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Mouth morphometry and body lengths with respect to the feeding habits of Hill stream fishes from Western Himalaya H.P. (India)

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Abstract
The hill stream fishes *viz*. *Barilius bendelisis* (Hamliton), *Crossocheilus latius latius* (Hamliton), *Garra gotyla gotyla* (Gray), *Pethia ticto* (Hamliton), *Schizothorax richardsonii* (Gray) and *Mastacembelus armatus* (Lecepede) collected from the streams of the Beas Drainage system (Himachal Pradesh) have been selected for the studies. The inter-relationship between mouth dimensions and relationship between mouth size dimensions & different body length *i.e*. HL and TL have been undertaken. Further, the mouth modification with respect to food and feeding habits has been explored which is helpful in understanding the trophic level of the fishes. During the studies it has been analysed that in case of *B. bendelisis* VG was almost equal to HG as such belong to the category of surface feeder- omnivore. *M. armatus* and *P. ticto* exhibited VG greater than HG and adopted for column-omnivore/carnivore feeding habit whereas in *G. gotyla gotyla, S. richardsonii* and *C. latius latius* HG was greater than VG and adopted for bottom-herbivore habit. The analytical techniques of statistics were used to analyse and interpret the results by using SPSS-16.0 software.

Keywords: Hill stream, Morphometry, Trophic, Analytical

1. Introduction

Fishes are the one of the most fascinating and remarkable animal form, that dominates water of the world through a marvellous variety of morphological, physiological and behavioural adaptations. The fresh water sources like rivers, canals, springs have different type of fish species owing to different habitats; as such they have developed and adapted for different types of food and feeding habits (herbivorous, carnivorous or omnivorous). It is well assumed that morphological differences in animals are due to the action of several environmental and biological factors which are related to feeding and other physiological activities of fish species. The various aspects of mouth morphometry like variation in shape and size of the feeding apparatus; mouth shape and position, teeth, structure and number of gill rakers related to the type of food being consumed; sympatric niche separation connected with morphological divergence; ontogenetic changes related to mouth; studies of mouth gape for the evaluation of the relationship between prey and predator size have been undertaken by some workers[1-19].

The Hilly State Himachal Pradesh is located in the Western Himalayas. It is traversed by five major river drainages *viz.* Satluj, Beas, Ravi, Chander Bhaga and Yamuna. The water of the state is endowed with rich fish diversity and 104 fish species have been recorded from the state [20]. Here, not only main river lines but small shallow rivers also provide refuge to large number of fish populations and are also facing major habitat alteration due to anthropogenic stresses. The fishes inhabit in unique ecological conditions, as such they are usually deprived of optimum feeding since with the course of time they have developed numerous morphological adaptations that are highly suitable for feeding in their living habitat. Keeping in view the importance of the mouth morphometry in relation to body parameters, the studies have been conducted. During the present studies six economically important fishes from the Beas Drainage System (Himachal Pradesh) has been selected. The studies will explore the morphological adaptations associated with their feeding (Omnivorous, Herbivorous and Carnivorous) and habitat preferences (surface, column or bottom dweller). The study is a new approach for hill stream fishes and would be helpful for their conservation and management.

2. Material and Method

Random sampling has been done at different sites (*i.e*., tributaries and sub-tributaries of river Beas) preferably at mid day hours, during the year 2011 and 2012 (Table-1). Specimens were retrieved using diverse gears like hooks and lines, cast net, hand net and some local fishing traps and were identified morphologically to lowest taxonomic level following standard references [22-24]. All the collected samples adhere to fish base and were preserved in 10% formalin until further subjected for detailed analysis. Various measurements such as horizontal mouth gape (HG), vertical mouth gape (VG), mouth area (MA), total length (TL), standard length (SL), fork length (FL), head length (HL), head width (HW), snout length (LS), eye diameter (ED), inter orbital diameter (IOD), body depth (BD), mouth width (MW), dorsal fin length (DFL), pelvic fin length (PFL), pectoral fin length (VFL), anal fin length (AFL) and caudal fin length (CFL) were measured with Vernieer calliper (Mitutoyo, nearest to 0.1 millimetres, mm) as per the criteria of Jayaram [23] and intact body weights (including gut and gonad weight) were measured by using digital electronic balance (0.1g). In order to find out the feeding habit (herbivore, carnivore and omnivore) the gut contents of fish has been analysed qualitatively and quantitatively by following the standard methods [26-28]. Fish mouth area has been calculated by following the ellipse model [29] as MA= 0.25 π (VG x HG), where: MA [mm^2] is the ellipse area (Mouth Area), VG [mm] and HG [mm] is the vertical and horizontal mouth gapes respectively. Inter-relationship between fish mouth dimensions were estimated by the following the equation as; (VG, HG) = *a* + *b* (HG, MA), while relationship between mouth size and different body length *viz*., HL and TL were estimated by applying equation: (VG, HG, MA, LS) = *a* + *b* (TL, HL), where: 'a' is the intercept and 'b' is the slope of the linear regression. The slope 'b' and correlation 'r' were calculated to access the unit growth rate and degree of association among different body parameters with their respective mouth dimensions, TL and HL respectively. Various body dimensions, intact body weight (BWT *i.e*. including both gut and gonad weight), gut weight (GWT), and gut length (GL) were also accessed for the regression statistics. The analytical techniques of statistics were used to analyse and interpret the results by using SPSS-16.0 software

Table 1: Fish collection sites at different sub-tributaries of River Beas.

