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Analysis of Growth Pattern and Variation in Some Morphometric Characters of Sympatric Hill Stream Teleosts *Barilius bendelisis* and *Barilius vagra*

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Abstract

In male and female *Barilius bendelisis* and *Barilius vagra* parameters showing most significant linear regression in relation to total length were snout length and least depth of caudal peduncle. The body parameters standard length and predorsal length were observed to be the least significant in both male and female *B. bendelisis* and *B. vagra*. In male and female *B. bendelisis* and *B. vagra* parameters showing most significant linear regression in relation to head length were length of rostral barbel and length of maxillary barbel while head depth and postorbital distance were observed to show least significant linear regression. These also grow in linear fashion but rate is relatively lower. Certain body proportions of the males and females of *B. bendelisis* and *B. vagra* differed but not significantly. On the basis of morphometric analysis, *B. bendelisis* with 54.5% of genetically controlled characters in males and 50% in females shows relatively wider distribution and greater tendency of subspeciation than *B. vagra* with 63.9% genetically controlled characters in males and 59.1% in females.

Introduction

Two closely related species may have overlapping ranges. Where two morphologically similar species occur together in an area of overlap, the populations are more divergent and easily distinguished, i.e. they "displace" one another in one or more characters. The characters involved can be morphological, ecological, behavioral, or physiological; they are assumed to be genetically based (Brown and Wilson 1956). The cause of variation in the morphometric and meristic characters may range from genetic variability to the influence of environmental parameters (Hubbs 1921, Vladykov 1934, McHugh 1954). This happens because some body parts tend to grow at different rates under varying environmental conditions. The role of environmental and other parameters (habitat temperature, elevation, slope, gradient, stream velocity, food productivity, length, sex, and age) has also been demonstrated (Hubbs 1926, Barlow 1961, Hampel and Blaxter 1963, Hopkirk 1973, Kirka 1974).

In view of the paucity of information on morphometric and meristic characters of hill stream teleosts *B. bendelisis* and *B. vagra*, a study was conducted on both species and their sex to analyze the similarities and differences in growth patterns and variations in their body measurements. Tendency of speciation in respective populations was also tested. In Garhwal region such studies have been performed for the catfish *Pseudecheneis sulcatus* (McClelland) (Singh and Dobriyal 1983), *Noemacheilus montanus* (McClelland) (Dobriyal and Bahuguna 1987), *Schizothorax richardsonii* and *S. plagiostomus* (Pandey and Nautiyal 1997) and *T. putitora* Hamilton (Bhatt et al. 1998). In India, a number of studies have been performed on this subject for marine and few freshwater fishes (Pillay 1957, Sarojini 1957, Tandon 1962, Chaterjee et al. 1977, Khumar 1985, Tamubi Devi et al. 1991).

Materials and Methods

Fishes were obtained by regular sampling at monthly intervals for one year, January to December 1997 in the Khanda, a lesser Himalayan stream. This springfed stream is a small tributary of the glacierfed river Alaknanda in the lesser Himalaya. The stream flows in a north-west direction from an elevation of 2143 m and meets the Alaknanda at Billokedar (520 m). The Khanda basin lies between latitudes 30^0 6' 42" to 30^0 13' 23" N and longitude 78^0 41' 48" to 79^0 5' 4" E covering an area of 96.7 sq. km. The stream is named Khanda Gad after the confluence of two parent streams, the Kathal syun (Nayal) Gad and the Nandal Gad at 720 m, 1 km upstream of the Khan da Chatti (Fig.1). Thus, the stream Khanda Gad is a first to six order stream for most of its (~29 km) length. The fishes *B. bendelisis* and *B. vagra* were collected using the trap method and fixed in 10% formalin, after giving an abdominal incision. A total of 272 *B. bendelisis* (142 male and 130 female) and 75 *B. vagra* (42 male and 33 female) were obtained in 12 months.

