Journal of Applied and Natural Science
11(1): 107 - 115 (2019)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Analysis and interdependence of morphometric characters in the Hill stream fish *Mastacembelus armatus* (Lacepede) from Garhwal Himalaya

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Article Info
DOI:10.31018/jans.v11i1.1981
Received: January 4, 2019
Revised: February 5, 2019
Accepted: February 9, 2019

How to Cite
Rashid, M. *et al.* (2019). Analysis and interdependence of morphometric characters in the Hill stream fish *Mastacembelus armatus* (Lacepede) from Garhwal Himalaya. *Journal of Applied and Natural Science*, 11(1): 107 -115

Abstract
Study of morphometric characters is generally carried out for species identification in fish biology. It includes the measurements of all body lengths and their inter relationships in terms of ratios and percentages to the independent lengths (Total length, standard length and head length). Present paper deals with the analysis of various morphometric characters with species characteristics in *Mastacembelus armatus* (Lacepede), which is one of the most important eel like hillstream fish belonging to order Mastacembeliformes and family Mastacembelidae from river Western Nayar (29^0 45' to 30^0 15' latitude and 78^0 34' to 79^0 12' longitude). Total length, standard length and head lengths were considered as an independent variables in ratio of which other lengths (caudal length, pre orbital length, post orbital length, maximum body depth, snout length and eye diameter) were analysed. The maximum size of fish was observed as 60 cm and the minimum being 10 cm. By using regression and correlation analysis, the modelling of data is presented to find out their interrelationship. The closest correlation was in between total length and standard length (r= 0.999) and the farthest between total length and caudal length (r= 0.878). The linearity of regression was tested by the analysis of variance (ANOVA) which showed that all the relationships were significant at the level of 5 % significance. The multivariate analysis was also done by using cluster technique which sowed except caudal length rest all characters were forming a close cluster.

Keywords: ANOVA, Cluster analysis, Interrelationships, *M. armatus*, Morphometrics, Regression

INTRODUCTION

The analysis and interpretation of morphometric characters play an important role in the systematic of fish species. Speciation depends on intra specific variations which are mainly caused by the microhabitat, temperature, gradient and velocity of stream or the difference in their genetic combination. Day(1878) was the first authority in fish taxonomy who described the taxonomy of various fishes of India, Burma, Pakistan and Ceylone in his book, *"The fishes of India",* based on all these characters. Recently Talwar and Jhingran 1991) has described fish taxonomy of inland fishes of India in detail. From Uttarakhand Badola(1975, 2009) and Singh *et al.* (1987) has given a comprehensive description of fish fauna of River Ganga and its tributaries. Reports on morphometric characterization of fishes are available from the work of Singh and Dobriyal (1983), Dobriyal and Bahuguna (1987), Tandon *et al* (1993) , Pandey and Nautiyal (1997), Bhatt *et al* (1998), Arunkumar (2000), Dobriyal *et al* (1988,2004,2006), Johal and Kaur (2005), Uniyal *et al*(2004,2005), Dobriyal (2001,2013), and Kumar and Singh (2018). However, detail taxonomic analysis of *Mastacembelus armatus* from Garhwal Himalaya has not been done so far, hence the present investigation was carried out.

MATERIALS AND METHODS

The fish, *M. armatus* were monthly collected from river Western Nayar and preserved on the spot in 5 to 7% formalin. The morphometric data were taken within a fortnight of collection and after tagging the fish they were preserved for further investigations.

Morphometrics: Parameters considered for morphometrics study were the total length, standard length, head length, caudal length, snout length, eye diameter, maximum body depth, pre orbital length and post orbital length. These variables were studied in relation to total length, standard length and the head length separately.

Measurements of morphometric characters: Sharp pointed needle like dividers were used for taking body measurements. For accurate readings, a stainless steel ruler with measurement in mm and an electronic digital balance which weight up to nearest 0.001gm were used. Different lengths (cm) were measured as described below:

Total length (TL): The distance between the most interior projecting parts of the head to the posterior– most tip of the caudal fin, including filamentous prolongations.

Standard length (SL): The straight distance from the anterior most part of the head to the end of the vertebral column.

Head length (HL): A straight measurement of the distance from the tip of the snout to the most distance point on the bony edge of the opercular membrane on the upper angle of the gill opening.

Eye diameter (ED): The distance between the bony margins of the cartilaginous eye balls across their corners.

Snout length (Snt.L): The distance from the most anterior mid point on the snout or upper lip to the front hard margin of the orbit.

Maximum Body depth (MBD): The vertical measurements from a point in the body of the fish on its back where its height is greatest to a straight line to the ventral surface.

Post-orbital length (Po.OL): The great distance from the posterior edge of orbit to the posterior tip of the fleshy operculum.

Pre orbital length (Pre OL): The great distance from the posterior edge of orbit to the anterior tip of the snout.