Tributary	Sub-tributaries	Latitude (φ)	Longitude (λ)
Mole	Tanda	32.088083	76.537204
	Rajpur	32.081429	76.533777
Neugal	Bhatuu	32.084184	76.493876
	BheduMahadev	31.970149	76.463290
	Nagni	31.979104	76.46705
Binwa	Chobhu Choobin	31.97277	76.676545
	Senthi	31.949031	76.693733

3. Results and Discussion

During the present investigation the association of morphological adaptations with their food or feeding habits (herbivore, carnivore or omnivore) and habitat preferences (surface, column or bottom dweller) has been conducted. Descriptive statistics of the fishes has been summarized in Table-2. Morphologically, it has been observed that cylindrical or approximately cylindrical body form of *Schizothorax richardsonii* (Gray) & *Mastacembelus armatus* (Lacepede) helped to brows well under fast water currents and *Pethia ticto* (Hamilton) & *Barilius bendelisis* (Hamilton) have suitable body shape and size (laterally compressed and small) for fast swimming and jumping over water surfaces. The body form of *Garra gotyla gotyla* (Gray) and *Crossocheilus latius latius* (Hamilton) is sub-cylindrical with small dorso-ventrally flattened (compressed) head suitable to inhabit in the fast water currents. Further, formation of adhesive or suctorial mouth parts helps in scraping the organic food from rocky substratum. The details of mouth and body adaptations in relation to feeding habit are summarized in Table-3 and food & feeding habit has been represented graphically (Fig.-1 to 6). The presence of anterior or terminal mouth in *B. bendelisis* (Hamilton) and long protruding snout of *M. armatus* (Lacepede) helps them to capture prey (Plate-1 and 6). In *C. latius latius* (Hamilton), *G. gotyla* gotyla (Gray) and *S. richardsonii* (Gray) the mouth is well modified to adapt bottom feeding habits. The upper lip of *C. latius latius* (Hamilton) is well developed into papillated free margin which helps in feeding (Plate-2). Further, the ventral or transverse, suctorial mouth of *G. gotyla gotyla* (Gray) consists of well modified upper and lower lips and in *S. richardsonii* (Gray) the inferior transverse mouth consists of hard cartilaginous covering in the lower jaw. Both fishes are well adapted for bottom dwelling and bottom feeding habits however *S. richardsonii* (Gray) feeds and browses well in water columns also (Plate-3 and 5). The presence of small head in *P. ticto* (Hamilton) makes suitable to it for inhabiting well near the marginal areas as well as water columns of rivers or ponds and the equal sized jaws of this fish also help in column feeding habits (Plate-4). Though, the earlier workers[30-31] has categorized fishes on the basis of habitat as surface dwellers, column dwellers and bottom dwellers. However, there is not clear cut demarcation for these categorise because there are many gradations depending upon the individual need for safety, food and reproduction, water quality parameters, weather conditions, diurnal and seasonal cycles.

The various food items have been identified from the respective gut of each species. The plant or animal based diets has been categorized both qualitatively and quantitatively. The presences of semi-digested/miscellaneous items (others) are also taken into account. Herbivorous fish like *C. latius latius* (Hamilton), *G. gotyla gotyla* (Gray) and *S. richardsonii* (Gray) exhibited higher percentage of plant based diets *viz*. Bacillariophyceae and Chlorophyceae mainly. On the other hand, fishes like *B. bendelisis* (Hamilton) and *P. ticto* (Hamilton) though displayed the presence of both animal and plant based diets. In *B. bendelisis* (Hamilton)-green algae and insects, *P. ticto* (Hamilton)- diatoms and green algae and *M. armatus* (Lacepede)- insects were abundantly found. Table-4 to 9 displays the statistical analysis of morphological relationships of the hill stream fishes. The different body lengths and mouth area have been estimated by evaluating the values of regression coefficients 'a' and 'b'. The value of 'b' (slope) represents unit increment in mouth area due to respective mouth dimensions or body length of different fish. The liability of the regression equation is accessed by the scrutiny of correlation coefficients 'r' at 0.01% level of significance ($p<0.01$).

Furthermore, the value of R^2 explained the percentage of variations with the respective body or mouth dimensions. Given to this, the standardized regression coefficients have also been accessed to check the impact of changing the explanatory variables by one standard deviation. The estimated linear relations between the mouth size dimensions and body lengths is tested for significance at 0.05% *i.e.* $p<0.05$. In *B. bendelisis* (Hamilton), a unit increase in VG resulted in -1001 and 0.202 mm growth in HG and MA respectively, likewise with HG, about 0.117 mm growth is observed in MA of fish. High degree of positive correlation ($p<0.01$) is observed among different mouth dimensions *i.e.* VG– HG 0.842, VG – MA 0.938; HG– MA 0.973; HL –VG 0.728, HL– HG 0.746, HL– MA0.769) and explained about=70.8%, 87.9%, 94.6%, 52.9%, 55.6% and 59.1% of the variation with their respective mouth dimension. Previous studies have pointed out that inter population variation in mouth morphology is usually correlated with differences in the availability of resources either through with other species or by geo-graphical differences in ecological conditions such as water temperature, salinity and food supply [32, 33]. Similarly conclusions have been drawn for other corporal structures and even for the body shape.

