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Ecological Dynamics of Fish Assemblage in River Chenab of the Himalayan River System (J&K): A Multivariate Analysis of Spatio-Temporal Disparities, Fisheries Condition Factor and Conservation Strategies

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River Chenab is one of the most significant bodies of water in J&K.Despite its economic importance, there is a significant research gap about the current state of its Ichthyofaunal Richness.With the aim to analyse the structure, composition, spatial and temporal patterns of diversity and abundance of Ichthyofauna in the River, extensive sampling of the River was carried out from August 2022 to August 2023.During the entire period of study a total number of 23 species were reported belonging to 9 families and 6 orders, with Cypriniformes as the most dominant family. Furthermore, it was observed that the mean number of species per site peaked during the monsoon, followed by pre-monsoon, and fell to its lowest, during the post-monsoon/winter period. Diversity was lowest in the upper catchment region, Kishtwar (Temperate zone) while it was highest in downstream region (Pargwal) due to favorable climatic and topographical conditions. Schizothorax esocinus, Oreochromis niloticus and Astanyx sps. were reported for the first time from the region. Also, the invasion of exotic species (Oreochromis niloticus, Cyprinus carpio) may pose a threat to the native fauna, necessitating the immediate planning of conservation programmes.The morphometric analysis of the five economically important dominant species (Schizothorax plagiostomus, Schizothorax labiatus, Schizothorax esocinus, Schizothorax richardsonii, Labeo boggut) revealed significant differences, underscoring the influential role of environmental variables in shaping their distinct characteristics. Additionally, the meristic examination established notable differences among the species, strongly indicating a genetic basis for meristic traits and highlighting notable variations both within and between species. In addition to it, analysis of Length-weight relationship of the five species reveals a lower value of K (K<1) indicating a reduction in the overall quality of the environment or the accessibility of food. In order to build conservation plans for native fish fauna in response to changing conditions, the study advises limiting overexploitation and illegal fishing, as well as doing more in-depth investigation regarding the effects of aquatic toxicity and invasive species on local fish fauna.

Keywords: Ichthyofauna, Schizothorax, Cypriniformes, Conservation, Morphometry, Fulton factor.

1. Introduction

Fish are fast-moving aquatic creatures that are often camouflaged. Thus, recognising its variety and quantity is challenging. Fish have more species and individuals than any other group of vertebrates and they inhabit practically all of the world's waterways (Wheeler et al., 1989).One fourth of the world's vertebrates are freshwater fish (Suetal.,2021), which provide valuable products and services being utilized since ages (Stewart, 1994).Fish constitutes essential dietary component because of its high protein content (Lim° & Dominyb, 1989)(Steffens, 2006) (Silva et al., 2014).Inland fish and fisheries significantly aid in addressing the problems that people, society, and the environment face in a changing world. From less than fraction of one percent of the total quantity of water present on earth, aquaculture and inland capture fisheries generate more than 40% of the total recorded finfish in the world and millions of people throughout the world are dependent on these fishes for their livelihood (Lynch et al., 2016).

Complexity of habitat and seasonal fluctuation have a substantial effect on fish numbers (Winemiller & Jepsen, 1998;Novaes et al., 2014) Seasonal fluctuation in ecological variables exerts a significant influence in a species recruitment, breeding patterns, food and feeding preferences (Lofts et al., 1968; Billard et al., 1981;Das et al., 2012).The aquatic environment therefore has a crucial influence in determining the organisation of fish assemblages and the diversity pattern (Hughes & Gammon, 1987;Brown, 2000;S. Giller et al., 2004) The primary determinants impacting the fish assemblage in aquatic environments are the effects of environmental elements at multiple spatial scales (Pont et al., 2006;Kamler, 2008;Dubey et al., 2012) Due to the availability of sufficient resources and services for feeding, refuges, and reproduction, an aquatic environment with a complex habitat structure can sustain more fish species and individuals (Dibble et al.,1997; Hayes et al.,1996; Schiemer, 2000) Thus, environmental factors are the most essential aspects for the conservation and management of fish populations (Davis et al., 2010; ERőS, 2007).