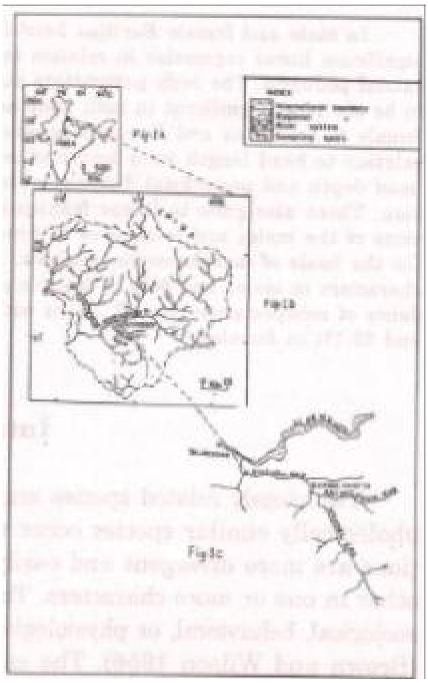

Fig. 1a. Location of Garhwal Himalaya
Fig. 1b. Major rivers of Garhwal Himalaya
Fig. 1c. The Khanda Gad system and its confluence with the Alaknanda

Based on the descriptions of Srivastava (1992) and Jayaram (1981), we recorded 14 and 8 morphometric measurements of total and head dimensions, respectively for each of the two species, *B. bendelisis* and *B. vagra* (Fig. 2). The variables PsDL, BD, SL, LPF, LDF, LCP, HL, DisPP, LAF, LCF, PrDL, LPelF, LDCP and SnL were examined in relation to total length (Fig. 2). The parameters considered in respect to head length were HD, HW, POD, PrOD, ED, IOD, LMB and LRB (Fig. 2).

These measurements were subjected to correlation and regression analyses. The coefficient of correlation (r) and regression (b) were tested for significance. The data were then used to compute the regression equation for each dependent variable (Y1 to Y22) to fit the straight line equation (Y= a+bx), where Y is the dependent variable 'a', the intercept 'b' the slope of the regression line and x, the dependent variable.

The ratios between several body dimensions, in relation to total and head length were also computed separately for males and females for each species. Mean ± standard error was obtained for each variable. They were then tested for significance by performing single factor ANOVA using the Data Analysis Tool Pak of MS EXCEL (Windows 98). The program took care of the unequal sample size. The various morphometeric characters were then classified on the basis of range into genetically (<10%), intermediate (10 to 15%) and environmentally (>15%) controlled characters (Johal et al. 1994). The classification of morphometric characters into genetic, environmental and intermediate was adopted in order to compare the morphometry of the *B. bendelisis* and *B. vagra* in the stream environment and ascertain distribution pattern.

Results

Various body measurements related to total and head length of sympatric *B. bendelisis* and *B. vagra* were compared on the basis of statistic 'r' (correlation coefficient), b (regression coefficient) and F (one way analysis of variance, ANOVA). The mean body measurements of both species have been compared in Fig. 3. In both males and females of *B. bendelisis* and *B. vagra*, the most highly correlated body parameters in relation to total length, were standard length and predorsal length (Table 1).

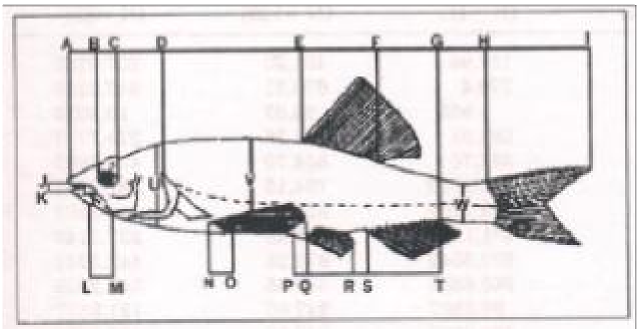

Fig. 2. Outline diagram showing morphometric features of *Barilius* selected for the study. AI-Total length (TL); FH-Post dorsal length (PsDL); V- Body depth (BD); AH - Standard length (SL); PR-Length of pelvic fin (LPelF), EF-Lenth of dorsal fin (LDF); AD-Head Length (D); OP-Distance between pectoral and pelvic fin (DisPP); ST - Length of anal fin (LAF); W - Length of caudal peduncle (LCP); AE-pre dorsal length (PrDL); NQ-Length of pectoral fin (LPF); FH-Least depth of caudal peduncle (LDCP); AB- Snout length (SnL); U-Head depth (HD); CD-Post orbital distance (PsOD); AB-Pre orbital distance (PrOD); BC-Eye diameter (ED); X-Interorbital distance (IOD); LM-Length of maxillary barbell (LMB); JK-Length of rostral barbell (LRB)