Table 2: Descriptive Statistics of six fill stream fishes

		N	R	Min	Max	X±SE	SD	V
1	TL	60	64.31	65.87	130.18	95.65±2.30	17.85	318.80
	BWT		26.88	3.56	30.44	11.64±.81	6.23	39.39
2	TL	47	88.34	53.43	141.77	98.93±3.84	26.33	693.77
	BWT		36.50	1.50	38.00	14.52±1.56	10.75	115.59
3	TL	40	77.07	83.10	160.17	1.160±3.02	19.14	366.50
	BWT		43.74	7.26	51.00	20.59±1.61	10.22	104.45
4	TL	60	31.13	41.60	72.73	52.91±0.96	7.47	55.83
	BWT		0.31	0.04	0.35	0.12±0.07	0.05	0.003
5	TL	60	204.02	87.71	291.73	1.65±7.72	59.82	3.57
	BWT		248.29	6.15	254.44	57.32±8.06	62.48	3.90
6	TL	35	237.89	72.66	310.55	1.95±11.90	70.45	4.96
	BWT		63.45	.83	64.28	24.94±3.28	19.42	377.33

1. *Barilius bendelisis* (Hamilton) 2. *Crossocheilus latius latius* (Gray) 3. *Garra gotyla gotyla* (Gray) 4. *Pethia ticto* (Hamilton) 5. *Schizothorax richardsonii* (Gray) 6. *Mastacembelus armatus* (Lacepede); N=No of Fish, R=Range, Min=Minimum, Max=Maximum, X±SE, Mean± Standard error SD=Std. Deviation, V=Variance

Table 3: Mouth and body adaptation in relation to feeding habit and habitat

	Mouth and body adaptations	Habitat preference	Feeding habit
1	Elongated, deep to shallow body, moderately and sharply pointed head. Mouth anterior, oblique, thin lips and hard jaws are present. (Plate-1)	Clear shallow or deep waters with pebbly and rocky bottoms and surface dwelling	Surface feeder omnivore
2	Elongated sub-cylindrical body. Head is dorso-ventrally compressed, mouth inferior and ventral. Upper lip developed in papillated free margin. (Plate-2)	Fresh water streams with gravel and stony bottoms. Bottom dwelling	Bottom feeder herbivore
3	Elongated, sub-cylindrical body. Mouth ventral, transverse and suctorial. Upper lip modified into fringed anterior labial fold. Beside semicircular suctorial disc, lower lips was modified as posterior labial fold and in pharyngeal portion, chin callous part and posterior part of disc was present. (Plate-3)	Fast moving fresh waters or stagnant water lakes having stones and rocky bottoms rich in algae and debris. Surface dweller but also browses well in middle portions of water bodies	Bottom feeder herbivore
4	Deep and laterally compressed body with small head. Mouth small, terminal having equal jaws. (Plate-4)	Fast water columns as well as near substrate in still, shallow marginal waters of small ponds	Column feeder omnivore
5	Elongate sub-cylindrical body with large head. Mouth inferior, transverse and lower jaw has hard cartilaginous covering. Thick lips, lower lip modified into sucker or adhesive disc (Plate-5)	Fast clear mountain streams usually rich in algae, plants and detritus etc near column and bottom of water bodies	Bottom feeder herbivore
6	Elongated cylindrical snake like body with prominent and conical head. Mouth terminal with sharp teeth, thick lips, snout was pointed with fleshy appendages. Upper jaw was longer than lower. (Plate-6)	Fast running water streams and rivers with sand, pebbles or boulder substrate near bottoms and lower columns.	Column feeder carnivore

1. *B. bendelisis* (Hamilton) 2. *C.latius latius* (Hamilton) 3.*G. gotyla gotyla* (Gray) 4. *P. Ticto* (Hamilton), 5. *S.richardsonii* (Gray) 6. *M. armatus* (Lacepede)

Higher growth rate of VG as compared HG may be due to their adaptation in different food and feeding guild. However, it is well known that the size and shape of mouth greatly depends upon the skull bones and muscles. The lips and mouth structures of both *S. richardsonii* (Gray) *and G. gotyla gotyla* (Gray) are well modified and different size groups of fish displayed higher growth in horizontal gape of mouth. Supporting the previous reports that VMO (vertical mouth opening) is largely dependent on the bone structure of the skull, whereas HMO (horizontal mouth opening) is more effected by the muscles and structure of fish lips [35].

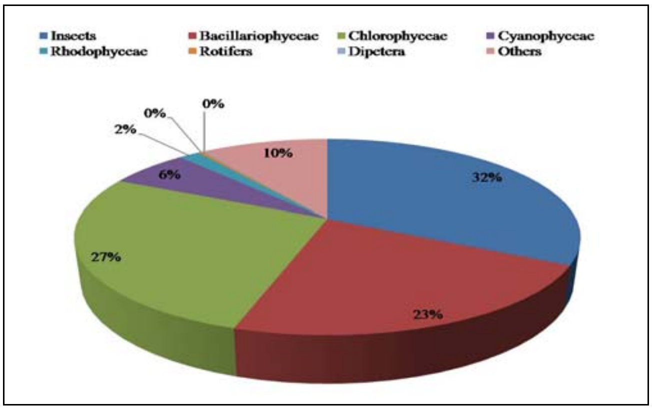

Fig 1: *Barilius bendelisis* (Hamilton)-[Omnivorous]

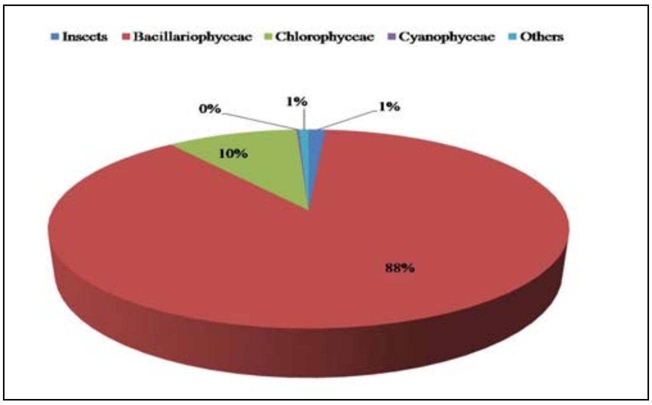

Fig 2: *Crossocheilus latius latius* (Hamilton)-[Herbivorous]

