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COMPARATIVE ANALYSIS OF MORPHOMETRIC CHARACTERS BETWEEN ARTIFICIAL AND NATURAL STOCKS OF ENDANGERED GOLDEN MAHSEER, *TOR PUTITORA* (HAMILTON) POPULATION FROM HIMACHAL PRADESH, INDIA

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ABSTRACT: *Tor putitora* (Hamilton), the golden mahseer a migratory fish contributes greatly to the commercial fishery in the Himalayan foothills and is regarded as the best sport and food fish. However, the stock of golden mahseer has declined sharply and is now considered as an endangered species. Constructions of dam, barrages, and weirs on Himalayan Rivers resulted in the fragmentation of its population. The comparative study on morphometric of *Tor putitora* from the state has not been reported yet, which would be very useful for its conservation for future aspect as an issue of Himalayan sustainability. This study is aimed to evaluate the phenotypic (morphometric and meristic indices) differentiation in the Pong reservoir, Seer stream and Giri river stocks of an endangered fish, golden mahseer, *Tor putitora* (Hamilton) in Himachal Pradesh. During the period of investigation, twenty one morphometric measurements were calculated in the percentage of total length except those of head depth, pre-orbital distance, post-orbital distance, inter-orbital diameter and eye diameter, which were calculated in the percentage of head length. The results of phenotypic analysis show no significant differences in most of the morphometric and meristic indices except in eye diameter in relation to head length, which differs significantly among three stocks of *Tor putitora*. Majority of morphometric characters in *Tor putitora* are genetically controlled as they exhibit narrow range differences (upto 5% only) with 86% (18 out of 21 dependent characters) genetically controlled characters in Seer stream stock and 72% (15 out of 21 dependent characters) in Giri River and Pong reservoir stock each, *Tor putitora.* It was observed that almost all the morphometric characters show high degree of coefficient of correlation ($r>0.90$) and correlation coefficient was significant at $p<0.05$ in all the variables from natural and reservoir populations.
Key words: *Tor putitora*, golden mahseer, morphometry, distribution, Himachal Pradesh.

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INTRODUCTION

The mahseer fishes are regarded as the best sport and most sought after food fishes in India and neighboring countries [1,2]. Among the mahseer fishes, the golden mahseer (*Tor putitora*), is of great commercial importance with its average production reaching up to 50 tons/ annum in Pong reservoir, 46 tons/ annum in Gobindsagar [3] and 59.5% of total catch in Bhimtal Lake. The population of *Tor putitora* has sharply declined in most of the Indo-Gangetic drainages and river Narmada in the peninsular India [4,5]. It is no more available in Kashmir and some parts of Himachal Pradesh and Uttrakhand [6]. *T. putitora* is categorized as an endangered species by the National Bureau of Fish Genetic Resources, and included in the IUCN Red Data Book [7,8]. The present study was aimed to generate basic morphometric and meristic data for the conservation of this important migratory fish.

Morphometric includes external measurements of an organism, while meristic counts deal with serial counts of body elements [9].

The comparative study on phenotypic characterization of three stocks of *Tor putitora* population from the Himachal Pradesh has not been reported yet, and present study was aimed to evaluate phenotypic (morphometric and meristic indices) characters in the population of this endangered fish, *Tor putitora*, in lentic and lotic waters of Himachal Pradesh.

MATERIALS AND METHODS

During the period of investigation, specimens of *T. putitora*, were collected and preserved from three water bodies, namely Pong reservoir (30^0 01' N 76^0 05E, Kangra) of the Beas basin, Seer stream (31^0 -26'-59"N and 16^0 -43'-11"E, Bilaspur) of the Sutlej basin and Giri River (25^0 30'N 81^0 53'E, Solan) of the Yamuna basin. For the present study, 21 dependent morphometric characters (standard length, pre-dorsal distance, post-dorsal distance, length of dorsal fin, depth of dorsal fin, length of anal fin, depth of anal fin, pre-anal distance, length of pectoral fin, length of pelvic fin, length of caudal fin, length of caudal peduncle, minimum body width, maximum body width, distance between pectoral and pelvic fin, distance between pelvic and anal fin, head depth, pre-orbital distance, post-orbital distance, eye diameter and inter-orbital distance) against two independent characters (total length and head length), and 8 meristic counts (Lateral line scale count, Scales above the lateral line, Scales below the lateral line, Dorsal fin rays count, Pelvic fin rays count, Pectoral fin rays count, Anal fin rays count and Caudal fin rays count) have been recorded. Body measurements were taken by using wooden tray fitted with a measuring scale and Vernier Calliper to the nearest 0.01 cm and the criteria given by Jayaram [10] has been followed.