Caudal length (CL): From the base of caudal rays to the caudal tip.

Regression analysis: The original data were grouped into class intervals and the average values for the dependent (Y) and the independent variables (X) were calculated. These values then fed into Microsoft excel 2007 for computing the values of coefficient of determination (r^2), correlation coefficient (r) and regression coefficient (b) along with intercept (a). The relationships determined by fitting into the following straight-line equation:

$$Y = a + b.X \quad \text{.......Eq. 1}$$

Where, Y= dependent variables, X = independent variables and a and b are the constants intercept and the slope respectively. The linearity of the regression was tested by the analysis of variance (F Test).

The growth of different body parts were studied in ratio of 3 independent variables separately, total length, standard length and head length. The multivariate analysis was done between different morphometric characters using cluster technique based on correlation similarity.

RESULTS AND DISCUSSION

On the basis of the collection of 35 fish specimens during 2014 and 2015 and as there was no differ-

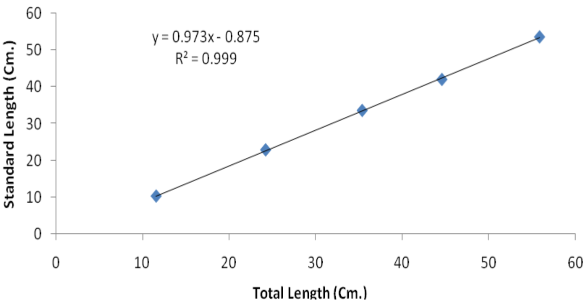

Fig.1. *Regression between total length and standard length of M.armatus.*

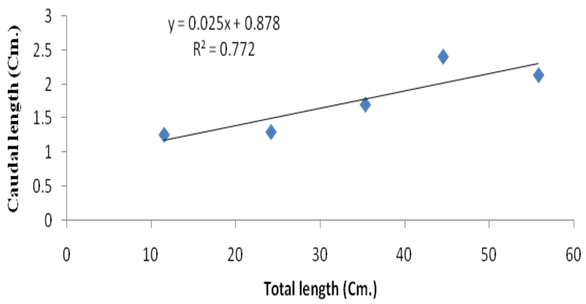

Fig.2. *Regression between total length and caudal length of M.armatus*

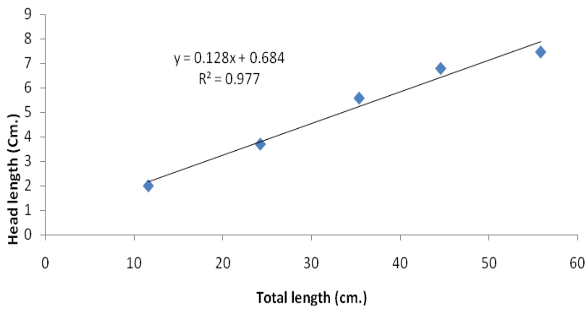

Fig.3. *Regression between total length and head length of M.armatus.*

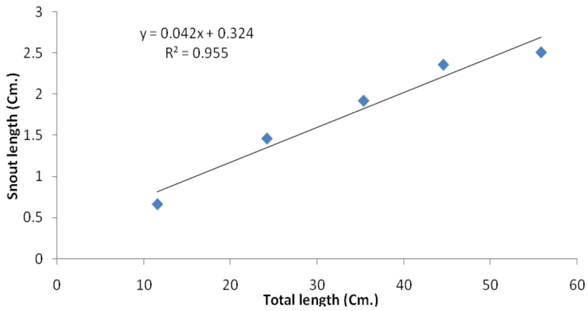

Fig.4. *Regression between total length and snout length of M.armatus.*

Table 1. Summarized data on morphometrics of *M. armatus* (Lacepede) collected during 2014-15 from Western Nayar River.

S.N.	Length Group (cm)	TL	SL	CL	HL	SnL	ED	Pre.OL	Post. ol	MBD
1	10-20	11.56 ±1.34	10.3 ±1.03	1.26 ±032	2.0 ±0.78	0.66 ±0.15	0.28 ±0.02	0.9 ±0.34	1.1 ±0.43	1.23 ±0.11
2	20-30	24.2 ±0.2	22.9 ±0.2	1.3 ±0.2	3.7 ±0.20	1.46 ±0.11	0.33 ±0.05	1.66 ±0.05	2.13 ±0.15	2.1 ±0.1
3	30-40	35.35 ±2.69	33.64 ±2.50	1.70 ±0.47	5.58 ±0.46	1.92 ±0.11	0.43 ±0.06	2.35 ±0.13	3.22 ±0.36	2.83 ±0.19
4	40-50	44.55 ±3.15	42.1 ±2.97	2.4 ±0.32	6.79 ±0.42	2.36 ±0.14	0.50 ±0.05	2.71 ±0.28	3.98 ±0.315	3.60 ±0.46
5	50-60	55.83 ±2.31	53.7 ±2.14	2.13 ± 0.28	7.46 ±0.24	2.51 ±0.07	0.55 ±0.05	2.75 ±0.35	4.55 ±0.17	4.41 ±0.41

TL (total length), SL (standard length), CL (caudal length), HL (head length), SnL (snout length), ED (eye diameter), PreOL (pre orbital length), Post OL (post orbital length), MBD (maximum body depth)

Table 2. Summarized data on growth of body parts in ratio of total length in *M. armatus* (Lacepede).