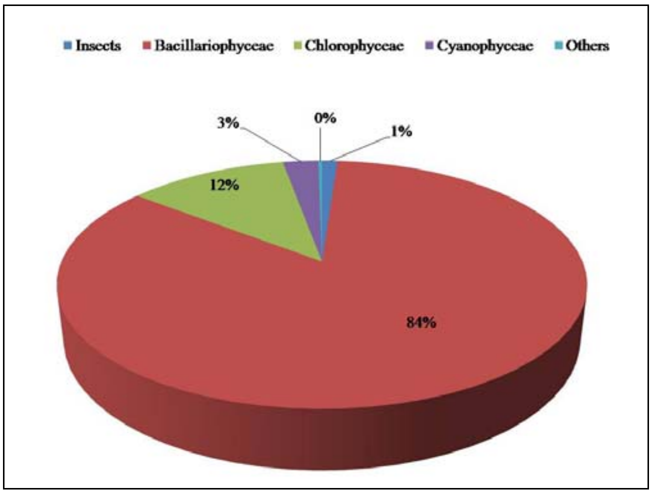

Fig 3: *Garra gotyla gotyla* (Gray)-[Herbivorous]

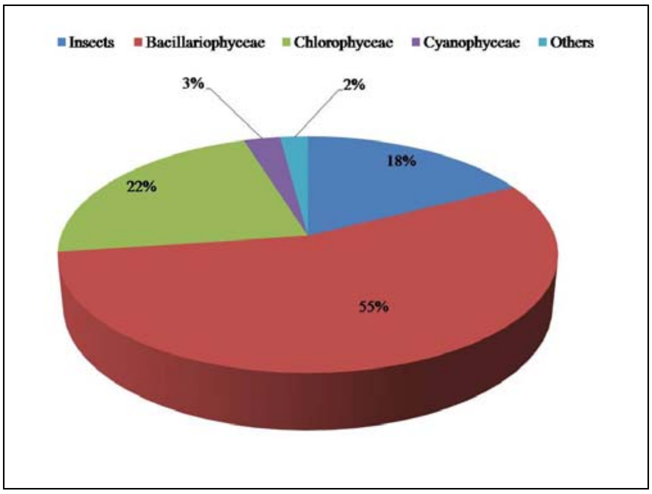

Fig 4: *Pethia ticto* (Hamilton)-[Omnivorous]

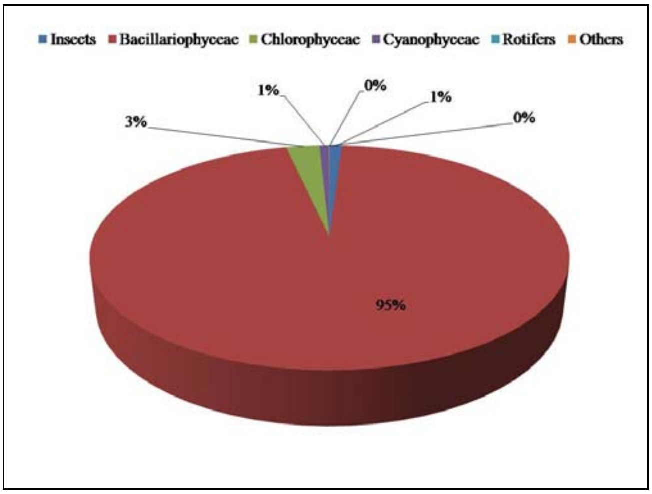

Fig 5: *Schizothorax richardsonii* (Gray)-[Herbivorous]

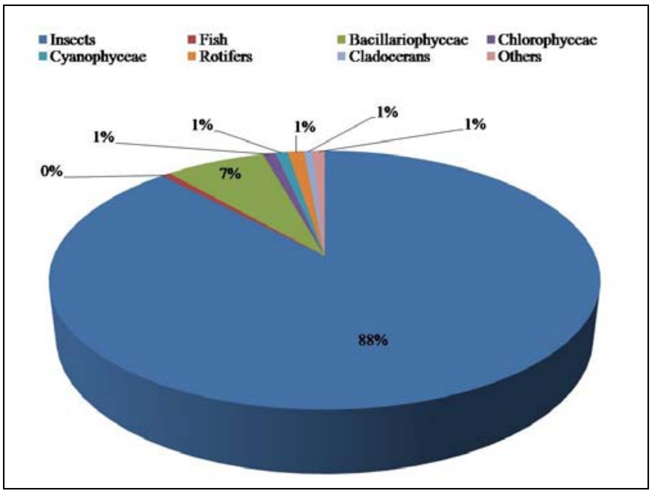

Fig 6: *Mastacembelus armatus* (Lacepede)-[Carnivorous]

Fig 1-6: represents food and feeding habits of six different hill stream fish of western Himalayas

Higher growth rate of VG as compared HG may be due to their adaptation in different food and feeding guild. However, it is well known that the size and shape of mouth greatly depends upon the skull bones and muscles. The lips and mouth structures of both *S. richardsonii* (Gray) *and G. gotyla gotyla* (Gray) are well modified and different size groups of fish displayed higher growth in horizontal gape of mouth. Supporting the previous reports that VMO (vertical mouth opening) is largely dependent on the bone structure of the skull, where as HMO (horizontal mouth opening) is more effected by the muscles and structure of fish lips [35].