The measurements were subjected to correlation and regression analysis using SPSS version 16.0. The coefficient of correlation (r) and regression (b) were tested for significance.

RESULTS

Comparative morphometric characterization

During the study mean values of morphometric measurements were compared and no significant differences were observed except in eye diameter (ED)/head length (HL), which differs at 5 percent level of significance among all the three stocks (Table 1). The highest mean values of most of the morphometric characters viz., standard length (SL)/total length (TL), pre dorsal distance (PreDD)/TL, post dorsal distance (PostDD)/TL, length of dorsal fin (LDF)/TL, depth of dorsal fin (DDF)/TL, length of anal fin (LAF)/TL, length of pectoral fin (LPF)/TL, length of pelvic fin (LpF)/TL, minimum body width (MinBW)/TL, maximum body width (MaxBW)/TL, distance between pectoral and pelvic fin (DistPec&Pel)/TL, distance between pelvic and anal fin (DistPel&Anal)/TL, length of caudal fin (LCF)/TL, length of caudal peduncle (LCP)/TL, head depth (HD)/HL, pre orbital distance (PreOD)/HL and inter orbital distance (IOD)/HL are observed within the Pong reservoir stock and are not significantly different from those of freely flowing waters of Seer stream and Giri river. Mean values of various morphometric characters show relatedness among the stocks from natural water bodies viz., Seer stream and River Giri than the stock from impounded water body i.e. Pong reservoir at 5% level of significance. This may be attributed to the fact that population in Pong reservoir has developed as self-sustaining population.

Various body measurements in relation to total length of *Tor putitora* are calculated for correlation coefficient (r) and regression coefficients (values of a and b in regression equations) were recorded (Table 2). High degree of positive correlation ($r>0.91$) with less than five percent level of significance ($p< 0.05$) between independent (total length and head length) and respective dependent morphometric characters indicate that morphometric characters increase in direct proportion to independent characters.

The 'b' values of different variable characters (Y) in proportion to total length (X) in *Tor putitora* indicated that the rate of growth in standard length (SL) is the highest from Seer stream, Giri river and Pong reservoir with 0.752, 1.054 and 0.853 values respectively. While in proportion to head length, 'b' value is the highest for inter-orbital distance (IOD) and the lowest for head depth (HD) from Seer stream and Pong reservoir. On the other hand in relation to head length, 'b' is maximum (0.769) for head depth (HD) and minimum (0.243) for eye diameter from Giri river samples.

From these observations it is evident that most of the characters included in present study increase in direct proportion to each other.

Majority of morphometric characters in *Tor putitora* are genetically controlled as they exhibit narrow range differences (upto 5% only) with 86% (18 out of 21 dependent characters) genetically controlled characters in Seer stream stock and 72% (15 out of 21 dependent characters) in Giri River and Pong reservoir stock each, *Tor putitora* is placed under Vladykov's category of restricted distribution (Table 3).

Table 1: Values of Different Morphometric Characters In *Tor Putitora* From Various Collection Sites Of Himachal Pradesh State, India.

