STM JOURNALS

Research & Reviews: A Journal of Life Sciences
ISSN: 2249-8656 (Online), ISSN: 2348-9545 (Print)
Volume 7, Issue 3
www.stmjournals.com

Morphometric Divergence of *Garra mullya* (Skyes, 1839) Populations from the Preferred River System of Southern Western Ghats Region, Tamil Nadu, India

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Abstract

The present study aims to describe the phenotypic divergence of Garra mullya from the preferred river sites of Southern Western Ghats, Tamil Nadu, India. A total of 18 morphometric characters were analyzed within populations from different localities. The species-wise and population-wise descriptive statistics viz., minimum, maximum, mean, standard deviation, the coefficient of variation (CV) of all morphometric traits, the multivariate coefficient of variation (CVp) and the principle component analysis were carried out. The bivariate scatter plot of component 1 and 2 was found to be sufficient to outline the morphological heterogeneity existing among Garra mullya populations. Even though, the morphologically characters are showed similarity between each other, but the population of kalikesam region shows completely distinct from other regions in clusters analysis. So, the study concluded that the morphometric divergence within populations, it may decline the fish species due to the habitat alterations by the influence of anthropogenic activities.

Keywords: *Garra mullya, morphometric, principle component analysis, anthropogenic activities*

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INTRODUCTION

Fish communities in relating the tropics streams are highly complex. Functional and structured constituents of running water are largely based on the system underlying, efficient incentive genesis and growth of those systems [1]. The morphological variation among three wild populations and inbred strains appear to be due to genetic differences and environmental factors [2]. *Garra mullya* (Silas, 1983) is a widespread species present throughout and endemic to peninsular India. This species is abundant in most of its known range and research on its population status, harvest and threats is essential [3].

Moreover the morphological and behavioral traits from river and lake environments revealed phenotypic differences in river and lake fish groups. Experimentally, difference in tactics and efficiency of defensive behavior are found in specimens from different habitats more efficient from the reservoir [4]. Morphometric and the meristic methods remains the simplest and most direct way among methods of species identification [5]. It is understood that the analysis of phenotypic variation in morphometric characters or meristic counts is the method most commonly used to delineate stocks of fish [6–8]. Despite the advent of techniques for variation of morphometric characters between inter and an intraspecific population, these conventional methods continues to have an important role in stock identification even to date [9]. In this study, the hypothesis that different sites samples may belong to single, homogenous populations of *G. mullya.* Individual morphometric variation would analyze the difference in that character level.

MATERIALS AND METHODS

Sampling was done from the five selected study sites of the Southern Western Ghats region. They were Kallar, Karaiyar, Manimuthar, Ramanathi and other one at Kalikesam, Kanyakumari district. Fishes were sampled at each site on one occasion by monofilamentous gill nets with varying mesh size (8–12 mm) and drag net. Fishes were identified in the field and then preserved in 10% formalin for morphometric studies. The morphometric characters of each fish were measured by using Aerospace china manufacturing digital caliper in millimeter. Individually imaged fish (with an mm scale) was used to collect data on standard length (^{L}S) and 17 other morphometric characters of fish, to the nearest 0.1 mm keeping character values between specimens [10].

RESULTS

The descriptive statistics for each of the morphometric variables of five populations of *G. mullya* are denoted in Table 1. Generally low coefficients of variation were obtained for the morphometric characters of five populations of *G. mullya* from Kallar (1.21–12.20%), Karaiyar (4.17–16.52%), Manimuthar (2.49–19.81%), Ramanathi (3.48–21.66%) and Kalikesam (1.96–26.16%). The multivariate generalized coefficient of variation (CVp) in each specimen from Kalikesam showed the highest CVp (12.91%) followed by Ramanathi (10.75%), Karaiyar (9.88%), Manimuthar (9.66) and Kallar (5.36%) with relatively low values; indicating minimal or very low intra-population variation. When the five populations of *G. mullya* were compared from different sites combined together for each species; the univariate analysis of variance also showed that, fish samples from different sites differed significantly (at $p<0.05$ and $p<0.01$ levels of significance) in 18 morphometric characters examined, respectively (Table 1). This leads to rejection of the null hypothesis of 'no heterogeneity in fish morphology among riverine populations' of these species. There were significant differences among samples measurement of *G. mullya* above the case of high F-values differences of characters on LPA, LPP, LPD, LPD and DPFV. The shorter F-values characters were of LH, LAFB, LDFB, LPF, HW, DPV, CPW and LCP. Larger mean was identified as LPD, LPP and LPA from all the five populations' specimens of *G. mullya*.

