Morpho and craniometric analysis among different Populations of *Bagarius bagarius*

JAWERIA SEHR[1], MUHAMMAD IMRAN[2], ABDUL MAJID KHAN[3], ARSHIA NASEER[4]

1, 2, 3 & 4: Institute of Zoology, University of the Punjab, Lahore, Pakistan.

ABSTRACT

Many natural fish populations undergo morphological and craniometric variations due to habitat alteration. The current study was planned to understand the influence of dissimilar habitats on fish growth. To analyze these variations, 14 morphometric and 06 craniometric characteristics of *Bagarius bagarius* from two sampling sites (head Balloki and Head Trimmu) were analyzed. A total of 20 fish samples (10 from each site) were collected from January to March 2022, and their morpho-craniometric variations were studied at the Institute of Zoology, University of the Punjab. The outcomes of the study presented definite differences among different populations of *B. bagarius*. Moreover, it is also depicted that the fish growth was more coherent at the head Trimmu site as compared to the head Balloki.

Keywords: *Bagarius bagarius*, Morphometric and craniometric variations, Inter and Intraspecific variations, Head Trimmu and Head Balloki, Freshwater Ecosystem.

INTRODUCTION

The species *B. bagarius* belongs to the genus *Bagarius* of the family Sisoridae. This genus is an inhabitant of most Asian countries. It is abundantly distributed in, drainages of the Ganges, Indus, southern India, XeBangfai Basin to Indonesia and Mekong Basin (Saha *et al*., 2021) and also in continental waters of Bangladesh, Pakistan, and India (Lashari *et al.,* 2016). *B. bagarius* has an appealing grayish or light yellowish color with large uneven black marks on the body. It acts as potential food (with different unique tastes and a few numbers of spines) and game fish in many South Asian countries like Bangladesh, Nepal, Bhutan, and India (Nagarajan *et al*., 2016; Paul *et al.,* 2019; Alice *et al.,* 2020).

Relative fish growth occurs at different developmental stages that are considered effective tools at sexually mature stage (Bhuiyan and Islam, 1990). Other Body parts (e.g fins, eyes etc.) increase positively as their length increases (Balai *et al.,* 2017). Morphometric analysis is very important to understand taxonomy, systematics, growth variability, and potential differences between different stocks of identical species. Intraspecific morphological variations occur due to anthropogenic alteration in fish habitats (fertilizers and pesticide induction). Fish is very sensitive to habitat change which is indicated by morphological variations (Kaur *et al.,* 2019). The phylogenetic and taxonomic interactions can be analyzed through skeletal morphology between different fish species (Mafakheri *et al.,* 2014). A craniometric analysis is useful to classify and understand the genetic relationship among different fish species (Diogo and Bills, 2006). The present study was planned to find the habitat suitability for fish (*B.*

bagarius) growth through morpho-craniometric analysis among different populations residing at Head Trimmu (river Chenab) and Head Balloki (river Ravi).

1. MATERIALS AND METHODS

1.1. *Collection of Samples and their processing:*

A total of 20 *B. bagarius* samples (10 from each site) were collected from Head Trimmu (31.14° N72.14° E) in District Jhang and Head Balloki (31.23° N73.87° E) in District Kasur located on river Chenab and river Ravi respectively in the territory of Punjab, Pakistan (Figure 1).

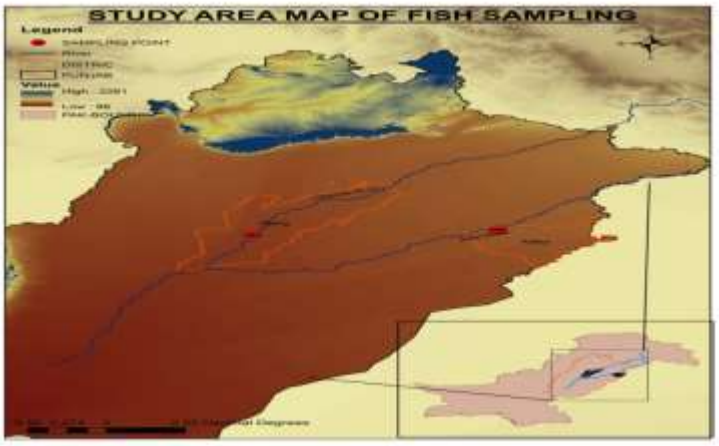

Fig 1: Map presenting the GPS locations of sampling sites (HB & HT)