Climate change has influenced distribution of fish and its productivity in both marine and freshwater species, which has a detrimental impact on the sustainability of fisheries and aquaculture, and thus on the lives of populations that rely on fisheries (K. M. Brander, 2007) (Ficke et al., 2007;Allison et al., 2009)(K. Brander, 2010)(Cinner et al., 2012).Cumulative Change in Biodiversity Facets, uncovered significant changes in biodiversity in more than 50% of the world's rivers, while 14% of the world's surface and River length remain least impacted. Understanding potential changes in the diversity, density and distribution of fish species is crucial to monitoring and conservation programs due to the importance of fish to mankind (Hu et al., 2017).The fish fauna of present day rivers is more homogenous; which inhabit species with various morphologies and longer evolutionary histories. River fragmentation and the introduction of exotic species are chiefly responsible for greatest impact in case of temperate rivers (Su et al., 2021). Biological invasions are an important factor contributing to global warming and have disastrous effects on the environment and the economy anywhere they occur(Gallardo et al., 2016).Introduction of non-native aquaculture and ornamental species, endanger ecosystem function and biodiversity by disrupting the food chain(Shuai & Li, 2022)

Fish appear to be useful indicators of the condition of aquatic communities and river ecosystems (Schneiders et al., 1993),hence are a vital component of environmental planning (Schiemer, 2000).It is common to analyse communities and their responses to anthropogenic or natural changes using trait-based methodologies, Morphological traits give integrated information about functional and evolutionary history (Caillon et al., 2018). One of the simplest, most accurate ways to identify any fish species is by studying morphometric traits and meristic counts (Nayman, 1965) (SHEIKH & AHMED, 2019)(Sidiq et al., 2021).

The characteristics of Length weight relationship (LWR) which are influenced by multiple ecological and anthropogenic factors, reflect the allometric growth of fishes (Perçin & Akyol, 2009). Fish LWRs are influenced by both external and internal factors, including length variation, population size, habitat type, periodicity, sex, and dietary habits (ABBASI et al., 2019).Length weight relationship in fishes is also highly significant as they allow conversion of growth in length equation into growth in weight equation, estimation of biomass in the fish and its overall health and condition.(Le Cren, 1951;Bolger & Connolly, 1989, Mendes et al., 2004;Cicek et al., 2006;Tarkan et al., 2006;Kalaycı et al., 2007; Arafat & Bakhtiyar, 2022).

The riverine fishery resources in India is immense. Fisheries sector is a source of livelihood for around 14.49 million individuals involved fully, partially or in secondary activities associated to the sector. India’s second-largest fish producer is Aquaculture after China (Acharya et al. 2019).

The territory of Jammu and Kashmir (J&K), also known as the "crown of India," is located in the Northwest Himalayas of India between 32.28°- 37.06° latitude and 72.53°- 80° east longitude. When total runoff, total water body area, and the extent of its drainage pattern are evaluated, Jammu and Kashmir stands out in terms of its water resources (Shukla and Ali, 2018).The subtropical climate of the Jammu region is accompanied by a plethora of water bodies that provide abundant water resources for the growth of fishing (Chib & Jasrotia, 2022; Chib et al., 2023).The state is renowned for its approximately 3650 wetlands and lakes The ice and snow melt waters of the region sustain the Chenab, Indus and Jhelum rivers, which give numerous resources to the 300 million inhabitants of the Indus basin (Dar & Khuroo, 2020).The River Chenab is a vital waterway that flows through India and Pakistan, making it a significant geographical and cultural feature in the region. Its importance can be highlighted in various aspects. Fish diversity of the river has been extensively studied in Pakistan by,(Altaf et al., 2008)(Altaf et al., 2011)(Altaf et al., 2015)(Latif et al., 2015)(Latif et al., 2016)(Bibi et al., 2018)(Muhammad et al., 2019).However there remains considerable research gap regarding the current status of fish diversity of River Chenab and state of its edible fishes in Jammu region (J&K).Present study attempts to fill the research gap and update the information on the current status of fish diversity of the River.