Difference was observed in the least correlated parameter, being length of anal fin in male and female *B. bendelisis* while post dorsal length in *B. vagra*. However, the highest correlation for standard length was recorded in males, especially *B. bendelisis*. In females, the highest correlation was recorded for *B. bendelisis* also. This was equally true for postdorsal length. The body measurements, head depth and preorbital distance in relation to head length of male *B. bendelisis* while postorbital distance and head depth in *B. vagra* were the most highly correlated parameters. The body measurements postorbital distance and preorbital distance in female *B. bendelisis*, while preorbital distance and head depth in female *B. vagra*, were the most highly correlated parameters.

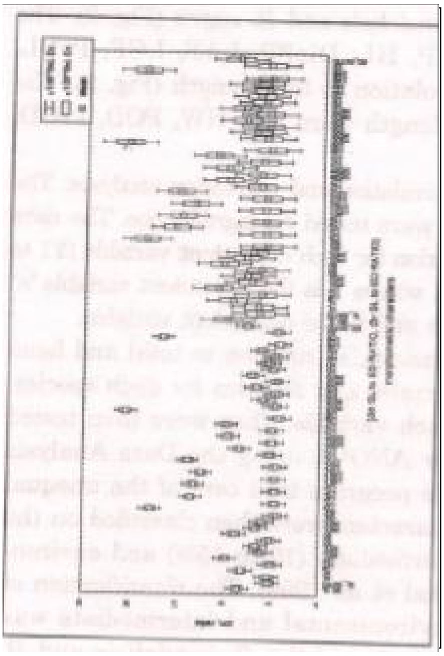
Fig. 3. Body measurements (cm) and their ratios in sympatric *Barilius* spp. (The left has data for *B. bendelisis* and the right half for *B. vagra*)

Table 1. Regression analysis (ANOVA – F) of various body parts in relation to total length and head length (parameters showing most significant linear growth in bold and marked with asterik). The abbreviations are shown in figure 2.

Body parts	Male		Female	
In relation to total length	*Barilius bendelisis* (N =142)	*Barilius vagra* (N =42)	*Barilius bendelisis* (N =130)	*Barilius vagra* (N =33)
PsDL	314.89	157.98	401.20	207.0767
BD	538.70	270.4	676.21	347.4265
SL	18.27	7.985	23.87	10.5935
LPF	588.07	282.98	747.36	379.7747
LDF	676.60	331.76	854.70	435.4993
LCP	594.91	288.2799	754.15	382.3796
HL	497.05	243.7299	623.89	316.6202
DisPP	596.47	271.1113	725.48	337.2143
LAF	682.86	337.5549	870.28	442.3744
LCF	527.02	265.6885	664.65	345.2838
PrDL	196.32	96.6897	247.66	121.3337
LpelF	667.75	323.6727	848.57	427.8826
LDCP*	695.41	340.5808	876.77	442.7437
SnL*	733.28	356.2998	924.73	485.8888
In relation to head length				
HD	72.25	38.07912	108.11	43.1252
HW	226.65	106.259	302.29	116.8957
PsOD	195.97	95.9407	255.88	99.9634
PrOD	395.24	207.0272	542.72	219.267
ED	497.64	268.0194	663.68	280.7659
IOD	353.17	198.0964	494.15	207.3477
LMB*	765.98	406.5425	1037.24	423.6945
LRB*	792.02	412.764	1068.39	429.0701

Coefficient of regression indicated that the males of *B. bendelisis* and *B. vagra* as compared with the females had the highest values for standard length followed by predorsal length in relation to total length, a pattern similar to that exhibited by correlation coefficient. In relation to head length, head depth was the parameter with the highest value and hence the highest growth in males and females of the sympatric *B. bendelisis* and *B. vagra*. The least observed values had no similarity. In male *B. bendelisis* length of maxillary barbel while in *B. vagra* length of rostral barbel were observed in this category of parameters showing slow rate of growth in relation to total and head length.

