 2.021 to 3.013 during the study and are in conformity with the findings of Koutrakis and Tsikliras (2003) [15] that allometric coefficients (*b*) may range from 2 to 4. The fish species of River Kosi showed isomeric growth pattern (*b*=3.013) while the rest of the fish species showed allometric growth pattern. Higher values of *b* indicate the general appetite conditions and a rather favourable environment for the fish (Mansor *et al*. 2010) [18]. The value of b for River Saryu was 2.74. Johal *et al*. (2005) [13] described the length weight relationship in *Tor putitora* for various rivers and found the value of *b* either 3 or close to it. Pervin and Mortuza (2008) [26] suggested that if *b* is greater than 3, large specimens increase in weight faster than length or the larger specimens in the environment are in better conditions than the smaller ones. The values of *b* in Lake Bhimtal, Nanak Sagar Reservoir and Farmed stock were 2.234, 2.021 and 2.692 respectively. Pervin and Mortuza (2008) [26] reported that when *b* is less than 3, either the small specimens have better nutrition or the large specimens have become more elongated due to inadequate feeding and empty stomach due to limited food availability in the lentic waters. The statistical analysis of length weight relationships showed that the value of exponent (*b* value) of the length weight relationships was significantly different from the cube value (3) and this indicates that fish species follows allometric growth pattern. Froese (2006) [8] stated that the values of *b* vary due to factors of geographical sampling, distinct environmental situations like fast flowing stream environments (Shukor *et al*. 2008) [29] or varied physiological growth conditions such as food availability and capturing efficacy of fishes.

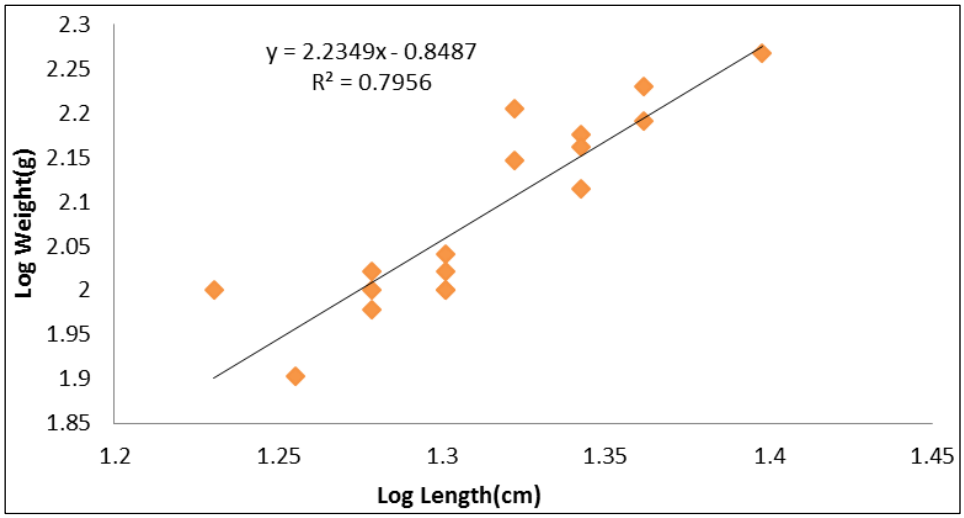

Fig 3: Length weight relationship of *Tor putitora* individuals collected from Lake Bhimtal