Plate 1: General Morphometry and Mouth modifications of *Barilius bendelisis* (Hamilton)

Plate 2: General Morphometry and Mouth modifications of *Crossocheilus latius latius* (Hamilton)

Plate 3: General Morphometry and Mouth modifications of *Garra gotyla gotyla* (Gray)

Plate 4: General Morphometry and Mouth modification of *Pethia ticto* (Hamilton)

Plate 5: General Morphometry and Mouth modifications of *Schizothorax richardsonii* (Gray)

Plate 6: General Morphometry and Mouth modifications of *Mastacembelus armatus* (Lacepede)

High values of correlation between mouth dimensions, body lengths and mouth area divulged high degree of correlation among aforesaid parameters except in case of *S. richardsonii* (Gray) that exhibited r≤0.5, i.e., 0.123, 0.074, 0.072 and 0.50 in VG – MA, HG – MA, HL – MA and TL – MA respectively. Thus, based on present study the fishes has been categorised into surface dwelling with omnivore feeding habit, column dwelling with omnivore/carnivore feeding habit and bottom dwelling with herbivore feeding habit. In *B. bendelisis* (Hamilton) VG was almost equal to HG as such belong to the category of surface feeder omnivore. Further, *M. armatus* (Lacepede) and *P. ticto* (Hamilton) exhibited VG greater than HG and adapted for column-omnivore/carnivore feeding habit whereas in *G. gotyla gotyla* (Gray), *S. richardsonii* (Gray) and *C. latius latius* (Hamilton), HG are greater than VG and adopted for bottom herbivore habit. Present findings supported the earlier [36-44].

Table 4: Statistical analysis for the morphometry of *Barilius bendelisis* (Hamilton)

Model		UC		SC	t	Sig.	95% CL for B		R	R^2
		B	SE	Beta			LB	UB	0-R	
a. VG	(Constant)	6.204	.191		32.548	.000	5.822	6.585		
	HG	-1.001	.069	-1.328	-14.563	.000	-1.139	-.864	.842*	0.708
	MA	.202	.008	2.231	24.459	.000	.185	.218	.938*	0.879
a. HG	(Constant)	2.624	.117		22.384	.000	2.389	2.859		
	MA	.117	.004	.973	32.102	.000	.110	.124	.973*	0.946
a. HL	(Constant)	9.772	9.272		1.054	.297	-8.810	28.354		
	VG	-.328	1.458	-.072	-.225	.823	-3.250	2.594	.728*	0.529
	HG	-1.074	1.648	-.312	-.652	.517	-4.378	2.229	.746*	0.556
	MA	.211	.308	.509	.685	.496	-.406	.827	.769*	0.591
	LS	1.920	.188	.817	10.200	.000	1.543	2.297	.921*	0.848
	(Constant)	13.780	17.531		.786	.436	-21.508	49.069		
a. TL	SL	.148	.278	.121	.531	.598	-.412	.708	.984*	0.968
	FL	.940	.257	.857	3.652	.001	.422	1.458	.989*	0.978
	HL	.491	.518	.101	.949	.348	-.551	1.533	.960*	0.921
	HW	-1.140	.399	-.169	-2.856	.006	-1.944	-.337	.841*	0.707
	HG	-3.266	3.308	-.196	-.987	.329	-9.924	3.392	.706*	0.498
	VG	-2.219	3.102	-.100	-.715	.478	-8.464	4.025	.712*	0.506
	BD	-.384	.422	-.083	-.909	.368	-1.234	.466	.942*	0.887
	BW	.728	.410	.102	1.777	.082	-.097	1.552	.894*	0.799
	LS	.915	.616	.081	1.485	.144	-.325	2.156	.902*	0.813
	BWT	-.122	.318	-.043	-.384	.703	-.763	.519	.936*	0.876
	GWT	1.351	1.562	.028	.864	.392	-1.794	4.496	.706*	0.498
	GL	-.035	.053	-.027	-.658	.514	-.143	.072	.824*	0.678
	MA	.621	.649	.311	.957	.343	-.685	1.927	.738*	0.544
a. GL	(Constant)	61.962	2.819		21.984	.000	56.320	67.604		
	GWT	27.152	3.300	.734	8.229	.000	20.547	33.757	.734*	0.538

Correlation significant at 0.01 % of significance level

Table 5: Statistical analysis for the morphometry of *Crossocheilus latius latius* (Gray)

Model		UC		SC	t	Sig.	95% CL for B		R	
		B	SE	Beta			LB	UB	0-R	
a. VG	(Constant)	3.928	.242		16.260	.000	3.441	4.415		
	HG	-.649	.095	-.967	-6.813	.000	-.840	-.457	.734*	0.538
	MA	.204	.016	1.804	12.711	.000	.172	.237	.893*	0.797
a. HG	(Constant)	2.181	.193		11.289	.000	1.792	2.571		
	MA	.159	.008	.943	18.947	.000	.142	.176	.943*	0.889
a. HL	(Constant)	10.967	1.903		5.762	.000	7.126	14.808		
	VG	-1.693	.455	-.436	-3.720	.001	-2.612	-.775	.659*	0.434
	HG	-1.083	.448	-.416	-2.416	.020	-1.988	-.178	.861*	0.741
	MA	.403	.104	.918	3.879	.000	.193	.613	.836*	0.698
	LS	1.546	.126	.860	12.229	.000	1.291	1.801	.958*	0.917
	(Constant)	-6.603	8.087		-.816	.420	-23.057	9.851		
a. TL	SL	.211	.281	.180	.751	.458	-.360	.783	.994*	0.988
	FL	.973	.294	.885	3.305	.002	.374	1.572	.995*	0.990
	HL	.096	.518	.015	.185	.855	-.958	1.150	.968*	0.937
	HW	-.172	.715	-.019	-.240	.812	-1.627	1.283	.966*	0.933
	HG	.873	1.560	.051	.560	.579	-2.300	4.047	.878*	0.770
	VG	-1.011	1.776	-.040	-.569	.573	-4.625	2.604	.677*	0.458

	BD	.378	.250	.071	1.510	.141	-.131	.888	.928*	0.861
	BW	.002	.005	.008	.500	.620	-.007	.012	-.205*	0.042
	LS	-.195	1.225	-.017	-.159	.874	-2.687	2.296	.976*	0.952
	BWT	-.415	.189	-.169	-2.196	.035	-.799	-.031	.945*	0.893
	GWT	1.290	3.151	.019	.409	.685	-5.120	7.700	.792*	0.627
	GL	.001	.011	.003	.065	.949	-.021	.022	.737*	0.543
	MA	.049	.426	.017	.115	.909	-.818	.916	.845*	0.714
a. GL	(Constant)	207.370	14.056		14.753	.000	179.059	235.680		
	GWT	262.255	19.329	.896	13.568	.000	223.324	301.186	.896*	0.802