S.N.	Length Group (cm)	SL	CL	HL	SnL	ED	Pre.OL	Post. ol	BD
1	10-20	0.88 ±0.015	0.10 ±0.01	0.16 ±0.04	0.05 ±0.007	0.024 ±0.0005	0.34 ±0.47	0.08 ±0.02	0.10 ±0.005
2	20-30	0.94 ±0.01	0.05 ±0.01	0.15 ±0.01	0.05 ±0.005	0.01 ±0	0.06 ±0.005	0.32 ±0.41	0.08 ±0.005
3	30-40	0.94 ±0.01	0.04 ±0.01	0.15 ±0.004	0.13 ±0.18	0.009 ±0.0003	0.06 ±0.003	0.08 ±0.005	0.07 ±0.005
4	40-50	0.94 ±0.007	0.05 ±0.005	0.14 ±0.006	0.04 ±0.002	0.009 ±0.0002	0.05 ±0.004	0.08 ±0.005	0.07 ±0.01
5	50-60	0.95 ±0.005	0.03 ±0.005	0.13 ±0	0.04 ±0	0.009 ±0.009	0.04 ±0.005	0.07 ±0.007	0.07 ±0.005
	Overall average	0.93 ±0.03	0.06 ±0.03	0.15 ±0.01	0.07 ±0.04	0.01 ±0.01	0.11 ±0.13	0.13 ±0.11	0.08 ±0.01

Table 3. Summarized data on Growth of Body parts in ratio of Stadard length in *M. armatus* (Lacepede).

S.N.	Length Group (cm)	CL	HL	Snt.L	ED	Pre.O.L	Post. O.L	BD
1	10-20	0.11 ±0.02	0.18 ±0.05	0.06 ±0.01	0.02 ±0	0.08 ±0.02	0.09 ±0.03	0.11 ±0.005
2	20-30	0.05 ±0.01	0.16 ±0.01	0.06 ±0	0.01 ±0	0.06 ±0.005	0.08 ±0.005	0.08 ±0.005
3	30-40	0.04 ±0.01	0.16 ±0.007	0.05 ±0.004	0.009 ±0.0003	0.06 ±0.005	0.08 ±0.025	0.07 ±0.003
4	40-50	0.05 ±0.006	0.15 ±0.006	0.04 ±0.002	0.01 ±0.02	0.05 ±0.005	0.08 ±0.003	0.08 ±0.008
5	50-60	0.03 ±0.005	0.13 ±0.004	0.04 ±0	0.009 ±0.0005	0.04 ±0.005	0.08 ±0.006	0.07 ±0.008
	Overall Average	0.05 ±0.03	0.15 ±0.01	0.05 ±0.008	0.01 ±0.004	0.06 ±0.01	0.08 ±0.006	0.08 ±0.01

Table 4. Summarized data on Growth of Body parts in ratio of Head length in *M. armatus* (Lacepede).

S.N.	Length Group (cm)	SnL	ED	Pre.OL	Post. ol	BD
1	10-20	0.35±0.08	0.15±0.05	0.44±0.005	0.54±0.011	0.68±0.271
2	20-30	0.38±0.04	0.08±0.01	0.43±0.015	0.56±0.01	0.55±0.02
3	30-40	0.34±0.01	0.07±0.008	0.42±0.02	0.57±0.02	0.5±0.01
4	40-50	0.34±0.01	0.07±0.008	0.39±0.029	0.58±0.01	0.52±0.05
5	50-60	0.33±0.005	0.06±0.007	0.36±0.04	0.60±0.02	0.57±0.05
	Overall average	0.35±0.02	0.09±0.04	0.41±0.03	0.57±0.02	0.57±0.07

ence on the basis of sex, the overall pooled data was considered and divided into 5 groups (Table 1).

The maximum size group was 50-60 cm in which largest fish measuring 60 cm was recorded, the average being 55.83 ± 2.31 cm. The minimum length group was 10- 20 cm, the average being 11.56 ± 1.34 cm. Body was elongated eel like with stronger upper jaw and pointed snout. Pre dorsal spine commenced over the pectoral fin which

Table 5. Statistical modelling of interrelationships between Total length and other body lengths in *M. armatus* (Lacepede).