2. MATERIALS AND METHODS:

2.1. Study area and sampling:

Origin and physiography:

River Chenab: (29°20′57″N 71°1′41″E) Chenab originates from two glacial melt-fed Himalayan streams - Chandra and Bhaga at an elevation of 5600 m above sea level. The Chandra after flowing south-east for 125 kms, conjuncts with Bhaga at Tandi. Hereafter, the river is known as Chandra-Bhaga (Moon river) or Chenab. After traversing 48 kms it receives Mujar nallah, which is the first tributary of Chenab. The river then continues to flow for another 96 kms, through the Pangi Valley of Chamba (H.P.) and thereafter it enters into the Padder valley of Doda (J&K) at an altitude of 1818 m. From Padder onwards, it traverses a total of 288 kms, between stiff cliffs of high mountains and another 40 kms through lower hills to Akhnoor. It continues into Pakistan after turning southwest, and passes from the uplands into the wide alluvial lowlands of Punjab province. The Chenab drains into the Sutlej River (an Indus River tributary) after receiving the Jhelum River close to Trimmu. The river's entire length is around 605 miles (974 km), and it feeds various irrigation canals in both the regions of India and Pakistan. The river is created by alluvial deposits and frequently faces riverbank and river channels dynamics owing to floods. https://indiawris.gov.in/wiki/doku.php?id=chenab

Hydro-ecological Status:

Three distinct river zones (one each at upstream, midstream, and downstream) were chosen (fig 1)(Table 1).The climate in the upstream region (Kishtwar) is temperate. The average yearly temperature ranges from 25°F to 77 °F, rarely dipping below 16°F or going over 83°F. Seasonally, the monthly precipitation in Kishtwar fluctuates considerably. July is the wettest month which receives an average precipitation of 8.5 centimeters, while November is the driest month with an average precipitation of 1.3 centimeters. The mid-stream region of Reasi, which is also a popular tourist destination, one of the most striking qualities of Reasi is that its summer temperatures will be lower than those of the rest of Jammu districts, but its winter temperatures will be higher. So, this makes the location almost ideal for all types of visitors. http://dcmsme.gov.in/old/dips/DPS_Reasi.pdf The average annual rainfall in the district is 205.01 centimeters, which fluctuates widely. August is the wettest month with an average of 61.16 centimeters of precipitation, while the winter months (December to February) account for around 13% of the annual average rainfall. The downstream portion of the Pargwal river has subtropical climate. The average annual temperature ranges from 43°F to 100°F, rarely falling below 38°F or rising above 108°F. Extreme seasonal variance in monthly rainfall is observed in Pargwal. Rainfall occurs year-round in Pargwal. July is the wettest month in Pargwal, with an average rainfall of 16.76 centimeters. November is the month with the lowest average rainfall, at only 1.02 centimeters. https://weatherspark.com