Parameters	Seer Stream					Giri Stream					Pong Reservoirt				
	Regression Equation Y=a+Bx	Mean	SD	Range Difference	Correlation coefficient (r)	Regression Equation Y=a+Bx	Mean	SD	Range Difference	Correlation coefficient (r)	Regression Equation Y=a+Bx	Mean	SD	Range Difference	Correlation coefficient (r)
In % age of Total Length															
Standard length (SL)	Y=-0.286+0.752X	73.61	1.29	4.66	0.958**	Y=-4.026+1.054X	73.97	6.37	19.31	0.996**	Y=-1.745+0.855X	77.41	1.88	7.13	0.991**
Predorsal length (preDD)	Y=-1.732+0.688X	40.20	0.49	2.3	0.978**	Y=1.552+0.272X	39.37	2.49	8.61	0.968**	Y=1.735+0.349X	43.08	1.82	6.88	0.975**
Post dorsal length (postDD)	Y=0.417+0.378X	59.18	1.03	3.51	0.976**	Y=4.465+0.258X	60.75	7.07	24.74	0.976**	Y=4.678+0.409X	62.82	3.58	12.76	0.994**
Length of dorsal fin (LDF)	Y=-0.171+0.205X	19.58	0.33	1.33	0.965**	Y=0.273+0.183X	20.50	1.57	5.59	0.902**	Y=-0.601+0.253X	22.56	0.68	2.77	0.987**
Depth of dorsal fin (DDF)	Y=-1.627+0.224X	13.43	0.68	2.17	0.941**	Y=-0.207+0.177X	16.15	0.83	3.64	0.967**	Y=0.263+0.180X	19.31	0.77	2.62	0.958**
Length of anal fin (LAF)	Y=-3.617+0.324X	12.34	1.25	3.59	0.969**	Y=-0.141+0.137X	12.61	0.85	3.75	0.965**	Y=-0.479+0.179X	15.75	0.40	1.53	0.996**
Depth of anal fin (DAF)	Y=-2.567+0.278X	13.58	0.91	3.36	0.976**	Y=-0.178+0.114X	10.09	0.71	2.88	0.970**	Y=0.915+0.091X	13.44	0.82	2.66	0.926**
Pre-anal distance (preAD)	Y=-2.606+0.335X	61.59	2.25	6.92	0.935**	Y=0.211+0.179X	62.91	5.48	16.88	0.931**	Y=0.251+0.162X	61.38	5.32	18.29	0.985**
Length of pectoral fin (LPF)	Y=-3.441+0.313X	12.24	1.23	4.3	0.958**	Y=-0.174+0.120X	10.70	0.82	3.55	0.962**	Y=1.590+0.087X	16.15	1.23	4.21	0.969**
Length of pelvic fin (LpF)	Y=-3.821+0.333X	12.14	1.44	4.66	0.952**	Y=-0.032+0.087X	8.47	0.58	2.27	0.958**	Y=2.198+0.034X	13.73	1.63	5.69	0.913**
Minimum body width (minBW)	Y=-1.489+0.130X	5.26	0.51	1.85	0.979**	Y=-0.094+0.069X	6.17	0.51	2.22	0.955**	Y=-0.002+0.087X	8.75	0.53	1.70	0.913**
Maximum body width (maxBW)	Y=-1.521+0.134X	15.72	0.34	1.7	0.973**	Y=0.038+0.121X	12.42	0.52	2.19	0.979**	Y=-1.294+0.296X	23.59	1.07	3.86	0.990**
Distance between pectoral & pelvic (dist.pect.&pelv)	Y=-3.124+0.358X	18.46	1.31	4.42	0.944**	Y=-0.091+0.137X	13.02	1.16	4.13	0.933**	Y=-0.060+0.274X	21.13	0.42	1.54	0.991**
Distance between pelvic & anal (dist.pelv.&anal)	Y=-4.110+0.431X	20.34	1.49	4.1	0.963**	Y=0.161+0.164X	17.67	1.17	4.70	0.941**	Y=0.717+0.226X	26.04	1.53	6.37	0.933**
Length of caudal fin (LCf)	Y=-3.383+0.392X	20.48	1.23	4.04	0.974**	Y=-1.072+0.234X	15.03	2.72	9.3	0.943**	Y=1.572+0.175X	24.92	1.53	5.01	0.944**
Length of caudal peduncle (LCP)	Y=-3.732+0.269X	6.24	1.27	4.18	0.963**	Y=-1.229+0.175X	7.95	1.02	7.68	0.940**	Y=-0.731+0.149X	11.50	1.26	5.09	0.849**
In % age of Head Length (HL)															
Head depth (HD)	Y=1.517+0.057X	76.22	6.06	19.88	0.975**	Y=-0.144+0.769X	72.25	4.64	14.94	0.965**	Y=0.858+0.042X	86.94	3.23	12.5	0.986**
Pre-orbital distance (preOD)	Y=0.598+0.868X	67.28	4.79	16.68	0.964**	Y=0.0880.330+X	35.84	2.44	9.56	0.952**	Y=0.178+0.701X	74.29	4.76	17.0	0.954**
Post-orbital distance (postOD)	Y=0.02+0.510X	51.68	2.82	8.89	0.943**	Y=-0.287+0.550X	45.74	3.82	13.05	0.974**	Y=0.356+0.404X	48.62	3.43	12.5	0.945**
Eye diameter (ED)	Y=0.108+0.220X	25.59	0.82	3.37	0.978**	Y=-0.084+0.243X	21.64	1.46	4.86	0.977**	Y=0.180+0.193X	23.46	1.47	5.33	0.961**
Inter- orbital distance (IOD)	Y=-1.205+1.091X	69.81	6.09	18.94	0.991**	Y=-0.370+0.422X	30.31	4.00	13.21	0.969**	Y=-1.274+1.119X	83.82	6.19	21.4	0.985**

Table 2: Means and standard deviation of quantitative phenotype traits based on morphometric character indices used for differentiation analysis among three stocks of *T. putitora* populations

(Mean±S.D.)