S.N.	Body Relationships	Intercept 'a'	Regression coefficient (Slope) 'b'	Coefficient of Correlation 'r'	Coefficient of Determination 'r^2'
1	TL / SL	- 0.875	0.973	0.999	0.999
2	TL / CL	0.878	0.025	0.878	0.772
3	TL / HL	0.684	0.128	0.988	0.977
4	TL / SntL	0.324	0.042	0.977	0.955
5	TL / ED	0.195	0.006	0.99	0.981
6	TL / PreorbL	0.566	0.043	0.96	0.922
7	TL / PostorbL	0.236	0.08	0.994	0.989
8	TL / MBD	0.362	0.072	0.998	0.998

Table 6. Statistical modelling of interrelationships between standard length and other body lengths in *M. armatus* (Lacepede).

S.N.	Body Relationships	Intercept 'a'	Regression coefficient (Slope) 'b'	Coefficient of Correlation 'r'	Coefficient of Etermination 'r^2'
1	SL / CL	0.909	0.026	0.871	0.759
2	SL / HL	0.807	0.132	0.986	0.974
3	SL / SntL	0.364	0.043	0.976	0.953
4	SL / ED	0.201	0.006	0.988	0.978
5	SL / PreorbL	0.609	0.045	0.958	0.919
6	SL / PostorbL	0.312	0.082	0.993	0.987
7	SL / MBD	0.428	0.074	0.998	0.997

Table 7. Statistical modelling of interrelationships between head length and other body lengths in *M. armatus* (Lacepede).

S.N.	Body Relationships	Intercept 'a'	Regression coefficient (Slope) 'b'	Coefficient of Correlation 'r'	Coefficient of Determination 'r^2'
1	HL / SntL	0.093	0.330	0.992	0.985
2	HL / ED	0.163	0.049	0.99	0.981
3	HL / PreorbL	0.301	0.347	0.98	0.98
4	HL / PostorbL	0.166	0.619	0.998	0.997
5	HL / MBD	0.054	0.544	0.984	0.969

Table 8. ANOVA between TL and other dependent different body parameters in *M armatus.*

TL and SL	Sum of sqrs	Df	Mean square	F	P	Critical value $F_{0.05}$
Between groups:	66.2516	1	66.2516	0.434	0.5123	4.0
Within groups	10380.8	68	152.659			
TL and HL						
Between groups:	19252.7	1	19252.7	240.9	4.878E-24	4.0
Within groups	5434.73	68	79.9225			
TL and Snt L						
Between groups:	23950.1	1	23950.1	304.2	8.447E-27	4.0
Within groups	5354.3	68	78.7397			
TL and CL						
Between groups:	24061.2	1	24061.2	305.6	7.429E-27	4.0
Within groups	5354.43	68	78.7417			
TL and ED						
Between groups:	26029.9	1	26029.9	331.2	7.748E-28	4.0
Within groups	5344.75	68	78.5993			
TL and Pre OL						
Between groups:	23522.9	1	23522.9	298.6	1.411E-26	4.0
Within groups	5356.65	68	78.7742			
TL and Post OL						
Between groups:	22164.6	1	22164.6	280.1	8.243E-26	4.0
Within groups	5380.43	68	79.1239			
TL and MBD						
Between groups:	22518.3	1	22518.3	284.9	5.167E-26	4.0
Within groups	5374.21	68	79.0326			

Table 9. ANOVA between SL and other dependent different body parameters in *M armatus.*

SL and HL	Sum of sqrs	df	Mean square	F	P	Critical value $F_{0.05}$
Between groups:	3317.54	1	3317.54	11.51	0.001159	4.0
Within groups	19605.3	68	288.313			
SL and Snt L						
Between groups:	21497	1	21497	289.7	3.273E-26	4.0
Within groups	5046.27	68	74.2099			
SL and CL						
Between groups:	21602.3	1	21602.3	291.1	2.862E-26	4.0
Within groups	5046.4	68	74.2118			
SL and ED						
Between groups:	23469.8	1	23469.8	316.9	2.691E-27	4.0
Within groups	5036.72	68	74.0694			
SL and Pre OL						
Between groups:	21092.4	1	21092.4	284.1	5.599E-26	4.0
Within groups	5048.62	68	5048.62			
SL and Post OL						
Between groups:	19807.2	1	19807.2	265.5	3.553E-25	4.0
Within groups	5072.4	68	74.5941			
SL and MBD						
Between groups:	20141.7	1	20141.7	270.3	2.179E-25	4.0
Within groups	5066.18	68	74.5027			

Table 10. ANOVA between HL and other dependent different body parameters in *M armatus.*