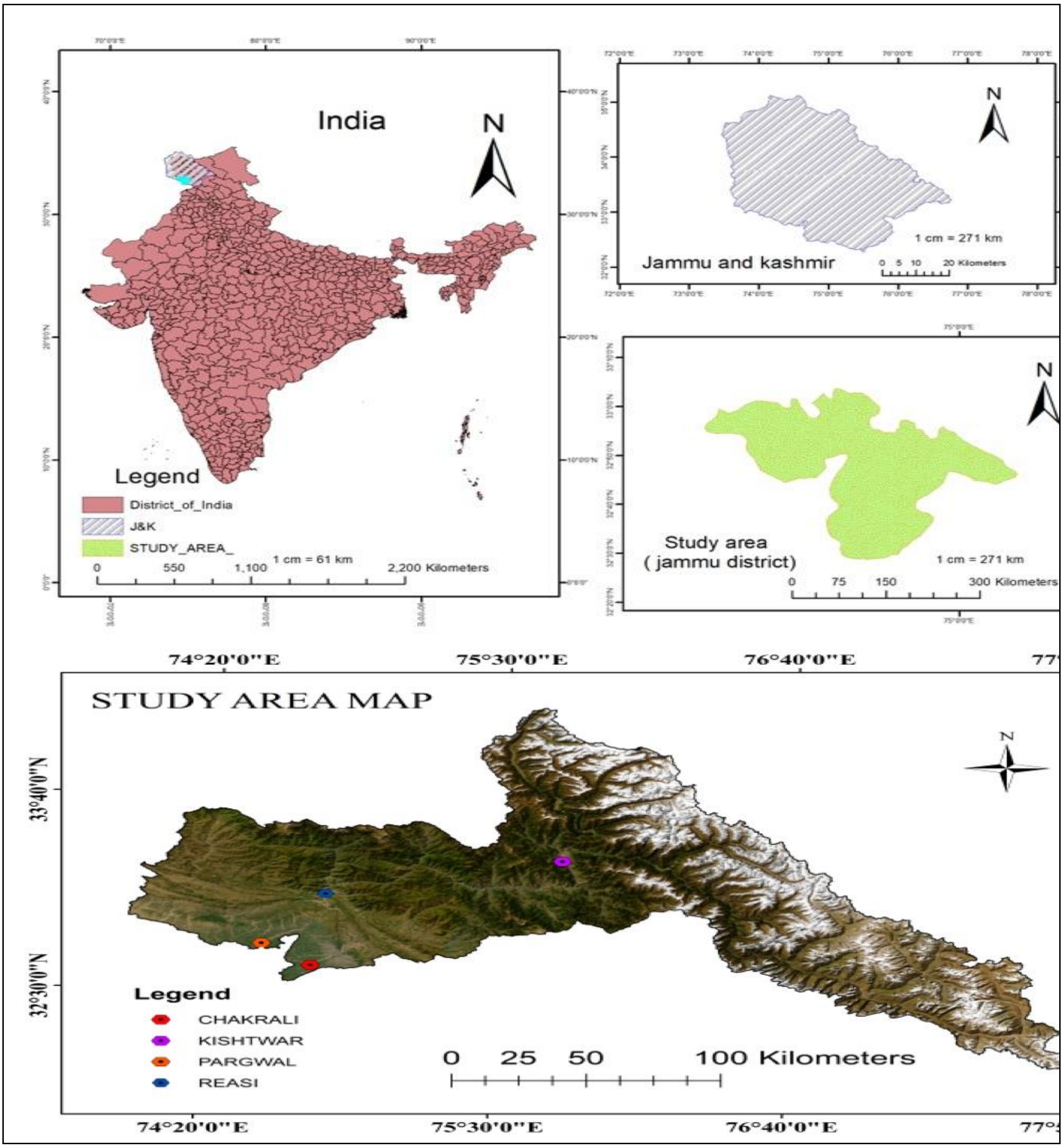

Fig.1: Study area Map (marked using ARC-GIS)

Table1-Sampling Stations

Sno.	Sampling station	Characteristic of sampling stations	Co-ordinates Lat	Long
1.	Kishtwar	Upstream location next to a popular pilgrimage place and residential area.	33°19'5"N	75°45'38"E
2.	Reasi	Mid-Stream Region located below the Chenab Bridge.	33°10'20.40"N	74°51'05.97"E

3.	Pargwal	Down Stream Residential area frequently visited by domestic animals for drinking water.	$32^0$46’52.16”N	$74^0$33’24.61”E
4.	Chakrali	Narrow distributary downstream with a shallow water depth and dense tree canopy on both the sides.	$32^0$39’07.27”N	$74^0$45’38.96”E

Station1. Kishtwar

Station2. Reasi

Station 3. Pargwal

Station 4.Chakrali

Fig 2: Images of sampling stations.

Sampling:

One monitoring station for each zone was established (Kishtwar, Reasi, Pargwal) along with one tributary (minor tributary at Chakrali most commonly exploited for fishing) at downstream region (fig2). Monthly visit of field was conducted in order to study local fish fauna, distribution pattern and dominating species. Fishes were collected using Cast nets and Gill nets. Large sized fishes were injected with 10% formaldehyde to prevent spoilage of visceral organs.

After collection, the fishes were transferred to Research Lab (Department of Zoology), Central University of Jammu, Species identification was done using standard taxonomic keys (Day, 1888)(Jayaram, 1999) (Talwar & Jhingran, 1991).Following the IUCN red list of vulnerable species, the conservation status was determined.