Correlation significant at 0.01 % of significance level

Table 6: Statistical analysis for the morphometry of *Gara gotyla gotyla* (Gray)

Model		UC		SC	t	Sig.	95% CL for B		R	R^2
		B	SE	Beta			LB	UB	0-R	
a. VG	(Constant)	6.992	.200		34.940	.000	6.586	7.397		
	HG	-.726	.051	-1.698	-14.268	.000	-.829	-.623	.682*	0.465
	MA	.130	.006	2.481	20.850	.000	.117	.143	.853*	0.727
a. HG	(Constant)	3.363	.330		10.187	.000	2.695	4.032		
	MA	.118	.006	.959	20.891	.000	.106	.129	.959*	0. 919
a. HL	(Constant)	13.374	6.675		2.004	.053	-.177	26.926		
	VG	-1.019	.962	-.251	-1.060	.297	-2.972	.933	.708*	0.501
	HG	-.326	.787	-.187	-.414	.682	-1.923	1.272	.918*	0.842
	MA	.187	.129	.880	1.457	.154	-.074	.449	.911*	0.829
	LS	.771	.135	.515	5.705	.000	.497	1.045	.919*	0.844
	(Constant)	16.066	18.052		.890	.382	-21.041	53.173		
a. TL	SL	-.054	.308	-.043	-.175	.863	-.686	.579	.985*	0.970
	FL	.877	.267	.753	3.287	.003	.329	1.425	.991*	0.982
	HL	.048	.607	.009	.078	.938	-1.200	1.295	.957*	0.915
	HW	-.252	.651	-.036	-.387	.702	-1.591	1.087	.934*	0.872
	HG	-.030	2.275	-.003	-.013	.990	-4.706	4.645	.884*	0.781
	VG	-.431	2.909	-.020	-.148	.883	-6.411	5.549	.698*	0.487
	BD	.382	.456	.078	.839	.409	-.554	1.318	.944*	0.891
	BW	-.269	.500	-.044	-.538	.595	-1.298	.760	.928*	0.861
	LS	.591	.568	.073	1.039	.308	-.578	1.759	.936*	0.876
	BWT	.564	.207	.301	2.723	.011	.138	.990	.962*	0.925
	GWT	-1.162	1.064	-.062	-1.092	.285	-3.349	1.026	.783*	0.613
	GL	-.005	.005	-.052	-1.005	.324	-.016	.006	.780*	0.608
	MA	.034	.379	.029	.089	.930	-.746	.813	.877*	0.769
a. GL	(Constant)	369.791	28.932		12.781	.000	311.222	428.360		
	GWT	157.352	15.949	.848	9.866	.000	125.065	189.638	.848	0.719

Correlation significant at 0.01 % of significance level

Table 7: Statistical analysis for the morphometry of *Pethia ticto* (Hamilton)

Model	UC	SC	t	Sig.	95% CL for B	R	R2			
	B	SE	Beta			LB	UB	0-R		
a. VG	(Constant)	4.646	.078		59.808	.000	4.490	4.801		
	HG	-1.924	.075	-2.032	-25.769	.000	-2.073	-1.774	.589*	0.347
	MA	.521	.015	2.738	34.719	.000	.491	.551	.792*	0.627
a. HG	(Constant)	.846	.080		10.642	.000	.687	1.005		
	MA	.192	.008	.958	25.290	.000	.177	.208	.958*	0.918
a. HL	(Constant)	.663	5.941		.112	.912	-11.242	12.569		
	VG	1.458	1.268	.592	1.150	.255	-1.083	3.999	.406*	0.165
	HG	2.741	2.548	1.175	1.076	.287	-2.365	7.848	.590*	0.348
	MA	-.547	.676	-1.167	-.809	.422	-1.901	.807	.581*	0.338
	LS	.702	.135	.500	5.184	.000	.431	.974	.628*	0.394
	(Constant)	25.180	7.803		3.227	.002	9.473	40.888		

a. TL	SL	.136	.128	.108	1.066	.292	-.121	.393	.972*	0.945
	FL	.432	.113	.400	3.832	.000	.205	.658	.988*	0.976
	HL	.337	.204	.065	1.650	.106	-.074	.748	.871*	0.759
	HW	.400	.368	.046	1.086	.283	-.341	1.141	.871*	0.759
	HG	-6.639	2.819	-.551	-2.355	.023	-12.313	-.965	.687*	0.472
	VG	-3.135	1.354	-.246	-2.315	.025	-5.862	-.409	.581*	0.338
	BD	.237	.275	.082	.862	.393	-.316	.790	.963*	0.927
	BW	.097	.274	.020	.352	.726	-.456	.649	.902*	0.814
	LS	.161	.214	.022	.756	.454	-.269	.591	.623*	0.388
	BWT	1.874	.929	.290	2.018	.049	.004	3.743	.983*	0.966
	GWT	-.211	4.656	-.002	-.045	.964	-9.582	9.161	.585*	0.342
	GL	.000	.014	.000	-.014	.989	-.028	.028	.702*	0.493
	MA	1.745	.733	.721	2.382	.021	.270	3.219	.718*	0.516
a. GL	(Constant)	41.373	3.967		10.428	.000	33.432	49.315		
	GWT	322.402	29.358	.822	10.982	.000	263.637	381.168	.822	0.676

Correlation significant at 0.01 % of significance level

Table 8: Statistical analysis for the morphometry of *Schizothorax richardsonii* (Gray)