HL and Snt L	Sum of sqrs	df	Mean square	F	P	Critical value $F_{0.05}$
Between groups:	256.132	1	256.132	173.9	2.079E-20	4.0
Within groups	100.181	68	1.47325			
HL and CL						
Between groups:	267.737	1	267.737	181.5	7.18E-21	4.0
Within groups	100.313	68	1.47518			
HL and ED						
Between groups:	510.03	1	510.03	382.7	1.236E-29	4.0
Within groups	90.6281	68	1.33277			
HL and PreOL						
Between groups:	213.676	1	213.676	141.7	2.729E-18	4.0
Within groups	102.527	68	1.50776			
HL and Post OL						
Between groups:	102.487	1	102.487	55.18	2.391E-10	4.0
Within groups	126.307	68	1.85746			
HL and MBD						
Between groups:	127.845	1	127.845	72.39	2.619E-12	4.0
Within groups	120.093	68	1.76607			

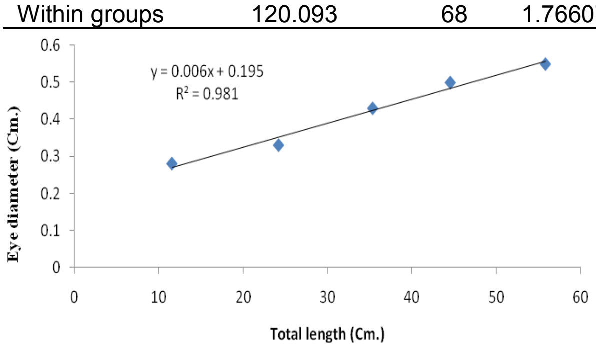

Fig.5. *Regression between total length and Eye diameter of M. armatus.*

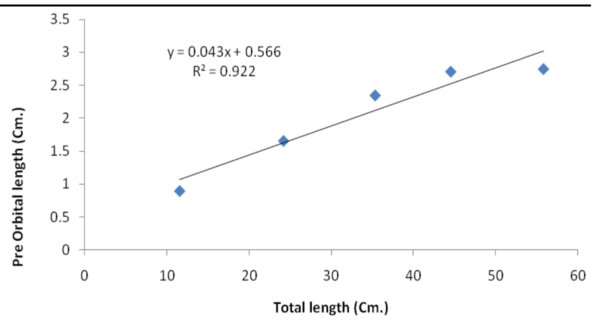

Fig.6. *Regression between total length and Pre-orbital length of M. armatus.*

were 35-37 in numbers. Dorsal fin was present in nearly last 1/3rd part of the body with about 76-86 fin rays. Pelvic and anal fin was nearly fused with the caudal.

In present study no any significant character is found which can be related to sexual dimorphism.

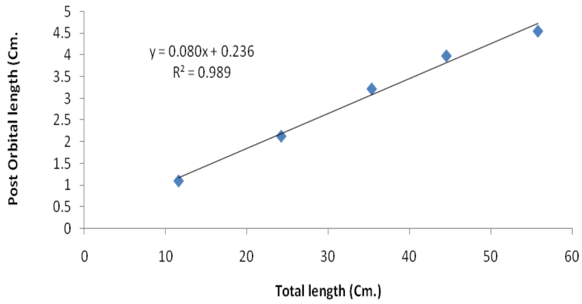

Fig.7. *Regression between total length and Post-orbital length of M.armatus.*

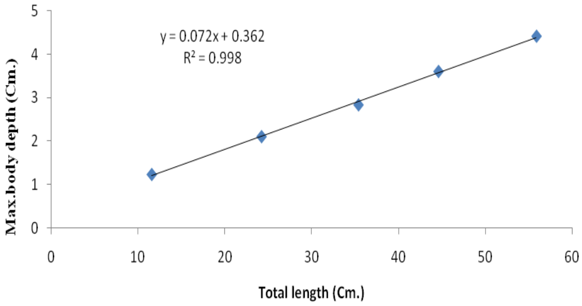

Fig.8. *Regression between total length and maximum body depth of M.armatus.*

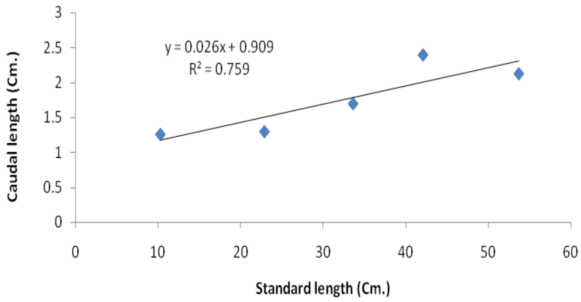

Fig.9. *Regression between standard length and Caudal length of M.armatus.*

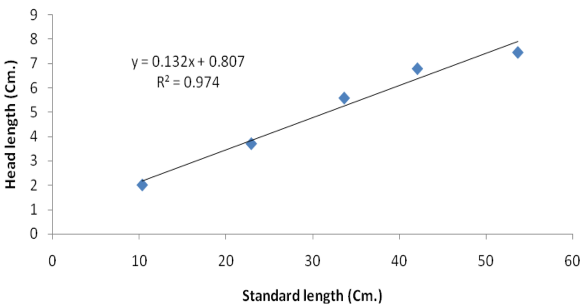

Fig.10. *Regression between Standard length and Head length of M.armatus.*

Generally several authors have reported sexual dimorphism on the basis of morphometric analysis. Oliva (1952) observed greater length of the adult male pectoral fin in*Noemacheilusbarbitula*. Tubercles in snout of mature males were sometime observed in the present study, which were also recorded by Desai (1973) in *Tor tor* from Narbada river. Badola *et al*. (1982) reported sexual