PCA of the 18 significant variables between five populations of *G. mullya* yielded three principal components accounting for 61.45% of the total variation in the original variables (Table 2). The variance explained by the three components was 11.43% and 7.3% whose factor loadings are shown in Table 2. The first component was mainly defined by measurements of standard length (*L*S), head length (*L*H), maximum body length (MBD), predorsal length (*L*PD), postdorsal length (PDL), prepelvic length (*L*PP), preanal length (*L*PA), distance between pectoral fin to ventral fin (DPFV), pelvic insertion to anal origin (PIAO), dorsal fin base (*L*DFB), anal fin base (*L*AFB), penduncle length (*L*P), penduncle depth (DP), distance between pelvic to ventral (DPV), pectoral fin length (*L*PF), and head width (HW). These indicated that the above morphometric characters contributed the maximum to differentiate *G. mullya* populations. The second component was mainly correlated with measurements of central pad length (*L*CP), central pad width (CPW), and the third component was correlated with measurements of predorsal length (*L*PD), respectively. The bivariate scatter plot of component 1 and 2 was found to be sufficient to outline the morphological heterogeneity existing among *G. mullya* populations (Figure 1). The samples collected from Kallar, Karaiyar, Manimuthar, Ramanathi and Kalikesam rivers showed similarity; it is depicted in the form of overlapping clusters analysis (Figure 2). These five populations of Garra mullya were closely related with each other, where Kallar and Ramanathi shows similar like Manimuthar and Karaiyar, but Kalikesam river shows completely distinct from other four populations.

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Table 1: *Descriptive Statistics of Transformed Morphometric Variables of Five Population of Garra mullya.*