Model	**UC**	**SC**	**t**	**Sig.**	**95% CL for B**	**R**	**R2**			
	B	**SE**	**Beta**			**LB**	**UB**	**0-R**		
a. VG	(Constant)	5.719	.197		28.984	.000	5.324	6.114		
	HG	.092	.018	.569	5.257	.000	.057	.127	.575*	0.331
	MA	6.875E-5	.000	.081	.747	.458	.000	.000	.123*	0.015
a. HG	(Constant)	10.294	.597		17.234	.000	9.099	11.490		
	MA	.000	.001	.074	.561	.577	.000	.002	.074*	0.005
a. HL	(Constant)	9.242	2.582		3.579	.001	4.068	14.416		
	VG	-.290	.439	-.021	-.661	.512	-1.171	.590	.555*	0.308
	HG	1.995	.155	.869	12.829	.000	1.683	2.307	.981*	0.962
	MA	-7.674E-6	.000	.000	-.025	.980	.000	.001	.072*	0.005
	LS	.287	.145	.134	1.983	.052	-.003	.578	.928*	0.861
	(Constant)	-.309	4.584		-.067	.947	-9.536	8.918		
a. TL	SL	.430	.157	.371	2.741	.009	.114	.745	.998*	0.996
	FL	.550	.143	.519	3.855	.000	.263	.838	.998*	0.996
	HL	.452	.390	.078	1.160	.252	-.332	1.236	.991*	0.982
	HW	.354	.440	.038	.805	.425	-.531	1.239	.978*	0.956
	HG	-.681	.520	-.051	-1.309	.197	-1.729	.366	.973*	0.947
	VG	-.036	.716	.000	-.050	.960	-1.477	1.405	.550*	0.303
	BD	-.017	.263	-.003	-.066	.948	-.547	.513	.974*	0.949
	BW	-.089	.271	-.012	-.326	.746	-.635	.458	.962*	0.925
	LS	.948	.315	.076	3.011	.004	.314	1.582	.941*	0.885
	BWT	-.046	.027	-.048	-1.742	.088	-.100	.007	.942*	0.887
	GWT	.095	.279	.007	.339	.736	-.467	.657	.861*	0.741
	GL	.008	.007	.030	1.096	.279	-.006	.022	.908*	0.824
	MA	.000	.000	-.011	-1.522	.135	-.002	.000	.050*	0.003
a. GL	(Constant)	172.381	17.187		10.029	.000	137.976	206.785		
	GWT									
	46.035	2.735	.911	16.833	.000	40.561	51.509	.911*	0.830	

Correlation significant at 0.01 % of significance level

Table 9: Statistical analysis for the morphometry of *Mastacembelus armatus* (Lacepede)

Model		UC		SC	t	Sig.	95% CL for B		R	
		B	SE	Beta			LB	UB	0-R	
a. VG	(Constant)	3.639	.468		7.767	.000	2.684	4.593		
	HG	.186	.282	.264	.660	.514	-.389	.761	.945*	0.893
	MA	.064	.037	.687	1.717	.096	-.012	.140	.949*	0.901
a. HG	(Constant)	1.555	.101		15.378	.000	1.349	1.761		
	MA	.131	.003	.990	41.105	.000	.124	.137	.990*	0.980

a. HL	(Constant)	-2.515	3.853		-.653	.519	-10.383	5.353		
	VG	.324	.885	.039	.366	.717	-1.485	2.132	.899*	0.808
	HG	1.780	1.412	.307	1.260	.217	-1.105	4.665	.915*	0.837
	MA	-.150	.187	-.195	-.800	.430	-.532	.233	.902*	0.814
	LS	2.502	.235	.844	10.627	.000	2.021	2.982	.982*	0.964
	(Constant)	1.660	18.894		.088	.931	-37.425	40.745		
a. TL	SL	2.904	1.808	.444	1.606	.122	-.836	6.643	.988*	0.976
	FL	.021	2.970	.001	.007	.994	-6.123	6.165	.949*	0.901
	HL	2.404	6.903	.063	.348	.731	-11.877	16.684	.881*	0.776
	HW	1.915	5.119	.036	.374	.712	-8.675	12.504	.865*	0.748
	HG	1.426	1.315	.111	1.085	.289	-1.293	4.146	.950*	0.903
	VG	-1.207	1.803	-.069	-.669	.510	-4.937	2.524	.854*	0.729
	BD	.550	3.307	.028	.166	.869	-6.290	7.390	.966*	0.933
	BW	1.195	.583	.330	2.051	.052	-.011	2.401	.936*	0.876
	LS	-4.016	3.227	-.081	-1.245	.226	-10.691	2.659	.707*	0.500
	BWT	.444	.166	.266	2.680	.013	.101	.787	.889*	0.790
	GWT	-.574	1.039	-.115	-.553	.586	-2.724	1.575	.867*	0.752
	GL									
	MA									
a. GL	(Constant)	81.199	7.570		10.726	.000	65.797	96.601		
	GWT	22.112	3.494	.740	6.328	.000	15.003	29.221	.740*	0.548

Correlation significant at 0.01 % of significance level

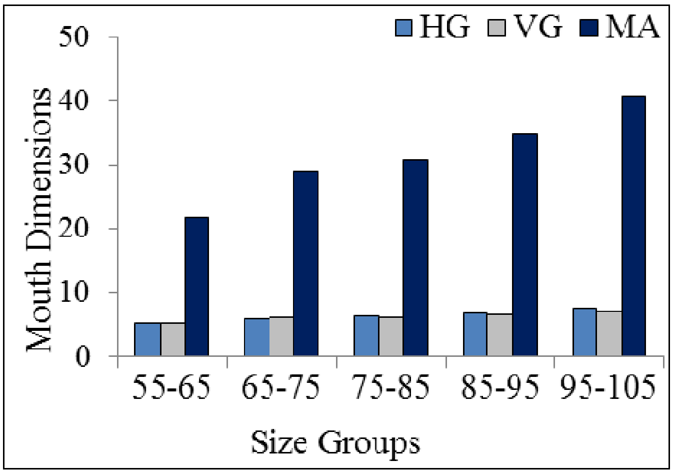

Fig 1: *Barilius bendelisis* (Hamilton)