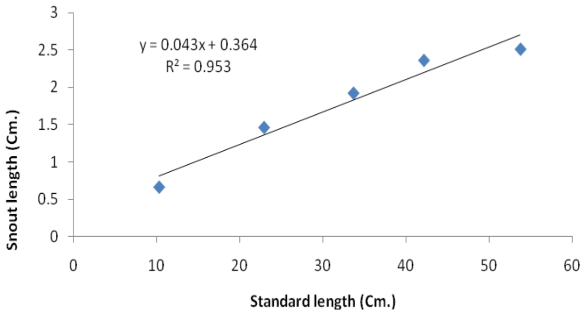

Fig.11. *Regression between Standard length and snout length of M.armatus.*

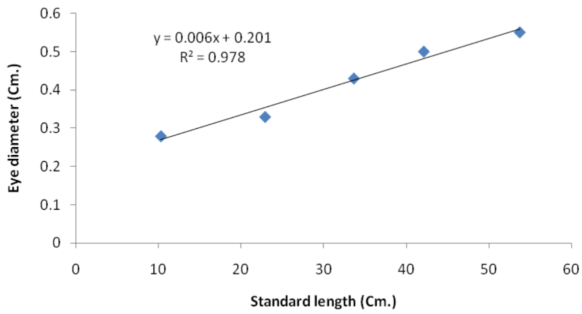

Fig.12. *Regression between Standard length and Eye diameter of M.armatus.*

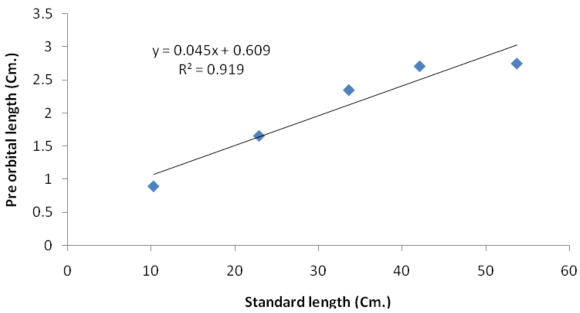

Fig.13. *Regression between Standard length and Pre-orbital length of M.armatus.*

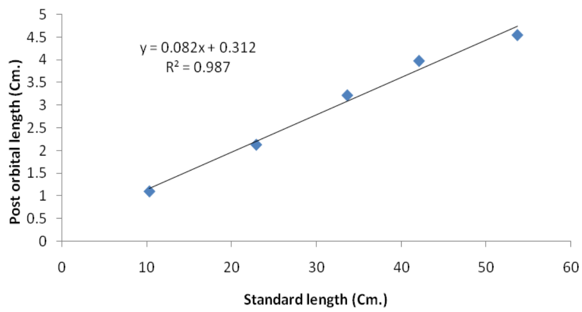

Fig.14. *Regression between Standard length and Post –orbital length of M.armatus.*

dimorphism in *Barilius bendelisis* and Dobriyal *et al*. (2007) in *Puntius conchonius*.

The growth of different body parameters were assessed in relation to 3 different independent variables, viz., total length (Table 2), standard length (Table 3) and head length (Table 4). Overall ratio between TL and SL was 1 : 0.93 ± 0.03. It was observed that the minimum differed ratio was

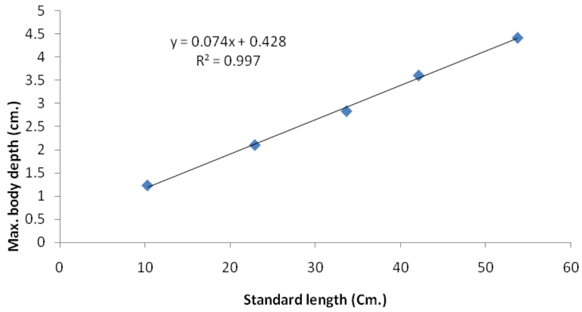

Fig.15. *Regression between Standard length and Maximum body length of M.armatus.*