After collection, the samples were transported to the University of the Punjab, while kept in an ice box (to avoid further digestion) At Laboratory, the samples were photographed, weighed and landmarks were applied by using tps-dig. The samples for craniometric analysis were prepared as (Taylor and Van Dyke, 1985):

(1) The heads of fish specimens were isolated and cooked in boiling water for ten minutes.
(2) The heads were placed in cold water for 15 minutes to stop the further cooking process.
(3) The tissues, muscles, and all other parts not required were removed with the help of sharp forceps.
(4) Skulls were kept in a 10% formaldehyde solution for one week.
(5) 70% dilute ethyl alcohol solution was used to soak the skulls (for removal of water and fats from the bones) for 7 days.
(6) Skulls were dried at room temperature.

1.2. *Morpho-craniometric analysis:*

A total of fourteen morphometric i.e. fork length, standard length, body depth, head length, total length, eye diameter, pre-dorsal length, pre-pectoral length, anal fin length pre-pelvic length, pelvic fin length, pectoral fin length, pre-anal length and dorsal fin base length were selected for analysis (Table 1, Figure 2).

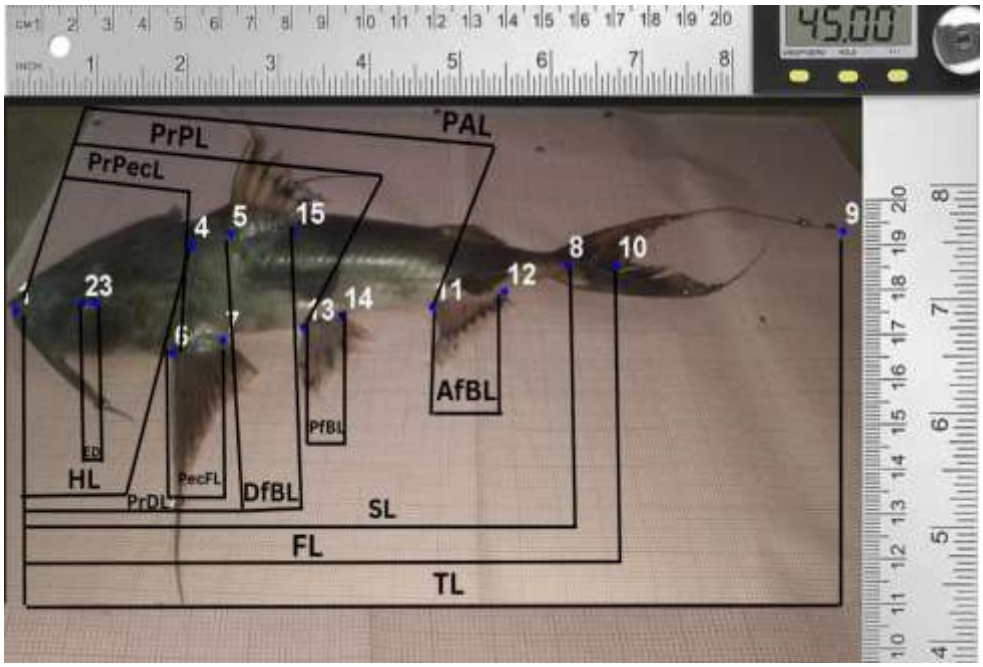

Fig 2: Specimen demonstrating the morphometric landmarks

Table 1: landmarks indication on the sample (*Bagarius bagarius*)