All body measurements were found to grow in a linear fashion (Table 2). In male and female *B. bendelisis* and *B. vagra* parameters showing the most significant linear regression in relation to total length were snout length and least depth of caudal peduncle. The body parameters standard length and predorsal length were observed to be the least significant in both male and female *B. bendelisis* and *B. vagra*. In male and female *B. bendelisis* and *B. vagra* parameters showing the most significant linear regression in relation to head length were length of rostral barbel and length of maxillary barbel while head depth and postorbital distance exhibited the least significant linear regression. These also grow in a linear fashion but rate is relatively lower.

ANOVA indicated that the body ratios of male and female *bendelisis* did not differ significantly (Table 3). It was also true for *vagra*. The mean ratios of *B. bendelisis* and *B. vagra* were compared in figure 3. On performing single factor

Table 2. Linear regression equation of some body measurements in relation to total length and head length of sympatric *B. bendelisis* and *B. vagra*.

Body parts	Male		Female	
In relation to total length	*B. bendelisis* (N =142)	*B. vagra* (N =42)	*B. bendelisis* (N =130)	*B. vagra* (N =33)
PsDL	0.3429x +-0.0545	0.3685x+0.1348	0.3334x +0.0885	0.3312x +0.0979
BD	0.2006x +0.1126	0.1838x +0.0808	0.2027x +0.109	0.2127x +0.2451
SL	0.8163x +0.0414	0.8352x +0.1193	0.8158x +0.0548	0.8348x +0.1156
LPF	0.1591x +0.0416	0.1702x +0.1016	0.152x +0.0192	0.1345x +0.0841
LDF	0.1188x +0.1412	0.1064x +0.0895	0.1093x +0.0815	0.1191x +0.1816
LCP	0.1482x +0.0023	0.1648x +0.1136	0.1372x +0.051	0.1414x +0.0162
HL	0.2058x +0.0503	0.1919x +0.1407	0.1982x +0.0959	0.209x +0.0156
DisPP	0.1366x +0.073	0.1539x +0.1423	0.1607x +0.10048	0.1848x +0.0315
LAF	0.1048x +0.0726	0.106x +0.1401	0.0808x +0.044	0.0926x +0.048
LCF	0.1773x +0.1063	0.161x +0.1472	0.175x +0.1044	0.1622x +0.1306
PrDL	0.4707x +0.032	0.4647x +0.01	0.4715x +0.0406	0.4869x +0.1121
LpelF	0.1083x +0.0338	0.1106x +0.0432	0.0996x +0.0043	0.0846x +0.1
LDCP	0.0865x +0.0006	0.0761x +0.0599	0.0845x +0.0044	0.0761x +0.064
SnL	0.069x +0.0352	0.0688x +0.035	0.0666x +0.0257	0.0647x +0.008
In relation to head length				
HD	0.6465x +0.0142	0.1702x +0.0133	0.x +0.	0.1793x +0.1793
HW	0.4593x +0.0302	0.1322x +0.0846	0.x +0.	0.1307x +0.072
PsOD	0.4626x +0.0189	0.115x +0.0742	0.1174x +0.0537	0.1206x +0.045
PrOD	0.3232x +0.0353	0.082x +0.03	0.0785x +0.0028	0.0894x +0.068
ED	0.1768x +0.0778	0.0374x +0.1268	0.050x +0.0597	0.046x +0.0702
IOD	0.3057x +0.041	0.0778x +0.019	0.062x +0.1197	0.0894x +0.043
LMB	0.0564x +0.0157	0.0118x +0.0305	0.0154x +0.0119	0.0171x +0.004

ANOVA between body proportions of *bendelisis* and *vagra* none were found to differ significantly. However, on applying ANOVA to four body proportions that seemed to differ, body depth, distance between pectoral and pelvic fin and length of maxillary barbel differed significantly in these sympatric species. Length of rostral barbel did not differ significantly (Table 3).

In male *B. bendelisis* genetically controlled characters comprised 54.54% while intermediate and environment controlled characters were 18.18% and 27.27%, respectively. In male *B. vagra* genetically controlled characters were 63.63% while intermediate and environmental controlled charaters were 9.09% and 27.27%, respectively. In female *B. bendelisis* genetically controlled characters were 50% while intermediate and environmental controlled charaters were 22.73% and 27.27%, respectively. In female *B. vagra* 59.09% were genetically controlled characters while 22.73% and 18.18% were intermediate and environmentally controlled charaters, respectively (Table 4).