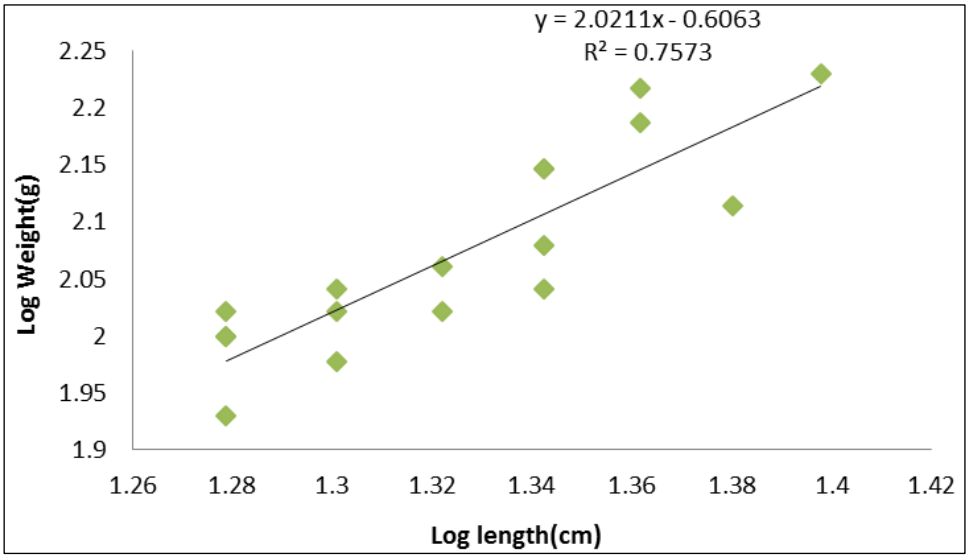

Fig 4: Length weight relationship of *Tor putitora* individuals collected from Nanak Sagar Reservoir

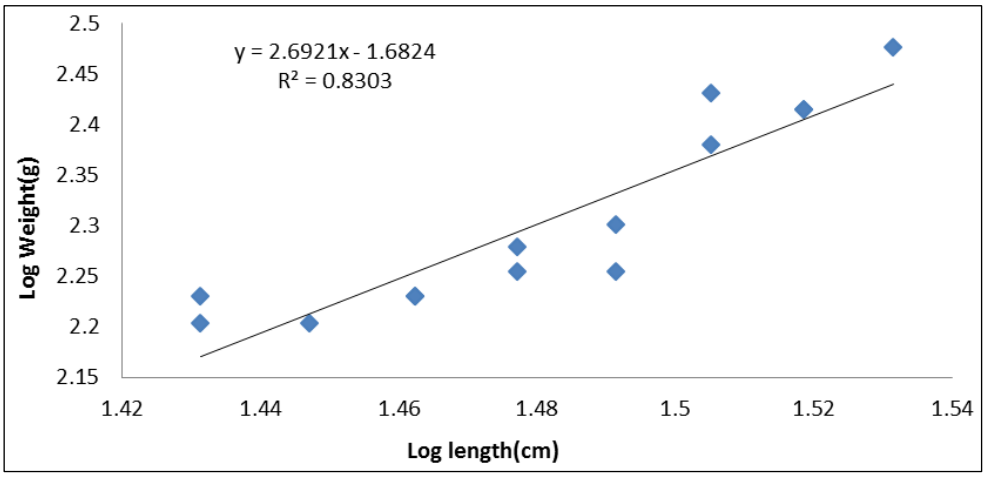

Fig 5: Length weight relationship of *Tor putitora* individuals collected from DCFR Farm, Bhimtal

Condition factor

Condition factor (K) is a numerical index of the state of well-being of the fish that investigates present and future success of a stock by its influence on survival, growth and reproduction. It reflects recent circumstances (biological and physical) and fluctuations caused by the interaction among physiological factors, feeding conditions, and parasitic infections (Le-Cren, 1951) [17]. Ricker (1975) stated that '*K*' is a quantitative measure by which length and weight of individuals are compared under standard conditions. The idea of condition factor is to detect the variations in the condition of the stock, which often varies with seasons, abundance of food and stage of gonads (King 1995) [14]. Condition factor (K) values were analysed on various length group basis to understand the well-being of the fish in different ecosystems.