Description	Landmarks	Description	Landmarks
Total length (TL)	1-9	Fork length (FL)	1-10
Pelvic fin base length (PfBL)	13-14	Pre-pectoral length (PrPecL)	1-6
Head length (HL)	1-4	Pectoral fin length (Pec FL)	6-7
Pre-anal length (PAL)	1-11	Pre-dorsal length (PrDL)	1-5
Pre-pelvic length (PrPL)	1-13	Eye diameter (ED)	2-3
Standard length (SL)	1-8	Anal fin base length (AfBL)	11-12
Dorsal fin base length (DfBL)	5-15		

The morphometric variables and weight were measured in centimeters (cm) grams (g) respectively. For craniometric analysis (by using Vernier caliper), landmarks were applied on the skulls to measure different variables including skull height, eye socket depth, interorbital length, skull width, eye socket length and skull length (Table 2, Figure 3a, 3b & 3c).

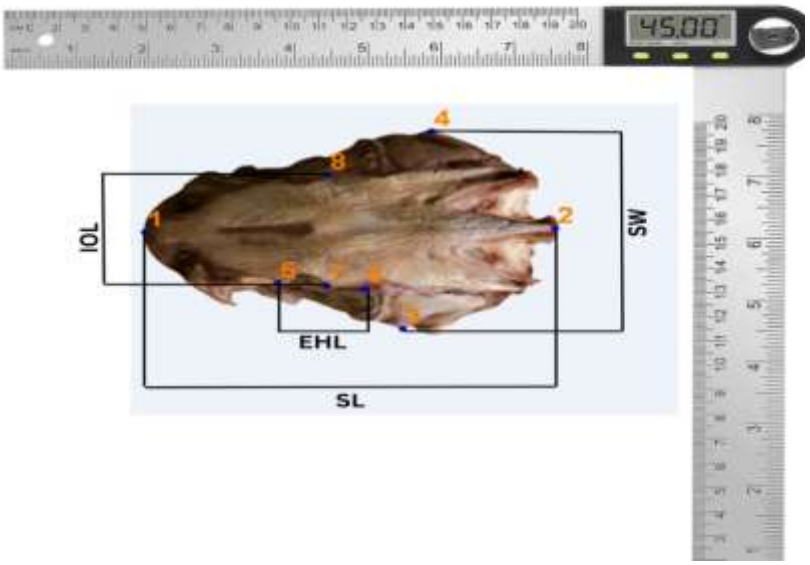

Fig 3a: Landmarks application on *B. bagarius*' skull (Dorsal View)

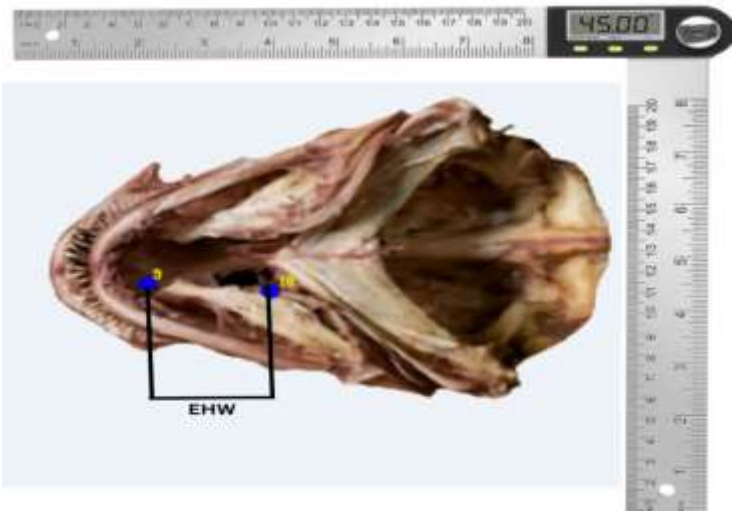

Fig 3b: Landmarks application on *B. bagarius*' skull (Ventral View)