In addition to the analysis of diversity the present study also assesses morphometric and meristic characterization of some dominant fishes of river Chenab, Jammu (J & K).Total 350 fishes (adult specimens) 70 each from five dominant species viz. Schizothorax esocinus (SE), Schizothorax plagiostomus (SP), Schizothorax labiatus (SL), Schizothorax richardsonii (SR) and Labeo boggut (LB) were collected seasonally (pre monsoon, monsoon and post monsoon) from selected sites (upstream, midstream and downstream).Total 30 variables, 23 morphometric (total weight, total length, fork length, standard length, pre pelvic length, pre pectoral length, pre dorsal length, pre anal length, pectoral fin height, pectoral fin length, pelvic fin height, pelvic fin length, dorsal fin height, pelvic fin length, anal fin length, anal fin height, caudal fin length, caudal fin height, maximum body depth, minimum body depth, pre orbital length, inter orbital length and head length) and six meristic (pectoral fin rays, pelvic fin rays, dorsal fin rays, caudal fin rays, anal fin rays, and lateral line scales) characteristics were assessed. The morphometric characteristics viz. weight was measured in grams (gms) whereas length, height and depth were measured in centimeters(cm). The meristic characteristics were assessed in scores (or counts). LWR (Length weight relationship), condition factor and values of "a" and "b" were reported. If "b" is less than three, the fish gets slender as its length increases. Therefore, the "b" value is fixed at three for ideal fish, with a lower or higher value of "b" indicating positive or negative allometric growth ranges, respectively (Kuriakose, 2017).

The main objectives of this analysis were (i) to find out any differences/variations in mean morphometric and meristic characteristics among species, (ii) to find out correlation between morphometric and meristic characteristics, (iii) to estimate length-weight relationship, (iv) to estimate condition factors of the species and (v) to estimate similarity/dissimilarity among species using morphometric and meristic characteristics and condition factors of the species.

Statistics:

The morphometric as well as meristic characters of five different species were summarized in Mean ± SD (standard deviation). Species were compared through one factor analysis of variance (ANOVA) and analysis of the significance of mean difference among the species was done by Tukey's HSD (honestly significant difference) post hoc test. Pearson correlation analysis was done to analyse association between the variables (morphometric and meristic characteristics). Simile linear regression (SLR) analysis was done to assess length-weight relationship ($y=a + bx$) considering the total length as independent variable (x) and total weight (including gonads) the dependent variable (y). The SLR analysis was done on Log_{10} transformed data of both total weight and total length. Cluster analysis (Single linkage and Euclidean distances) was done to assess similarity/dissimilarity among species using standardized mean morphometric and meristic characteristics and condition factors. A two-tailed ($\alpha=2$) $P < 0.05$ was considered statistically significant. The analysis was done through STATISTICA software (TIBCO Software Inc., Version 13.5.0.17).

3. RESULTS AND OBSERVATIONS:

3.1. Fish diversity and major species

A total number of 23 Fish species were reported (Table 2) (fig3) belonging to 8 families and 6 orders during the entire period of study with Cypriniformes as the most dominant family (fig4). In the Kishtwar (upstream region), only four species were recorded. From the midstream region of Reasi, as many as Eight different species were recorded, Fourteen species were collected from Pargwal, and the number of species expanded to twenty-three when tributary (Chakrali) was sampled. Also, it was noted that the mean number of species at each sampling station peaked during the monsoons, dropped to its lowest point during the post-monsoon/winter season, and then rose again during pre-monsoon.

3.2. Fish assemblage structure and classification of fishes.

Based on variations in flora and fauna in running water systems, several attempts have been made in the past for casting a division of riverine systems into different zones or classifying various river systems into distinct groups (Maitland, 1978). Several workers have devised schemes of zonation for running water systems studied by them by restricting themselves to the analysis of one or more factors. For example, Harrison and Elsworth (1958) based their scheme of zonation on the type of substrata. Grimes (1940), classified river into several zones based on the vegetation and Schmitz (1955), classified river into several zones on the basis of invertebrates.

Nonetheless, the most commonly acceptable method of differentiation of zones in the rivers is, using distribution pattern of fish species found .The scheme was described originally by Thienemann (1912) for European rivers and later highlighted by Carpenter (1927). However, in the meantime Singh (1988) and Singh & Kumar (2000) categorized glacier-fed Himalayan streams, based on the altitude, stream width and dominant fish species, into five zones viz;

1.No fish zone (2400-3600 m and above),

2.Glyptothorax and Pseudoechenesis zone (1800-2400 m),

3.Schizothorax or snow trout zone (1200-1800 m),

4.Mahseer (Tor) zone (600-1200 m), and

5.Crossocheilus zone (300-600 m).