Discussion

Brown and Wilson (1956) stated that when two species occur together in the area of overlap, the populations are more divergent and easily distinguished, i.e. they "displace" one another in one or more characters. The character involved can be morphological, ecological, behavioral, or physiological; they are assumed to be genetically based. The morphological [morphometric and meristic] characters of *B. bendelisis* (Hamilton) and *B. vagra* (Hamilton) were classified into three categories proposed by Vladykov (1934) to determine the characters more prone to variation (environmental characters). Hence, a parameter increasing in a rapid linear fashion in one environment tends to increase in a slow linear pattern in another environment.

All body measurements exhibited a linear pattern of growth. Snout length and least depth of caudal peduncle showed rapid linear increment in relation to total length, while standard length and predorsal length showed less linear growth for male and female *B. bendelisis* and *B. vagra*. Length of maxillary barbel and length of rostral barbel showed rapid linear growth in relation to head length. HD showed slow linear growth in relation to head length of both male and female *B.bendelisis* and *B.vagra*. Linear relationship of body characters of both males and females with the total length of the fish was observed

Table 3. Statistics of single factor ANOVA to determine the differences in body proportions and different body parts of sympatric *B. bendelisis* and *B. vagra*

Parameters	F	F crit (P 0.05)	P
B. bendelisis (M & F); N = 272	0.004	4.07	0.95
B. vagra (M & F); N = 75	0.00462	4.04	0.982
B. bendelisis vs *B. vagra*	0.00004	4.04	0.984
BD vs TL	8.3037	3.8685	0.0042
DisPP vs TL	150.594	3.8685	0.000
LCF vs TL	44.346	3.8685	0.000
LRB vs HL	0.9490	3.8713	0.3303
LMB vs HL	3.7430	3.8685	0.0538

by Chaterjee et al. (1977) in *Labeo bata*, Singh and Dobriyal (1983) in *Pseudecheneis sulcatus* (McClelland), Khumar (1985) in *L. calbasu*, Dobriyal and Bahuguna (1987) in *Noemacheilus montanus* (McClelland), Tamubi Devi et al. (1991) in *Rita rita*, Pandey and Nautiyal (1997) in *Schizothorax richardsonii* and *S. plagiostomus* and Bhatt et al. (1998) in *T. putitora* (Hamilton) in the foothill section of the river Ganga.

As far as the male and female *B. bendelisis* are concerned, the body ratios which differed (though not statistically) in relation to TL and HL were LPF, LAF, LCF, LDF, DisPP, PrDL, SnL, HW, PsOD, LMB, and LRB (Fig. 2). In the case of *B. vagra* LPF, LPelF, LAF, LCF, LDF, LCP, DisPP, HL, PsDL, SnL, LDCP, HW, PsOD, PrOD, IOD, LMB and LRB (Fig. 2) differed in males and females. The differences, however, were not statistically significant. The meristic features barbels; fin rays, vertical bars, lateral line scales and predorsal lateral line scales did not vary in males and females of either *B. bendelisis* or *B.vagra*.

Table 4. Range differences in body parts of male and female *B. bendelisis* and *B. vagra*