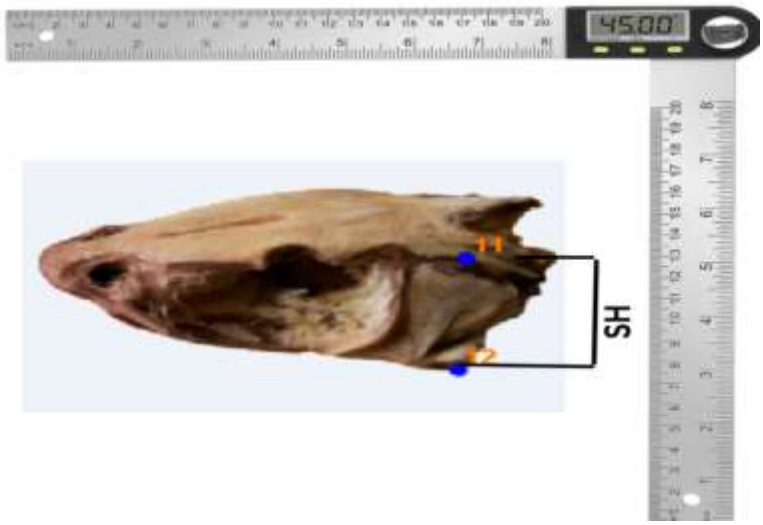

Fig 3c: Landmarks application on *B. bagarius*' skull (Lateral View)

Table 2: Craniometric landmarks indication on B. bagarius's skull

Landmarks	Description
1-2	Skull length (SL)
3-4	Skull width (SW)
5-6	Eye socket length (EHL)
7-8	Inter-orbital length (IOL)
9-10	Eye socket depth (EHW)
11-12	Skull height (SH)

2. Results and Discussion:

The values of the coefficient of correlation (R) for the morphometric variables (including FL, SL, HL, OD, BD, Pre DL, DFBL, Pre Pec L, Pec FL, Pre Pel L, Pel FL, Pre AL, and AFL) were as 0.79, 0.76, 0.83, 0.87, 0.74, 0.74, 0.79, 0.80, 0.81, 0.81, 0.85, 0.75, and 0.85 respectively from the Head Trimmu site while in the same fashion from head Balloki were recorded as 0.95, 0.98, 0.96, 0.94, 0.92, 0.94, 0.98, 0.97, 0.48, 0.91, 0.72, 0.74 and 0.96 respectively (Table 4).

From the current findings, it can be interpreted that most of the morphometric variables show a positive correlation with the total length (independent variable) but varies. A good correlation (0.75-0.1) was observed among ten variables i.e. FL, SL, HL, OD, DFBL, Pre Pec L, Pec FL, Pre Pel L, Pel FL, and AFL) while three variables (BD, Pre DL, and Pre AL) showed moderate (0.50-0.75) correlation. A weak correlation (0.25-0.50) was not observed in the

samples harvested from Head Trimmu. A good correlation (0.75-1) among 10 (FL, SL, HL, OD, BD, Pre DL, DFBL, Pre Pec L, Pre Pel L, and AFL), moderate (0.50-0.75) among two (Pel FL and Pre AL) while weak correlation (0.25-0.50) was recorded in one parameter (Pec FL) in the samples collected from head Balloki (Table 4).

Table 3: Morphometric variables from head Balloki (River Ravi) and head Trimmu (River Chenab)