But as per Singh and Kumar (2000), these above mentioned zones do not represent strict boundaries as in some glacier-fed streams such as Alknanda and Bhagirathi, the Schizothoracids have been reported from 600m to 1800 m or above.

Since the present study involves only the middle stretch of river Chenab, so the 'no fish zone' can't be determined. But as far as other zones are concerned, there is a steep gradient as Glyptothorax zone varies from 300 m to 600 m; Schizothorax zone extends from 300 m to 1400m, Mahseer zone varies from 240 m to 940 m, thereby suggesting that the so casted zones overlap each other in case of Chenab drainage system. Thus, on the basis of adoption of above said classification, the river Chenab can be divided into two divisions i.e.,

1.Snow trout zone, where members of native snow trouts like Schizothorax plagiostomus, Schizothorax richardsonii, Schizothorax esocinus and Schizothorax labiatus dwell.

2.The barbel zone (where carps with barbels such as Glyptosternum reticulatum, Glyptothorax pectinopterum etc. dwell.

Owing to their temperature tolerance fishes have been categorised into two types, on the basis of culture practices viz:

1.Warm water fisheries (those culturable fishes which flourish at temperatures above 20°C).

2.Cold water fisheries (those culturable fishes whose optimal temperature range varies between 10°C to 20°C).

In line with this, based on the temperature tolerance, the fishes of Chenab drainage system could be classified into three broad categories namely:

1.Eurythermal fishes: These fishes tolerate wide range of temperature from 10° C to 30°C and inhabit both main river and its tributaries equally well and this category includes the following fish species viz; Tor putitora, Tor tor, Garra gotyla.

2.Cold stenothermal or cold water fishes: These fishes live exclusively in the main river & the optimal temperature range in their case varies from 10° C to 20° C. This category includes following fish species viz; Glyptosternum reticulatum, Schizothorax richardsonii, Schizothorax labiatus, Schizothorax esocinus and Schizothorax plagiostomus.

3.Warm stenothermal or warm water fishes: Mastacembalus armatus, Mystus vittatus are the fishes included in this category and they live exclusively in tributaries and their optimal temperature tolerance range varies from 20°C to 30°C, respectively.

Here Cyprinus carpio seems to have got inadvertently released from the experimental station of Fisheries Department at Gatha, Bhaderwah and the fish has acclimatized itself to the ecological conditions of Neeru (Nallah) waters and by now have spread in almost all the regions of river Chenab.

Out of the total 23 species of fish that the Chenab drainage system harbors, more than half a dozen are significant from the point of view of commercial fisheries, including the categories of both, edible fishes and ornamental fishes. Also it was observed that the downstream region Pargwal (tropical zone) inhabits highest number of species and catch per unit effort, while the fish fauna of tributary is entirely different from that of the main course and generally inhabits mostly the ornamental fishes.

Table2. FISHERY RESOURCE OF RIVER CHENAB, JAMMU (J&K).

Species	Family	IUCN Status	Exploitation Status	Kishtwar	Reasi	Pargwal	Chakrali
1.Schizothorax plagiostomus	Cyprinidae	VU	FD	_	+	+	_
2.Schizothorax labiatus	Cyprinidae	NE	FD	_	+	+	_
3.Schizothorax esocinus	Cyprinidae	VU	FD	_	+	+	_
4.Schizothorax richardsonii	Cyprinidae	VU	FD	+	_	_	_

5.Oncorhynchus mykiss	Cyprinidae	NE	FD	+	_	_	_
6 Tor tor	Cyprinidae	DD	FD	_	+	+	_
7 Tor putitora	Cyprinidae	EN	FD	_	+	+	_
8 Glyptosternum reticulatum	Sisoridae	LC	OR	+	_	_	_
9 Glyptothorax punjabensis.	Sisoridae	LC	OR	_	+	+	+
10 Channa punctata	Channidae	LC	FD	_	_	+	+
11Channa marulius	Channidae	LC	FD	_	_	+	+
12 Puntius chonchonius	Cyprinidae	LC	FD/OR	_	_	_	+
13Mastacembelus armatus	Mastacembelidae	LC	OR	_	_	+	+
14Ompok pabda	Siluridae	NT	FD	_	_	+	+
15Mystus seenghala	Bagridae	LC	FD	_	_	+	+
16Garra gotyla	Cyprinidae	LC	OR	_	+	+	+
17Rasbora danioconius	Cyprinidae	LC	OR	_	_	_	+
18 Rasbora sps.	Cyprinidae	LC	OR	_	_	_	+
19Labeo boggut	Cyprinidae	LC	FD	_	_	+	+
20Cyprinus carpio	Cyprinidae	VU	FD/OR	+	+	+	+
21Oreochromis niloticus	Chichlidae	LC	FD	_	_	_	+
22Astyanax sps.	Characidae	NE	FD	_	_	_	+
23Xenentodon cancilla	Belonidae	LC	OR	_	_	_	+