Morphometric characters	Kallar (n=10)__ Mean±SD(Min-Max)	CV	Karaiyar (n=10)__ Mean±SD (Min-Max)	CV	Manimuthar (n=10)___ Mean±SD (Min-Max)	CV	Ramanathi (n=10)__ Mean±SD (Min-Max)	CV	Kalikeasan (n=10)___ Mean±SD(Min-Max)	CV	F-value
^{L} S	102.47±12.68(90.69-118.76)	-	90.89± 10.92(80.63-105.83)	-	98.74±6.08(88.47-103.55)	-	44.41±2.36 (40.78-46.37)	5.31	44.37±1.34 (42.17-45.57)	3.03	1.13
^{L}H	24.10±2.94(20.44-27.77)	12.20	22.13±3.32(19.24-26.51)	14.99	23.65±4.68(20.01-31.62)	19.81	24.94±1.08 (23.57-26.25)	4.34	24.88±1.33 (23.05 - 26.35)	5.33	0.15
MBD	22.52±1.03(21.27-23.91)	4.56	20.52±2.79(17.77-24.86)	13.5	26.41±2.48(24.29-29.14)	9.40	27.19±1.00 (26.0l-28.77)	3.66	27.31±0.80 (26.31-28.27)	2.91	0.25
^{L}PD	44.08±0.53(43.65-44.70)	1.21	37.78±1.82(35.46-39.41)	4.82	45.00±3.04(41.54-48.51)	6.76	60.49±3.33 (55.88-64.11)	5.51	60.03±2.96 (56.98-63.51)	4.93	0.18
PDL	53.24±1.39(51.79-55.02)	2.60	45.23±2.67(41.29-48.36)	5.91	54.67±2.59(51.93-58.07)	4.74	41.10±1.79 (38.87-43.88)	4.36	41.12±1.64 (39.17-43.38)	3.99	0.05
^{L}PP	48.72±1.66(46.83-50.89)	3.40	43.31±2.74(40.26-47.36)	6.32	52.27±1.45(50.36-53.81)	2.77	47.52±1.41 (45.82-49.32)	2.97	47.32±1.01 (45.82-48.58)	2.14	0.31
^{L}PA	73.89±2.89(70.15-76.99)	3.91	64.66±2.70(61.64-68.65)	4.17	63.39±2.30(60.35-65.68)	3.63	64.21±0.74 (63.01-64.96)	1.16	64.24±1.35 (62.60-66.06)	2.11	0.33
DPFV	48.52±1.77(47.08-51.55)	3.65	42.95±2.76 (40.33-47.01)	6.44	41.32±1.03(40.11-42.91)	2.49	36.84±0.78 (35.95-37.92)	2.12	36.90±1.32 (35.22-38.44)	3.57	0.41
PIAO	20.29± 0.95(18.73-21.34)	4.71	16.63±2.07 (14.92-18.96)	12.46	18.18±2.31(14.95-21.04)	12.71	17.12±0.64 (16.41-18.15)	3.73	16.98±0.84 (16.11-17.98)	4.94	0.19
^{L}DFB	16.43±0.79(15.24-17.39)	4.81	15.88±1.34 (14.54-17.88)	8.45	16.83±1.83(13.97-18.39)	10.86	16.25±0.89 (15.22-17.47)	5.49	16.25±0.72 (15.37-17.17)	4.41	0.08
^{L}AFB	7.66±0.63(6.73-8.35)	8.19	8.07±1.31 (7.11-10.24)	16.21	8.91±1.62(7.65-11.63)	18.23	21.50±1.39 (19.90-22.98)	6.46	21.27±0.96 (20.16-22.78)	4.49	0.76
^{L}P	12.92±0.98(11.84-14.01)	7.55	11.70±1.26 (10.67-13.86)	10.76	12.49±2.08(10.41-15.82)	16.65	14.30± 1.41(12.45-15.79)	9.88	14.24±1.38 (12.05-15.69)	9.68	0.88
DP	11.90±0.98(10.91-13.36)	8.28	11.78±1.03(10.51-13.21)	8.77	12.83±0.98(11.86-14.19)	7.62	10.53±1.04 (8.88-11.77)	9.92	10.53±0.96 (9.18-11.77)	9.12	0.32
DPV	18.24±0.65(17.50-19.25)	3.55	16.12±2.10(13.71-18.41)	13.03	17.69±2.50(14.69-20.17)	14.12	13.55±1.43 (11.12-14.51)	10.53	13.65±1.56 (11.02-14.89)	11.61	0.24
^{L}PF	22.12±0.91(20.68-23.11)	4.10	20.50±1.94(18.49-23.45)	9.45	22.60±2.02(20.34-24.46)	8.94	23.57±1.19 (21.73-24.82)	5.07	23.49±1.80 (20.53-24.91)	7.66	0.14
HW	17.50±0.53(16.79-18.16)	3.01	15.98±2.64 (13.56-20.15)	16.52	16.36±1.65(14.25-17.78)	10.09	50.30± 1.05 (49.13-51.73)	2.08	50.28±0.50 (49.74-51.08)	1.00	0.26
^{L}CP	18.75±2.06(15.95-21.48)	10.98	17.98±1.77 (16.68-20.97)	9.87	18.75±2.06(15.95-21.48)	10.98	16.18±0.87 (15.13-17.26)	5.36	16.16±1.04 (14.93-17.06)	6.44	0.11
CPW	28.73±1.29(27.74-30.84)	4.49	25.51±1.59 (23.77-27.76)	6.23	27.74±1.29(27.74-30.84)	4.49	30.41±1.42 (29.49-32.90)	4.68	30.25±1.76 (28.19-32.80)	5.81	0.38
CV*p*		**5.36**		**9.88**		**9.66**		**10.75**		**12.91**	

CV= Coefficient of variation of each measurement; CVp= Multivariate coefficient of variation of each species; F-values (derived from the analysis of variance).

Table 2: *PCA and Factor Loading Analysis for the Morphometric Variables of Garra mullya Populations.*

Morphometric variables	Eigen values	% of variance	Cumulative %	PC1	PC2	PC3
LS	11.061	61.452	61.452	.758	.063	.388
LH	2.059	11.436	72.889	.827	.071	-.083
MBD	1.314	7.300	80.188	.796	.359	.113
LPD	.925	5.136	85.325	.770	-.065	.508
PDL	.662	3.676	89.001	.866	-.118	.362
LPP	.483	2.685	91.686	.845	-.206	.348
LPA	.355	1.973	93.658	.723	-.529	.226
DPFV	.354	1.967	95.625	.796	-.206	.009
PIAO	.260	1.445	97.071	.947	-.018	-.035
LDFB	.174	.965	98.035	.882	.100	-.307
LAFB	.109	.608	98.643	.741	.085	-.236
LP	.074	.409	99.052	.754	.013	-.214
DP	.058	.324	99.376	.853	-.039	-.314
DPV	.040	.221	99.597	.881	.137	-.148
LPF	.032	.178	99.775	.859	.338	-.257
HW	.024	.132	99.907	.899	.154	-.244
LCP	.010	.058	99.965	-.326	.804	.123
CPW	.006	.035	100.000	.098	.846	.351
Explained variance (%)		**61.45**		**11.44**		**7.30**