Morphometric variables	Head Balloki (HB)			Head Trimmu (HT)		
	N=10			N=10		
	Range/cm		Mean & SD	Range/ cm		Mean & SD
	Min. Value	Max. Value		Min. value	Max. Value	
TL	49.2	80.6	66.17±11.79	19.8	26.8	24.23±2.52
FL	40.4	58.5	49.03±6.79	16.1	22.3	19.4±2.12
SL	33.2	51.8	43.1±6.74	14.1	20.8	17.73±2.33
HL	6.9	13.7	11±2.50	3.4	5.1	4.27±0.51
OD	1.1	2.2	1.67±0.35	0.3	0.7	0.53±0.12
BD	8.3	12.1	10±1.27	3.5	5.3	4.38±0.62
Pre DL	12.8	16.9	15.07±1.68	6.1	7.4	6.70±0.44
DFBL	3.1	6.8	5.13±1.40	2.1	2.6	2.4±0.15
Pre Pec L	12.2	14.4	13.4±0.74	3.9	5.9	4.9±0.59
Pec FL	2.4	5.1	3.43±0.99	1.1	1.9	1.5±0.24
Pre Pel L	20.4	27.1	23.27±2.55	7	12.1	9.3±1.73
Pel FL	2.0	5.0	3.23±0.94	1.1	1.7	1.43±0.18
Pre AL	29.1	40.5	33.02±3.72	10.5	15.1	13.33±1.44
AFL	3.5	6.7	5.37±1.27	1.2	1.8	1.53±0.18

Table 4: Regression analysis of morphometric characteristics of *B. bagarius*

Morphometric variables	*B. bagarius* (Head Balloki)			*B. bagarius* (Head Trimmu)		
	Y= a+ bX	R	p-value	Y= a+ bX	R	p-value
FL	12.823+0.547	0.95	0.016	3.818+0.643X	0.79	0.01
SL	5.999+0.561	0.98	0.051	-0.012+0.732X	0.76	0.006
HL	-2.519+0.204	0.96	0.087	0.231+0.167X	0.83	0.03
OD	-0.198+0.028	0.94	0.000	-0.472+0.041X	0.87	0.001
BD	3.395+0.100	0.92	0.008	-0.049+0.183X	0.74	0.013
Pre DL	6.210+0.134	0.94	0.000	3.443+0.134X	0.74	0.013
DFBL	-2.610+0.117	0.98	0.000	1.265+0.047X	0.79	0.006
Pre Pec L	9.325+0.062	0.97	0.000	0.283+0.191X	0.80	0.005
Pec FL	0.801+0.040	0.48	0.155	-0.420+0.079X	0.81	0.004
Pre Pel L	10.262+0.197	0.91	0.000	-4.156+0.555X	0.81	0.005
Pel FL	-0.615+0.058	0.72	0.018	-0.041+0.061X	0.85	0.002
Pre AL	17.363+0.237	0.74	0.013	2.910+0.430X	0.75	0.012
AFL	-1.478+0.103	0.96	0.000	0.059+0.061X	0.85	0.002

The moderate and weak correlations present a significant effect of the environment on morphology and fish growth. The variation controlling factors may be pollution and the feeding competition among aliens (e.g., Tilapia) and native species (*B. bagarius*) or any other stress. Fish growth pattern at head Balloki is more affected than head Trimmu which might be the result of intensive pollution. Ravi river continuously is being contaminated through population (Ullah *et al.*, 2009; Fordyce *et al.*, 2007). The Environment Protection Department of Punjab claimed that about 1120 industrial units add 800,000 m^3 of untreated waste (less dilution) which leads to the extinction of the fish population. River Ravi is facing highest level of pollution than other Pakistani rivers (Ahmed and Ali, 2000). Its physicochemical parameters are rapidly changing as a result of anthropogenic activities which ultimately lead to water quality deterioration and make it unfit for biological purposes (Hussain *et al.*, 2013).

Most of the craniometric characters (SL, SW, IOL, and SH) from both sampling sites showed significance while two (EHL and EHW) had non-significant correlations (Table 6).