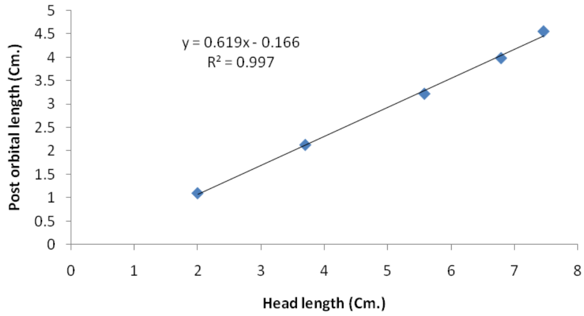

Fig.19. *Regression between Head length and Post-orbital length of M.armatus.*

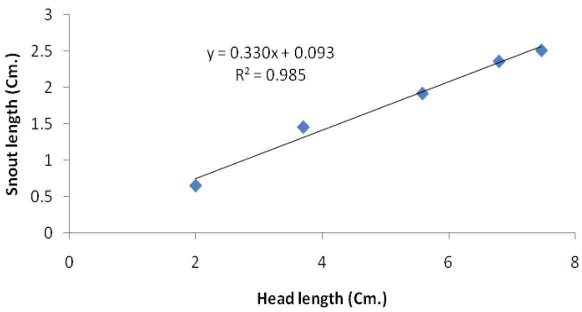

Fig.16. *Regression between Standard length and Snout length of M.armatus.*

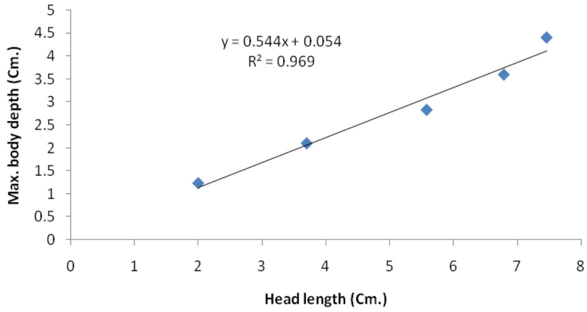

Fig.20. *Regression between Head length and Maximum body length of M.armatus.*

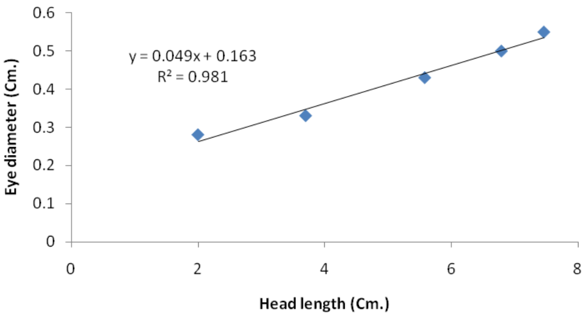

Fig.17. *Regression between Head length and Eye diameter of M.armatus.*

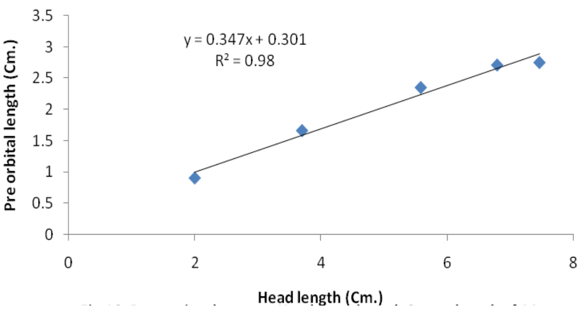

Fig.18. *Regression between Head length and Pre-orbital length of M.armatus.*

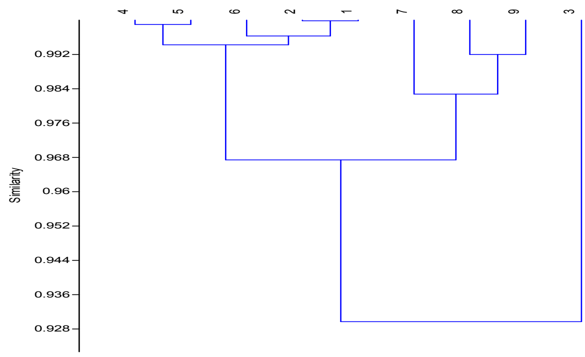

Fig. 21. *Cluster analysis between different morphometric characters based on correlation similarity in M. armatus.*

in smallest size group 10-20 cm (0.88 ± 0.015) which continuously increased up to the maximum size group 50-60 cm (0.95 ±0.005). The average ratio between TL and CL was 1 : 0.06± 0.03, the minimum being 0.03 ±0.005 in 50-60 cm group and maximum being 0.1 ±0.01 in 10-20 cm size group. Average ratio between TL and HL was 1 : 0.15 ± 0.01. The average ratio between TL and Sn L (1: 0.07 ±0.04), TL and Eye diameter (1 : 0.01 ±0.001), TL and Pre orbital length (1: 0.11 ±0.13), TL and Post orb.L (1 : 0.13 ±0.11) and TL and Maximum Body depth (1 : 0.08 ± 0.01) also showed similar pattern of variation. It was noticed that all body parts grow in accordance to total length of body. This observation is almost similar to earlier description given for *M. armatus* by Day (1887) and Badola (2009).