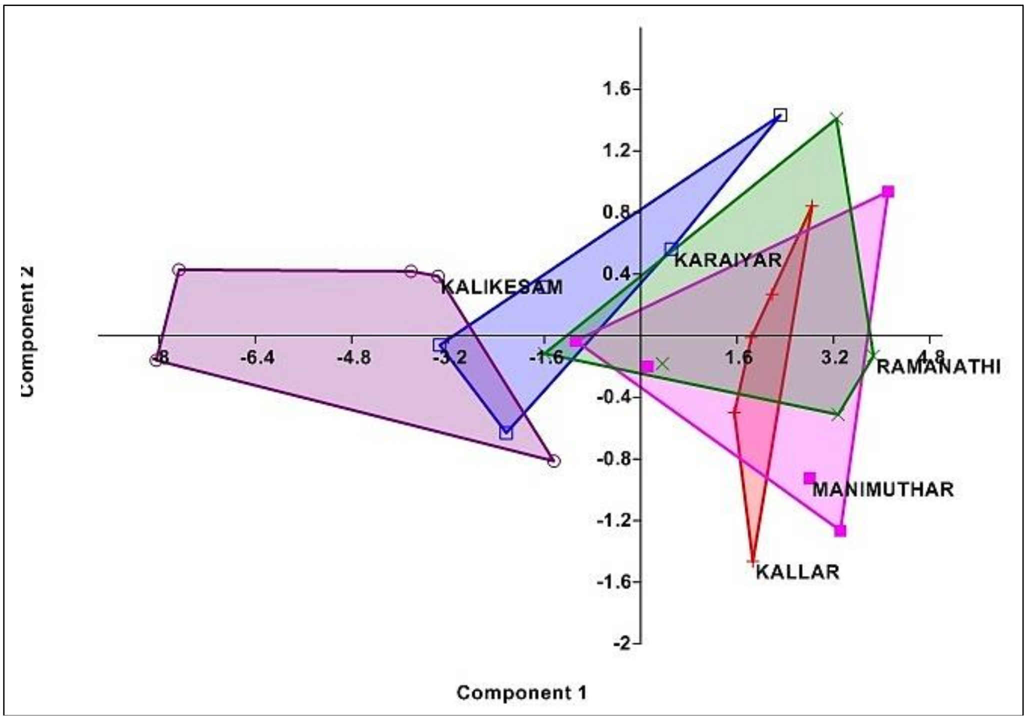

Fig. 1: *Scattered Diagram for Garra mullya (Green cross – Ramanathi, Square Blue – Karaiyar, Pink Filled Square – Manimuthar, Red Cross – Kallar, Purple Circle – Kalikesam).*

Research & Reviews: A Journal of Life Sciences
Volume 7, Issue 3
ISSN: 2249-8656 (Online), ISSN: 2348-9545 (Print)