Table 5: Craniometric measurements of *B. bagarius* from River Ravi (HB) and River Chenab (HT)

Craniometric characteristics	***B. bagarius*** (Head Balloki)			***B. bagarius*** (Head Trimmu)		
	N=10			**N=10**		
	Range (mm)		**Mean & SD**	**Range (mm)**		**Mean & SD**
	Min. Value	**Max, Value**		**Min. Value**	**Max. Value**	
SL	10.97	14.52	13.01±1.17	4.35	5.94	5.12±0.58
SW	6.3	8.81	7.78±1.01	1.39	2.33	1.86±0.31
EHL	1.5	1.66	1.597±0.05	0.78	0.89	0.83±0.04
IOL	2.9	4.11	3.496±0.50	1.19	1.96	1.49±0.28
EHW	0.36	0.39	0.38±0.01	0.2	0.31	0.27±0.04
SH	3.13	5.54	4.44±0.90	2.5	3.61	2.99±0.45

Table 6: Craniometric analysis of *B. bagarius* from Head Trimmu and Head Balloki

		EHL	**SW**	**EHW**	**IOL**	**SH**	**SL**
SL	Pearson Correlation	.500	.732*	.147	.689*	.792**	.749*
	Sig. (2-tailed)	.141	.016	.686	.028	.006	.013
SW	Pearson Correlation	.508	.786**	.237	.647*	.858**	.788**
	Sig. (2-tailed)	.134	.007	.510	.043	.002	.007
EHL	Pearson Correlation	.530	.787**	.335	.667*	.878**	.792**
	Sig. (2-tailed)	.115	.007	.345	.035	.001	.006
IOL	Pearson Correlation	.658*	.708*	.263	.848**	.836**	.813**
	Sig. (2-tailed)	.039	.022	.463	.002	.003	.004
EHW	Pearson Correlation	.639*	.933**	.250	.709*	.910**	.898**
	Sig. (2-tailed)	.047	.000	.487	.022	.000	.000
SH	Pearson Correlation	.555	.712*	.161	.751*	.785**	.767**
	Sig. (2-tailed)	.096	.021	.657	.012	.007	.010

*. Significant Correlation is at 0.05 level (2-tailed)
**. Significant Correlation is at 0.01 level (2-tailed)

The variations among the craniometric variables might be due to the nature of food and water quality (Cooper *et al.,* 2009). This study also confirmed that the growth of fish was more affected at the head Balloki as compared to the head Trimmu. The results are harmonized with the prior studies conducted on *L. rohita* by Kaur *et al.,* (2019) and confirmed the strong correlation among morphometric variables. Habib *et al.,* (2019) analyzed the morphometric characteristics of species belonging to the family Cyprinidae at Jinnah Barrage, river Indus, Pakistan, and confirmed the good correlation between total length (TL) and other morphological characteristics. Allendorf and Phelps (1980) and Wimberger (1992) affirmed that environmental factors like the availability of food, habitat allocation, temperature range, and invasive pressure are the main cause of morphological variations among fish populations.

CONCLUSION:

The present study concluded that the TL and almost all other morphometric variables of *B. bagarius* were in a high positive correlation with each other indicating the positive boost in the morphometric characters when compared to the TL of the fish species at both sampling sites (HT and HB). A moderate correlation of some variables in the samples of HT (river Chenab) showed that there are some environmental factors affecting the relationship of TL with other variables which in the future may produce more severe effects on morphological variations. A moderate and weak correlation in the samples of HB (river Ravi) is more prominent as compared to HT which can be increased shortly in the absence of appropriate measures. Some craniometric characters showed variation from each other in the samples collected from head Balloki and head Trimmu. This may be due to the effect of environmental factors differently on the craniums of both sites' fish. Further studies can be designed concerning the length-weight relationship and craniometric analysis to find the effect of pollution, stress, and competition of alien and native species for better management of fish and aquatic ecosystems.

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CONFLICT OF INTEREST:

The authors have declared that no conflict of interest exists.

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AUTHORS

First author:

Jaweria sehr (BS Hons. Zoology), Institute of Zoology, University of the Punjab, Lahore.

Second author:

Muhammad Imran (Ph.D. Zoology), Institute of Zoology, University of the Punjab, Lahore.

Third author:

Abdul Majid Khan (Ph.D. Zoology), Institute of Zoology, University of the Punjab, Lahore.

Forth author:

Arshia Naseer (M. Phil Zoology), Institute of Zoology, University of the Punjab, Lahore.

Correspondence Author: Muhammad Imran