DD(data deficient), EN(endangered), LC(least concern),NT(near threatened),VU(vulnerable), FD(food), OR-(Ornamental) Source: (Fish base.org ; IUCN, 2017).

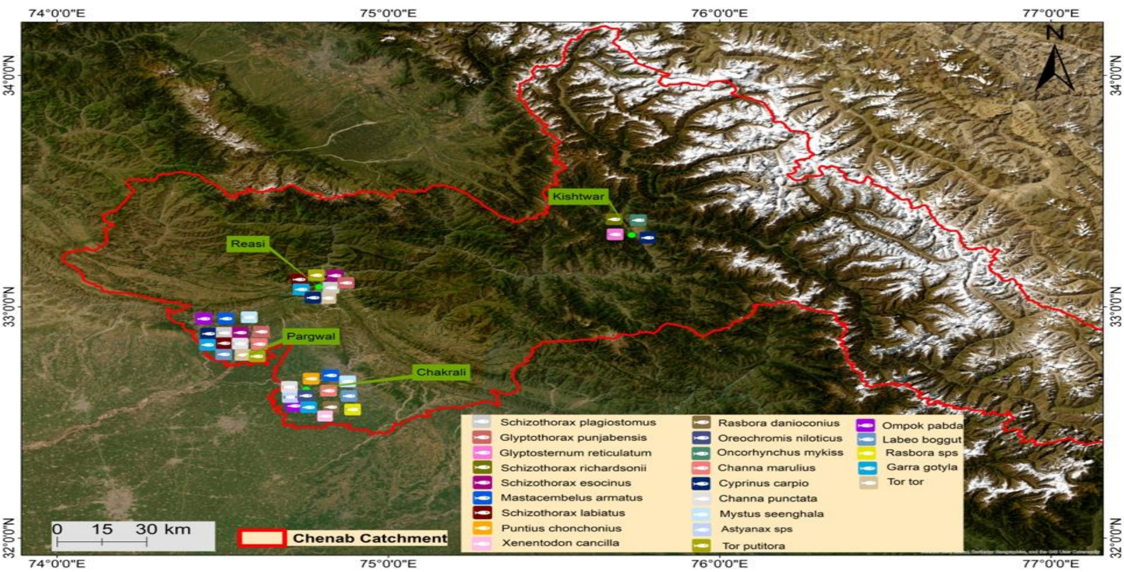

Figure 3. Ichthyofaunal diversity of the Chenab marked through ARC-GIS.

3.3 Fish Species Distribution and Abundance

The results of the present study depicted that these fishes illustrated an uneven distributional pattern (fig3) Schizothorax which contributed maximum to the total weight of fish catch (99.44% at Kishtwar; 97.56% at Pargwal; 76.18% at Reasi) at different stations. Mahseer (Tor sps.) dominated the catch at Reasi during winters and contributed 68.36% to the total weight of fish fauna caught, while 14.80% to the total weight of the fauna caught at Pargwal. Labeo boggut constitute 20% of the catch in the midstream and downstream region. In the head waters of River Chenab (at Kishtwar) Glyptosternum was recovered which contributed 1% to 2.45% to the total weight of fish caught, which is replaced by Glyptothorax in lower waters. Garra is typically found at Reasi and is caught in downstream waters of Pargwal during the monsoons, Channa inhabits both the main River Channel and its tributaries.

3.4. First time reports: Fish species reported for the first time from the region include Schizothorax esocinus, Oreochromis niloticus and Astanyx sps.