Morphometric characters in relation to total length	Stocks of *Tor putitora* populations		
	Seer stream	Pong reservoir	Giri river
SL/TL	73.61±1.29[a]	77.41±1.88 [a]	73.97±6.37 [a]
Pr DD/TL	40.20±0.49[a]	43.08±1.82 [a]	39.37±2.49 [a]
Po DD/TL	59.18±1.03[a]	62.82±3.58 [a]	60.75±7.07 [a]
LDF/TL	19.58±0.33[a]	22.56±0.68 [a]	20.50±1.57 [a]
DDF/TL	13.43±0.68 [a]	19.31±0.77 [a]	16.15±0.83 [a]
LAF/TL	12.34±1.25 [a]	15.75±0.40 [a]	12.61±0.85 [a]
DAF/TL	13.58±0.91 [a]	13.44±0.82 [a]	10.09±0.71 [a]
Pr AD/TL	61.59±2.25 [a]	61.38±5.32 [a]	62.91±5.48 [a]
LPF/TL	12.24±1.23 [a]	16.15±1.23 [a]	10.70±0.82 [a]
LpF/TL	12.14±1.44 [a]	13.73±1.63 [a]	8.47±0.58 [a]
Min BW/TL	5.26±0.51 [a]	8.75±0.53 [a]	6.17±0.51 [a]
Max BW/TL	15.72±0.34 [a]	23.59±1.07 [a]	12.42±0.52 [a]
Dist. pec.&vent. /TL	18.46±1.31 [a]	21.13±0.42 [a]	13.02±1.16[a]
Dist. pel.& anal/TL	20.34±1.49 [a]	26.04±1.53 [a]	17.67±1.17 [a]
LCF/TL	20.48±1.23 [a]	24.92±1.53 [a]	15.03±2.72 [a]
LCP/TL	6.24±1.27 [a]	11.50±1.26 [a]	7.95±1.02 [a]
Morphometric Characters in relation to Head Length			
HD/HL	76.22±6.06 a	86.94±3.23 [a]	72.25±4.64 [a]
Pr-OD//HL	67.28±4.79 a	74.29±4.76 [a]	35.84±2.44 [a]
Po-OD/HL	51.68±2.82 a	48.62±3.43 [a]	45.74±3.82 [a]
ED/HL	25.59±0.82 a	23.46±1.47[b]	21.64±1.46[c]
IOD/HL	69.81±6.09 a	83.82±6.19 [a]	30.31±4.00 [a]

Mean values in the same row having the same letters do not differ significantly (P ≤0.05).

Table 3: *Tor Putitora* Population from Various Collection Sites Showing Range Difference For Plastic And Non-Plastic Characters

Sr. No.	*Tor putitora* population from all collection sites	Range Difference-I (Up to 5%)	Range Difference-II (Up to 5-20%)	Range Difference-III (20% and above)
I. In relation to Total length				
1.	Seer Stream	SL, pre DD, post DD, LDF, DDF, LAF, DAF, pre AD, LPF, LpF, minBW, maxBW, dist.Pect.&Pelv., dist.Pelv.& Anal, LCF and LCP	Ab	Ab
2.	Giri River	pre DD, LDF, DDF, LAF, DAF, LPF, LpF, minBW, maxBW, dist.Pect.&Pelv., dist.Pelv.& Anal, LCF and LCP	Ab	SL, post DD, pre AD
3.	Pong Reservoir	SL, pre DD, LDF, DDF, LAF, DAF, LPF, LpF, minBW, maxBW, dist.Pect.&Pelv., dist.Pelv.& Anal, LCF and LCP	post DD	Pre AD
II. In relation to Head Length				
1.	Seer Stream	post OD, ED	Ab	HD, pre OD, IOD
2.	Giri River	Pre OD, ED	HD, post OD, IOD	Ab
3.	Pong Reservoir	ED	HD, post OD	Pre OD, IOD

Comparative Meristic analysis of *Tor putitora* stocks

The meristic characters observed among all the three stocks of *Tor putitora* show no significant differences except lateral line scale counts which differ significantly among the three stocks of *Tor putitora* (t- test; $p<0.05$) (Table 4). This may lead to conclude that meristic counts are independent of body size and there is no change in meristic counts with increase in body length observed.