Characters	Male (N=142) *B. bendelisis*		Female (N = 130) *B. bendelisis*		Male (N =42) *B. vagra*		Female (N=33) *B. vagra*	
	Body parts	Range diff.	Body parts	Range diff.	Body parts	Range diff.	Body parts	Range diff.
In relation to total length								
Intermediate	PsDL	13.67	PsDL	13.34	PsDL	13.18	PsDL	10.32
characters	BD	11.25	BD	11.25	HL	10.62		
	SL	11.75	HL	11.82				
	LPF	11.15	SL	10.99				
			LPF	10.91				
Genetic	LDF	9.61	PrDL	9.61	BD	8.23	HL	9.02
characters	LCP	9.33	LDF	8.39	PrDL	7.43	BD	8.60
	HL	8.29	LCP	7.91	DisPP	7.37	SL	7.59
	DisPP	8.28	LAF LCF	7.14	LCF	6.32	LCF	6.65
	LAF	8.05	DisPP	6.82	LDF	5.69	DisPP	6.43
	LCF	7.94	LPelF	6.52	LAF	5.69	LPelF	6.14
	PrDL	6.67	LDCP	5.83	SL	5.04	PrDL	5.69
	LPelF	5.72	SnL	5.7	LPF	4.85	LCP	5.55
	LDCP	5.1		4.47	LCP	4.30	LPF	5.27
	SnL	4.67			LPelF	3.57	LAF	4.70
					SnL	3.19	LDF	4.70
					LDCP	3.13	SnL	3.85
							LDCP	3.66
In relation to Head length								
Environmental	HD	41.07	HD	36.11	HD	28.8	HD	21.29
characters	HW	34.1	HW	34.64	ED	27.96	PsOD	20.30
	PsoD	29.17	PsoD	29.12	HW	25.56	HW	17.00
	ProD	16.66	ProD	21.8	PsoD	17.89	PrOD	15.29
	ED	19.05	IOD	19.4	IOD	16.40		
	IOD	16.45	ED	19.05	ProD	15.78		
Genetic	LMB	6.45	LRB	7.3	LRB	11.78		
characters	LRB	9.8	LMB	9.4	LMB	11.16		
Intermediate							ED	14.20
characters							IOD	13.46
							LRB	11.61
							LMB	10.83

A large number of body proportions were similar in sexes of both species. The body proportions BD, LCP, HL, LAF, PrDL, LDCP, PsDL, PsOD, HW, ED and SL (Fig. 2) were similar in males of *B. bendelisis* and *B. vagra*. Hence, those different were LMB, LRB, IOD, HD and PrOD in relation to HL while DisPP, LCF, SnL, LPF, LPelF and LDF in relation to TL (Fig. 2) were not statistically significant. Similarly, among females of *B. bendelisis* and *B. vagra* some of the body proportions in relation to total and head length showed significant differences.They were BD, LPF, LCP, DisPP, HL, LAF, LCF, PrDL, LDCP, SnL, PsDL, LDF, HD, HW, IOD, LMB and LRB (Fig. 2). Hence, in the sympatric females 17 out of 22 characters were different indicating greater difference in females compared to the males where only 11 characters were different (not tested for statistical significance), nevertheless. This appears to be one of the strategies to avoid competition in sympatric species of *Barilius* by ensuring successful breeding through proper recognition of female counterparts. The body ratios of *B. bendelisis* and *B. vagra* in relation to total length differed largely for body depth, distance between pectoral and pelvic fin and lengh of caudal fin. Slight differences were obtained for length of pectoral fin, length of dorsal fin, snout length, postdorsal length, standard length, length of caudal peduncle and head length. The body proportions showing considerable difference in relation to head length were interorbital distance, length of maxillary barbel and length of rostral barbel. Those showing slight differences were head depth, head width, postorbital distance and preorbital distances. No difference was observed for eye diameter. These differences were not statistically significant (Table 3).

The parameters length of maxillary barbel followed by length of rostral barbel showed maximum difference. Coming next in descending order of importance were distance between pectoral and pelvic fin, length of caudal fin and body depth. In *B. bendelisis* length of maxillary barbel proportion varied from 15 to 20 while in *B. vagra* from 16.1 to 16.3. Similarly for length of rostral barbel, it was 20.5 to 20.6 in *bendelisis* and 17.2 to 19.5 in *B.vagra*. In the case of distance between pectoral and pelvic fin the proportions recorded for *B. bendelisis* were 6.3 to 6.7 and for *B.vagra* from 5.3 to 6.3 in *B. bendelisis* and 5.2 to 5.4 in *B. vagra*. The body depth varied from 5.6 in *B. bendelisis* to 5.9 in *B. vagra*. Female *B. bendelisis* revealed lack of significant difference in them. It was also true when male and female *B. vagra* were compared. On performing single factor ANOVA on each of the five body proportions individually, barring length of rostral barbel, the body depth, length of maxillary barbel, distance between pectoral and pelvic fin and length of caudal fin differed significantly ($P>0.05$). It suggested that the proportions of four of these parameters varied significantly among *B. bendelisis* and *B. vagra*. The study of body proportions thus brings out definite demarcation in the morphology of *B. bendelisis* and *B. vagra*.