When growth pattern of different body parts in terms of ratio to Standard length was studied, it was observed that the largest ratio was with head length (1 : 0.15 ± 0.008), followed in decreasing order with post orbital and maximum body depth (1:0.08 ±0.006, 1: 0.08 ±0.08), pre orbital length (1 : 0.06 ±0.01), caudal length (1 : 0.05 ±0.01) and snout length (1 : 0.06±0.03). Growth pattern of body parts in ratio of HL is presented in Table 4 which indicated that the largest ratio of HL was with Post OL (1 : 0.57 ±0.02) and MBD (1: 0.57 ±0.07). With Pre OL it had a ratio of 1:0.41 ±0.03) and with ED and Snt L 1: 0.09 ±0.04 and 1: 0.35 ±0.02 respectively.

To show the relationship between TL and related dependent parameters regression analysis was performed and modelling of data was done (Table 5) and Figs 1-8. Closest relationship was observed between TL and SL (r = 0.999) followed in decreasing order with MBD (r = 0.998), Post OL) (r = 0.994), ED (r = 0.990) HL (r = 0.988), Snt L (r = 0.977), Pre OL (r = 0.960) and CL (r = 0.987).

Relationship between SL and related dependent parameters were also analysed by regression analysis (Table 6 and Figs 9-14). The Closest relationship was observed between TL and MBD (r = 0.998) followed in decreasing order with Post OL (r = 0.993), ED(r = 0.988), HL(r = 0.986) Snt L (r = 0.976), Pre OL (r = 0.958), and CL (r = 0.871).Regression analysis between HL and dependent parameters is shown in Table 7and graphically presented in Figs 15-20. The Closest relationship was observed between HL and Post OL (r = 0.998) followed in decreasing order with Snt L (r = 0.992), ED(r = 0.99), MBD (r = 0.984) and Pre OL (r = 0.98).

The linearity of regression between TL and its dependent parameters is tested by the ANOVA (Table 8) which indicated that variation was significant at 5 % level of significance (Critical value $F_{0.05}$ = 4.0) between TL and HL (F= 240.9), TL and Snt L (F= 304.2), TL and CL (F= 305.6), TL and ED (F= 331.2), TL and PreOL (F= 298.6), TL and Post OL (F= 280.1) and TL and MBD (F= 284.9). Lowest significant value was obtained between TL and SL (F= 4.34).Almost similar results were obtained when linearity was tested with Standard length (Table 9) and Head length (Table 10) as independent variables with dependent body parameters. Standard length had closest significance difference with HL (F= 11.51; Critical value $F_{0.05}$ = 4.0). Rest other relationships were strongly significant difference (SL/ Snt L- F= 289.7, SL/ C L- F= 291.1,SL/ ED- F= 316.9,SL/ Pre OL- F= 284.1, SL/ Post OL- F= 265.5 and SL/ MBD- F= 181.5). Relationship of HL and dependent parameters was also highly significant (HL/ Snt L- F= 173.9, HL/ C L- F= 181.5,HL/ ED- F= 382.7,HL/ Pre OL- F= 141.7, HL/ Post OL- F= 55.18 and HL/ MBD- F= 72.39).

Present study on racial analysis concludes that there was only one stock of *M. armatus* in the river Western Nayar. Similar homogeneity in population stock was reported by Jones (1954) for *Hilsa ilisha* in river Hooghly, Sarojini (1957) for *Mugil parsia* in Bengal waters, Lal and Dwivedi (1969) in *Rita rita* from Varanasi, Singh and Dobriyal (1983) in *Pseudecheneis sulcatus* from river Alaknanda and Dobriyal and Bahuguna (1987) in *Noemacheilus montanus* from Khanda gad stream.

Multivariate analysis for morphometric characters is explained in depth by Mojekwu and Anumudu (2015) by using univariate, bivariate and multivariate technique. In the present study it was performed using cluster analysis technique with correlation similarity (Fig 21).

It showed that primary cluster was made between TL and SL, SntL and HL, Post OL and ED. The secondary cluster was made between TL-SL and ED, Post OL-ED and Pre OL. The tertiary cluster was made by TL-SL-ED and HL-Snt. The quaternary cluster was made by TL-SL-ED -HL-Snt and ED, Post OL-ED and Pre OL. Top level cluster was made between Caudal length and rest all other parameters. Such studies were also done by Ujjania and Kohli (2011) in *Catla catla* , Mir *et al* (2013) in *Labao rohita,* Hossen *et al*. (2016), Nawer *et al*. (2017) in *Pethia ticto* and Azad *et al*. (2018) in *Glossogobius giuris*.

Conclusion

Present study on the morphometric characterization of the hillstream fish *M. armatus* (Lacepede) from river Western Nayar, Uttarakhand concludes that all body parts of the fish grow in accordance with total length of the body. There is a single population stock and no sexual dimorphism. The conclusion is based on regression analysis, analysis of variance and multivariate cluster analysis.

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