The values of condition factor of fish samples of different habitats were given in Table-1. The values of condition factor ranged from 0.77 to 1.65. The value of K in Kosi, Saryu, Bhimtal, Nanak Sagar and farmed stock were 1.45, 1.65, 1.32, 1.26 and 0.77 respectively. River Saryu showed maximum value of K (1.65) while the farmed stock showed minimum value of K (0.77). The best condition of River Saryu may be attributed to sub-tropical and temperate forests which cover the whole catchment area of the river (Negi, 1991) [21]. River Saryu and Kosi have a total catchment area of 2473.6 km^2 and 3420 km^2 respectively which ensures proper food availability and potamodromous migration of the mighty mahseer. According to Pant *et al*. (2017a) [24] the activities of river shed have a great impact on the production and to ensure the use of resources in an organized fashion can be extremely helpful for sustainable future and reducing the degradation of resources. Uttarakhand has 180 large and small hydroelectric stations (Valdiya, 2014) [31] but Saryu is still untamed ensuring free migration and providing optimal habitat to Golden mahseer. The results depicted that River Kosi and River Saryu provide best conditions for Putitor mahseer that clarifies the fact that the fish adapts well in lotic ecosystems. Lake Bhimtal is a mesotrophic lake (Pant *et al*, 2017b) [25] with comparatively higher anthropogenic pressure due to heavy tourism round the year. The catchment area is 11.4 km^2 which is quite less in comparison to lotic systems, limiting the presence of food. According to Freeman *et al*. (2002) [7] the construction of dams usually breaks the migration paths of fishes contributing to the heterogeneity of biota, leading to lowest condition factor of the selected Reservoir Nanak Sagar. Results also deciphered that environment plays a significant role on the well-being, growth and development of the fishes and catchment area also influences the production pattern of an ecosystem.

Table 1: Parameters of length weight relationship and condition factor of *Tor putitora* collected from five different ecosystems

Parameters	Sampling sites				
	Lotic ecosystem		Lentic ecosystem		Farmed stock
	River Kosi	River Saryu	Lake Bhimtal	Nanak Sagar	
Mean length (cm)	29.00	21.27	20.64	19.25	30.42
Mean weight (g)	204.23	137.8	125.30	120.53	207.85
Growth coefficient '*b'*	3.013	2.704	2.234	2.201	2.692
Correlation coefficient 'r'	0.86	0.95	0.89	0.87	0.91
Coefficient of determination 'R^2'	0.754	0.914	0.795	0.757	0.830
Condition factor 'K'	1.45	1.65	1.32	1.26	0.77

The value of condition factor is good in all the length groups thereby, indicating a general well-being of fish. Bennet (1970) [4] reported that fishes with condition factor values more than 0.56 are considered in good condition. Thus the present study revealed that the conditions of all the selected habitats were good in general. Gupta *et al*. (2011) [12] suggested that the difference in K values can be due to the food organism's availability at a particular time along with differences in gonad development. The farmed fishes showed minimum value indicating that the fishes could survive better in natural ecosystems as compared to captive conditions. Since the fishes were ripen and majority of the energy of fish was being diverted to gonads, condition factor of farmed stock could be less than unity. Goswami *et al.* (2008) [10] reported that lower values of K may be due to more developed gonadal stage. A high degree of positive correlations between length and weight was depicted by all the three populations stating length of fish increases with increase in the weight of fish (Komulu *et al.* 2010) [16] by coefficient of correlation (r) which is presented in Table 1. A maximum amount of positive correlation of 0.95 was observed in River Saryu. The goodness of fit of the regression model is indicated by the 'R square' value in the output. Linear regressions were significant for all species (p<0.05), with R^2 values ranged from 0.75 to 0.91. The higher values of "R square" show that relationships fitted to be good.

Conclusion

In conclusion, the present investigation observed that *T. putitora* stocks of River Kosi, River Saryu, Lake Bhimtal, Nanak agar Reservoir and DCFR Farm, Bhimtal had distinct habitat conditions and varied biometrics due to several factors like differences in food availability in lotic and lentic environments, the total catchment area, hydroelectrical projects and other environmental conditions. Most of the fish represented allometric growth except River Kosi where the growth is isomeric and the fish body maintains a constant shape. Although the analysis of condition factor deciphered that the untamed River Saryu has better environment. Water abstraction due to damming of rivers leads to slow growth as in Nanak Sagar Reservoir. The rivers proved to be more suitable habitat among the selected ecosystems reflecting the fact that running water bodies support a conducive and optimal environment for the well-being and growth of *Tor putitora* in comparison to lentic systems.

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