Day (1878) reported a greater proportion of length of caudal fin (5 to $5^{1}/2$) in *B. bendelisis* than in *B. vagra*. In the present study the ratio of distance between pectoral and pelvic fin and length of caudal fin were also higher in *B. bendelisis* compared to *B. vagra*, while body depth was higher in *B. vagra* (5.9) than in *B. bendelisis* (5.6). The body depth of *B. bendelisis* ($4^{1}/_{4}$) was less (5 to 6) than *B. vagra*. Talwar and Jhingran (1991) also indicated the proportion of body depth in head length. According to him it was less (3.8 to 4.2) in *B. bendelisis* than (4.5

to 4.6) in *B. vagra*. The implications of body depth are manifested in the body profile of these two species. *B. vagra* has a distinct horizontal profile dorsally and deeply convex, ventrally. Owing to this body depth is more in *vagra*. In *B. bendelisis* the dorsal as well as the ventral profile were convex, not so deep as in *B. vagra*. In addition to these morphological peculiarities, the position of the mouth in *B. bendelisis* was terminal while in *B. vagra* it was superior, curved upwards.

Badola et al (1982) described sexual dimorphism in *B. bendelisis* collected from the River Nayar of Garhwal Himalaya. The fish exhibit marked sexual dimorphism in breeding season and other dimorphic characters throughout the year. They took some characters for differentiating male and female individuals such as color, size, tubercles, fins, branchiostegal rays, caudal peduncle and sex ratio as also observed in the present study. They found two varieties 'Cocsa' and 'Chedra', which appear to be the sexually different forms of the same species, 'Cocsa' the female and 'Chedra' the male *B. bendelisis*. Godsil (1948) and Marr (1955) said that the ratio between various body parts and increase in length at different stages of life might not exhibit constant relative growth. Pritchard (1931) and Tandon (1962) stated that the ratio between various parts of males and females in the fish species studied by them were different.

Based on range differences, the morphological characters were categorized into genetic, intermediate and environmental characters. In *B. bendelisis* among the 22 variables selected for the study, 12 were found to be genetic, 4 were intermediate and 6 were environmental. Except for head length, an intermediate character for female and genetic for male *B. bendelisis*, all other showed no differences on sexual basis. The reverse was true for *B. vagra* where HL was an intermediate character in male and genetic in female. *B. vagra* seems to be more versatile as discussed later. In *B. bendelisis* the genetic characters included LDF, LAF, LCF, LPelF, HL, DisPP, PrDL (Fig. 2), along with the fast growing least depth of caudal peduncle and snout length and slow growing predorsal length while length of maxillary barbel and length of rostral barbel in relation to head length.The intermediate ones included length of pectoral fin, postdorsal length, body depth and standard length while environmental ones were HD, HW, PsOD, PrOD, ED and IOD (Fig. 2), all from the head region.These characters tend to vary with environment.

In *B. vagra* considerable difference occurred in males and females. Twelve genetic characters common to both sexes were LCF, LDF, LAF, LEF, LPelF, BD, LDCP, PrDL, DisPP, SnL, LCP and SL (Fig. 2). In males, additional genetic characters were length of maxillary barbel and length of rostral barbel. They were intermediate in females along with interorbital distance and eye diameter. In this category postdorsal length was common to both sexes. In males head length, as already stated above, was an intermediate character. Thus, a total of 5 characters were intermediate in females and only 2 in males. The environmental characters common to both sexes were head depth, head width, postorbital distance and preorbital distance. Those specific to males, were eye diameter and interorbital distance. The only difference between *B. bendelisis* and *B. vagra* was in the intermediate characters. Barring postdorsal length, which is common in species standard length, body depth and length of pelvic fin, were found in the former, head length in males while interorbital distance and eye diameter in females.