On the basis of present observations the meristic formula is summarized as:

D = 12 (4/8), P=15 (1/14), p=9 (1/8), A=8 (3/5), C=17, Ll= 23-28, Ltr=7

Table 4: Means and standard deviations of quantitative phenotype traits based on meristic counts used for differentiation analysis between three geographically different stocks of *Tor putitora*

S.No.	Parameters	Seer stream		Giri river		Pong dam		t-test
		Mean	SD	Mean	SD	Mean	SD	
1	Lateral line scale count	25.5	0.479	25.0	1.252	27.0	0.508	**
2	Scales above lateral line	4½	0.00	4½	0.00	4½	0.00	NS
3	Scales below lateral line	2½	0.00	2½	0.00	2½	0.00	NS
4	Dorsal fin ray count	4′8″	0.00	4′8″	0.00	4′8″	0.00	NS
5	Pectoral fin ray count	1′14″	0.00	1′14″	0.00	1′14″	0.00	NS
6	Pelvic fin ray count	1′8″	0.00	1′8″	0.00	1′8″	0.00	NS
7	Anal fin ray count	3′5″	0.00	3′5″	0.00	3′5″	0.00	NS
8	Caudal fin ray count	17	0.00	17	0.813	17	0.00	NS

t-test: ** $p<0.05$ NS: non-significant

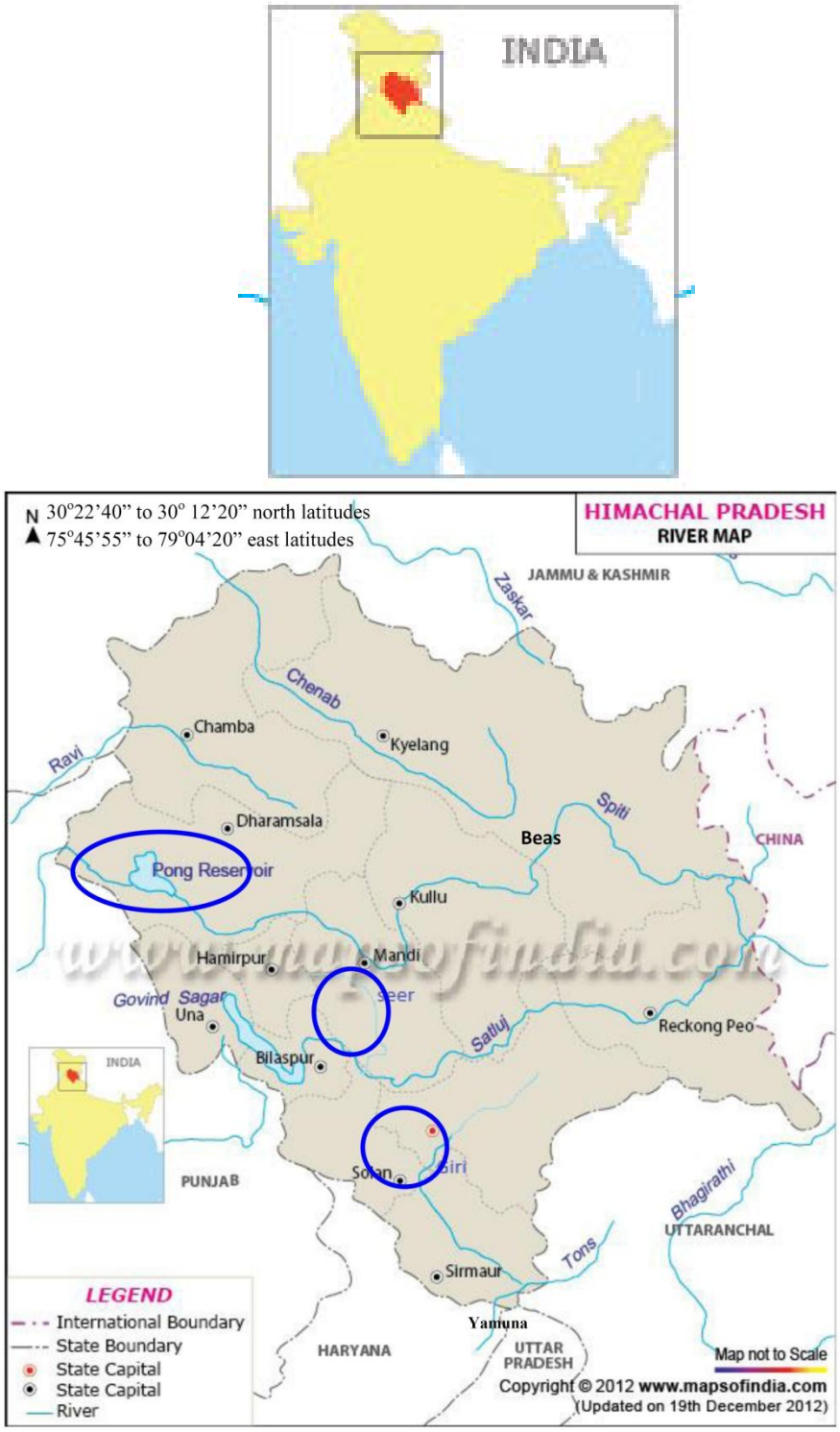

Fig. 1: Map showing fish collection sites from Himachal Pradesh, 1- Pong reservoir, Kangra; 2- Seer stream, Bilaspur.and 3- Giri river, Solan

DISCUSSION

The present investigations on *Tor putitora* show no significant differences among all the mean values of morphometric measurements except in the eye diameter/head length (ED/HL) which differs significantly among all the three stocks (Table I). Tandon et al. [11], Johal et al. [12], and Bhatt et al. [13] have also reported striking resemblance in mean indices values between various morphometric characters in *Tor putitora* from Gobindsagar reservoir, Bilaspur in Himachal Pradesh and river Ganga at Hardwar in Uttrakhand. Bhatt et al. [13] further suggested that these characters may be important in studies on sub speciation in *Tor putitora*. Mean indices values vary in their highest and lowest proportions among all three stocks under present study but no significant variation is observed between them at $p<0.05$ level of significance. These results are consistent with the findings of Joseph and Jayasankar [14] on two different coastal stocks of *Nemipterus mesoprion* in Chennai and Ibanez-Anguirre [15] on *Mugil curema* in Mexico.

On the contrary, significant differences ($P \leq 0.05$) have been observed between morphometric character indices among different wild and cultured Nile tilapia (*Oreochromis niloticus*) populations in Egypt [16], wild populations and inbred stocks of *Gobiocypris rarus* in China [17], geographically isolated populations of *Puntius seenghala* [18] in Sri Lanka.