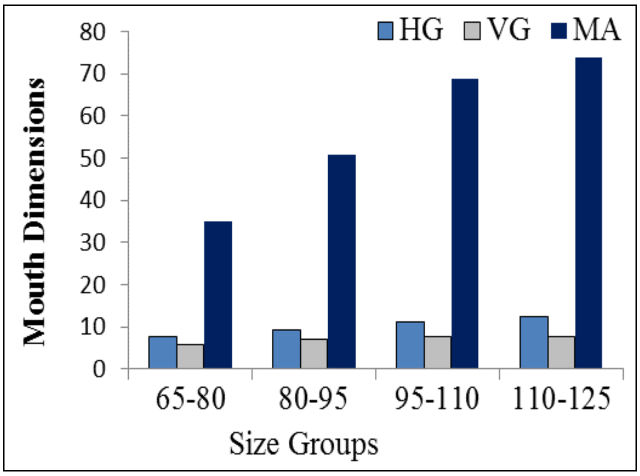

Fig 3: *Garra gotyla gotyla* (Gray)

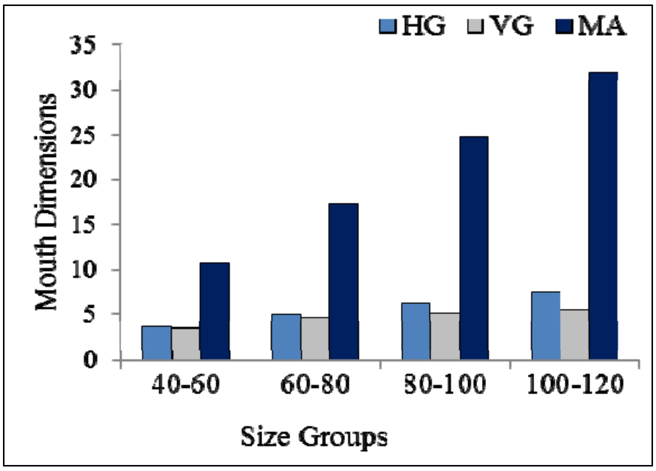

Fig 2: *Crossocheilus latius latius* (Hamilton)

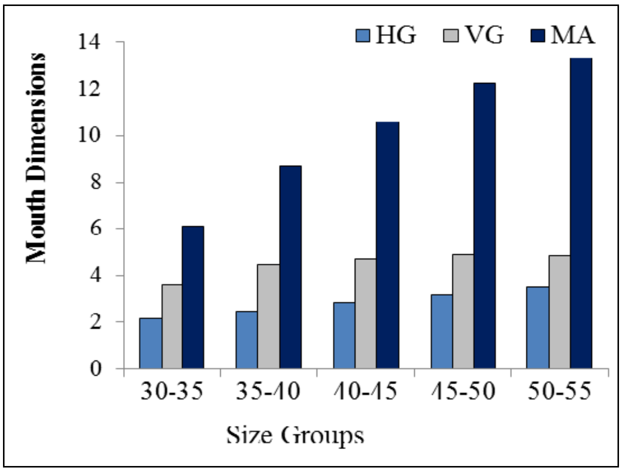

Fig 4: *Pethia ticto* (Hamilton)

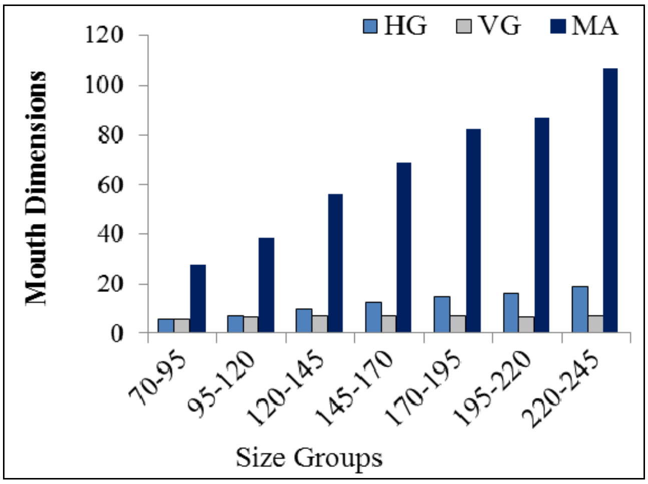

Fig 5: *Schizothorax richardsonii* (Gray)

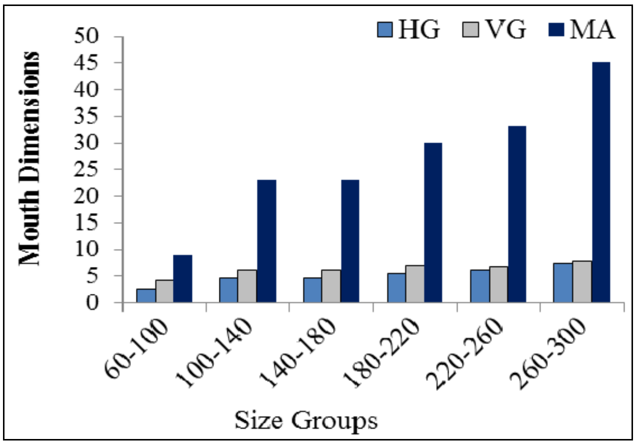

Fig 6: *Mastacembelus armatus* (Lacepede)

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