Based on morphometric analysis, *B. bendelisis* with 54.5% of genetically controlled characters in males and 50% in females shows relatively wider distribution and greater tendency of subspeciation than *B. vagra* with 63.9% in males and 59.1% in females. In both spp. the share of genetically controlled characters were high while that of environmentally controlled characters were low (18.2 to 27.3%). Vladykov (1934) maintains that in fish species showing restricted distribution, the majorities of morphometric characters show a narrow range and are genetically controlled. On the contrary, in species that have a wide range of geographical distribution, most of the characters are strongly influenced by the environment. Based on this criterion *B. bendelisis* and *B. vagra* have restricted zoogeographical distribution because the majority (50 to 63.9%) of their morphometric characters show narrow range differences and are genetically controlled. The environmentally controlled characters are few (18.2 to 27.3%).

Jayaram (1981) described the distribution of *Barilius* spp. throughout India, Pakistan, Nepal, Bangladesh, Sri Lanka and Burma to Malaysia. *Barilius* species are also found in Egypt, West Africa, and Zambesi River. According to Talwar and Jhingran (1991), *B. bendelisis* and *B. vagra* are distributed throughout India, Pakistan, Nepal, Bangladesh, Sri Lanka and Burma and inhabit streams and rivers along the base of hills. According to Srivastava (1992), *Barilius* spp. occurs only in the Oriental region while *B. bendelisis* is distributed in Assam and Himalaya through the continent of India as far as the Western Ghats not recorded from Malabar or Canara, or from Sind.

Among the Oriental fishes showing similar distribution, Tandon et al. (1993 a,b) studied *Cirrhinus reba* (Hamilton), *Tor putitora* (Hamilton) from Gobind Sagar Reservoir and Bhatt et al. (1998) studied *Tor putitora* from the foothill section of the Ganga. In *C. reba* 14 out of 19 and in *G. chapra* 13 out of 18 morphometric characters exhibited wide range differences and were hence environmentally controlled. According to the criterion of Vladykov they fall in the category of fish showing wide distribution. On the contrary in *Tor putitora* restricted to Himalayan foothills, 13 out of 27 characters were genetically controlled, showing narrow range difference, 9 were environmental characters in Gobind Sagar reservoir stock, 12 out of 20 were genetically controlled while 3 were environmentally controlled in the population inhabiting the foothill section of the Ganga.

These observations support the hypothesis of Vladykov, that fishes with restricted distribution have greater numbers of genetic characters, as was also evident in *B. bendelisis* and *B. vagra*. Of the 22 morphometric characters examined in their males and females, 11 to 14 were in the category of genetically controlled. This suggests that the above mentioned species of *Tor* and *Barilius* are more restricted in distribution as compared to *C. reba* and *G. chapra* and the tendency of subspeciation is low. Tandon et al. (1993a) states that Pivnicka and Hensel (1978) reported seven subspecies of *Thymallus thymallus* from Europe, Siberia, Alaska and Canada. Obviously, it is a species with distribution across the globe (Nearctic and Palaearctic) as compared with *B. bendelisis* and *vagra*, restricted primarily to the Oriental region.

Tandon et al. (1993 a,b) demonstrated that 50% of the morphometric characters of *C. reba* were in the intermediate category while those of *Hypophthalmichthys molitrics* from Gobindsagar had few intermediate characters. Quite a few of them had wide ranging body proportions (eye diameter, preorbital distance, post orbital distance and inter orbital distance) and thus plastic characters suitable for racial analysis. They maintain that in India only a few species have been subjected to such studies (Tandon et al. 1989).

Conclusions

All body measurements exhibited a linear pattern of growth. Snout length and least depth of caudal peduncle showed rapid linear increment in relation to total length of *B. bendelisis* and *B. vagra*. Length of maxillary barbel and rostral barbel showed rapid linear growth in relation to head length. Certain body ratios of male and female *B. bendelisis* and *B. vagra* differed but not significantly. Barring length of rostral barbel, the body depth, length of maxillary barbel, distance between pectoral and pelvic fin and length of caudal fin differed significantly ($P>0.05$) among *B. bendelisis* and *B. vagra* indicating definite demarcations in the morphology of *B. bendelisis* and *B. vagra*. On the basis of morphometric analysis, *B. bendelisis* with 54.5% of genetically controlled characters in males and 50% in females shows relatively wider distribution and greater tendency of subspeciation than *B. vagra* with 63.9% genetically controlled characters in males and 59.1% in females.

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