Present study revealed that majority of morphometric characters in *Tor putitora* are genetically controlled. These results are corroborated by the morphometric studies on *Tor putitora* from Gobindsagar reservoir and Ganga stocks having 60% genetically controlled characters [11, 13] (Table IV). Morphometric studies on some other Himalayan hill stream fishes with restricted distribution also show predominance of genetically controlled characters: *Barillius bendelensis* (54.54% in males and 50% in females), *Barillius vagra* (63.63% in males and 59.09% in females) [19], *Hypophthalmichthys molitrix* (73%) [11] and *Shizothorax richarsonii* (90%) [20].

Observations on regression coefficient 'b' in *Tor putitora* also have relatedness with the findings of Nautiyal, [21-24].

High degree of positive correlation ($r>0.91$) with less than five percent level of significance ($p<0.05$) between independent (total length and head length) and respective dependent morphometric characters indicate that morphometric characters increase in direct proportion to independent characters. These results are corroborated by a similar study on biometry of *Tor putitora* from Meghalaya [25] and from Pakistan [26].

Similar results have also been obtained in other cold water fishes namely *Chlorophthalmus agassizi* in Greece, *Shizothorax richardsonii* in Uttarakhand [20] and *Puntius sophore* in Bangladesh [27].

Meristic counts in *Tor putitora* population from Seer stream, Giri River and Pong reservoir, show no significant differences statistically. This lends support to the premise that meristic counts are independent of body size and there is no change in meristic counts with increase in body length observed [9, 28].

CONCLUSION

By this study, we have revealed, for the first time, the intra-population and inter population phenotypic variability between the three populations of *T. putitora* in Himachal Pradesh, India. The results of the present study can be used as a baseline for further study involving this threatened species in the country. The present studies on *Tor putitora* population show no significant differences in morphometric characters and meristic counts, and its various stocks in Himachal Pradesh are homogenous. However, Bhatt et al. [13] records indicate raciation in *Tor putitora* in its various stocks in the Ganges river and found significant differences ($p<0.005$) among all the variables of morphometric study. A more definite conclusion, however, may be reached with larger number of samples including other rivers (if possible to collect) with TRUSS network analysis for morphometric characters.

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