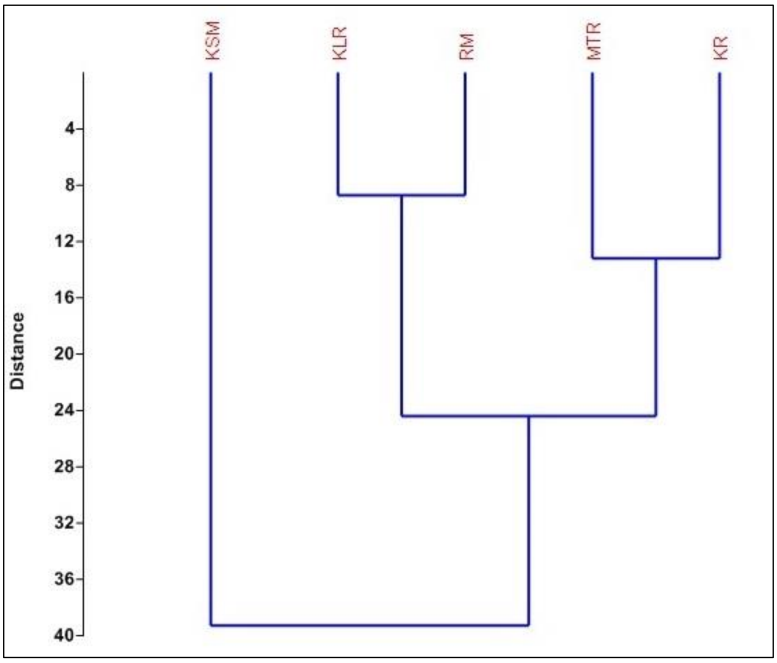

Fig. 2: *Cluster Analysis for Garra mullya Populations.*

DISCUSSION

The phenotypic divergence among *G. mullya* samples revealed the existence of five morphologically differentiated stocks viz., the Tamiraparani river population and the Kalikesam river population. The distinction among the samples may suggest a relationship between the extent of phenotypic heterogeneity and geographic distance, showing limited intermingling among the populations of selected tributes of the river [11]. The five different populations of *G. mullya* morphometric characters are moreover similar to each other; but Kalikesam river showed completely distinct form from the other sites. Morphometric analysis showed a clear morphologic heterogeneity existing among five sites populations of *G. mullya*. These morphometric characters were statistically analyzed between the five populations of *G. mullya.* The multivariate generalized coefficient of variation (CVp) was determined in each specimen. The coefficient of variation observed in the present study was comparatively lower ranging from 5.36% (Kallar) to 12.91% (Kalikesam). In fishes, the coefficients of variation within populations are usually far greater than 10% [12]. Similar results were obtained by Mamuris *et al.* [5], in the seven populations of red mullet (*Mullus barbatus*) and by Quilang et al. [13], in the four populations of Silver perch (*Leiopotherapon plumbeus*).

The Principal Component Analysis has clearly demonstrated an intraspecific morphological variation among the populations of *G. mullya*. The variations observed are related to measurements such as *L*P, *L*PA, *L*AFB, DPFV, *L*PP and *L*CF. Measurements of these characters were the most discriminating variable in this study. From this examination of *G. mullya* populations characters variation related measurements such as *L*PA, *L*PP, LPD, *L*PD and DPFV were the separating variables. Scatter plots of the populations represented that Kallar, Karaiyar, Manimuthar and Ramanathi were overlapping, while the populations of Kalikesam river showed distinct while compared to other four populations. Other related studies reported were *Puntius dorsalis* [14]; *Puntius bimaculatus* [15]; genus *Puntius* [16]. Hence, the study of selected sites populations of *G. mullya* was morphologically variable between their characters. These environmental factors may affect morphological characters. In some studies, environmental conditions, particularly temperature, which prevailed during some sensitive developmental stages, have been shown to have the greatest influence on morphological characters [17]. Taning [18] has explained the effect of temperature on morphological characters based on the study in Paradise fish (*Macropodus opercularis*). The detected pattern of phenotypic discreteness also suggested a direct relationship between the extent of phenotypic divergence and geographic separation, indicating that geographic separation is a limiting factor to migration among stocks. It is well known that morphological characteristics can show high plasticity in response to differences in environmental conditions. This raises the possibility that phenotypic plasticity may itself be adaptive, allowing stocks to shift their appearance to match their ecological circumstances [19]. The phenotypic plasticity of fish allows them to respond adaptively to environmental change by modifications in their physiology and behavior, which lead to changes in their morphology, reproduction or survival, which mitigate the effects of environmental change [20]. In this investigation the phenotypic variations among the identical species of *G. mullya* from the preferred areas of Southern Western Ghats river region was concluded.

CONCLUSION

In the present study the morphologically variation between different characters of *G. mullya* from the river region of Southern Western Ghats was studied. It may get influenced by the habitat alteration and other anthropogenic activities in the riverine ecosystem. However, the aquatic environment causes transformation of their characters, alteration of fish species and aquatic life. In case of that the prior conserve the riverine system.

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ISSN: 2249-8656 (Online), ISSN: 2348-9545 (Print)

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Cite this Article

Sabaridasan A, Edwinthangam P, Soranam R. Morphometric divergence of Garra mullya (Skyes, 1839) populations from the preferred river system of Southern Western Ghats region, Tamil Nadu, India. *Research & Reviews: A Journal of Life Sciences*. 2017; 7(3): 7–13p.