3.5 Exotic fish species: As a result of sewage water discharge into Lakes Mansar and Surinsar, many native freshwater fish perished from an unspecified disease, prompting the introduction of exotic carp species. Due to its Omnivore nature, Carp eradicated Jellyfish and other sensitive local fish fauna and has affected the aquatic vegetation as well. Furthermore, the State Fisheries Department has also introduced Ctenopharyngodon idella, Catla catla, Labeo rohita , Hypothalmichthys molitrix ,Cyprinus carpio communis, and Cyprinus carpio specularis into different water bodies of the region (Dutta, 2015;Sharma et al., 2016).

Gradual Invasion of Carp and advent of Nile Tilapia: Cyprinus carpio has already invaded most of the water bodies of Jammu and Kashmir, based on the comparative study of the River (Baba et al. 2014) the Carp was previously documented exclusively in the tributaries of the upstream region, but has now steadily infiltrated the downstream region as well. Even though Cyprinus carpio makes up less than 2% of the overall catch, it has colonized the entire body of water and is catchable from the head waters to all the way down Pargwal. This gradual invasion of the Carp could prove a potent threat to Schizothorax, Tor and other endemic fish Species.

The presence of Nile Tilapia (Oreochromis niloticus) has been documented as a nuisance in various water bodies, raising concerns about potential serious implications in the current context. The invasion of Nile Tilapia is associated with a decline in the diversity and trophic status of native fish species, leading to a shortened food chain.This underscores the need for careful consideration of the potential ecological consequences of Nile Tilapia introduction.

Figure 4. Relative contribution of various Orders, families and species to fish diversity of River Chenab.

Table 3: Summary statistics (Mean ± SD) and comparisons of morphometric and meristic characteristics among five species using ANOVA

Variable	SP (n=70)	SL (n=70)	SE (n=70)	SR (n=70)	LB (n=70)	F value	P value
Total weight (gm)	193.93 ± 80.03	318.60 ± 79.62	270.21 ± 113.50	109.33 ± 128.20	256.30 ± 91.55	45.14	< 0.001
Total length (cm)	28.16 ± 3.69	33.70 ± 2.35	31.36 ± 3.55	21.41 ± 7.98	30.79 ± 3.71	71.48	< 0.001
Standard length (cm)	23.19 ± 3.18	28.21 ± 2.14	26.22 ± 3.19	17.50 ± 6.67	24.92 ± 2.94	74.39	< 0.001
Fork length (cm)	25.09 ± 3.37	30.23 ± 2.11	28.44 ± 3.33	19.11 ± 7.22	26.67 ± 3.15	71.25	< 0.001
Pre pectoral length (cm)	4.66 ± 0.71	6.00 ± 0.60	6.22 ± 0.80	3.66 ± 1.10	4.81 ± 0.44	132.96	< 0.001
Pre pelvic length (cm)	11.54 ± 1.55	14.11 ± 1.10	13.72 ± 1.61	8.93 ± 3.23	11.81 ± 1.31	81.62	< 0.001
Pre dorsal length (cm)	11.13 ± 1.69	13.52 ± 1.71	13.30 ± 1.79	8.37 ± 3.03	10.25 ± 1.18	83.44	< 0.001
Pre anal length (cm)	17.28 ± 2.31	20.20 ± 4.07	19.74 ± 2.47	12.54 ± 4.50	17.99 ± 2.15	61.51	< 0.001
Pectoral fin length (cm)	0.91 ± 0.13	1.08 ± 0.12	1.03 ± 0.12	0.63 ± 0.32	1.12 ± 0.19	73.20	< 0.001
Pectoral fin height (cm)	3.90 ± 0.56	4.51 ± 0.84	4.25 ± 0.43	2.86 ± 0.92	4.30 ± 0.67	60.11	< 0.001
Pelvic fin length (cm)	0.92 ± 0.16	1.09 ± 0.10	1.03 ± 0.11	0.60 ± 0.29	1.07 ± 0.20	81.17	< 0.001
Pelvic fin height (cm)	3.69 ± 0.56	4.46 ± 0.41	4.01 ± 0.43	2.68 ± 0.89	4.08 ± 0.67	83.49	< 0.001
Dorsal fin length (cm)	2.71 ± 0.50	3.18 ± 0.29	2.77 ± 0.37	1.98 ± 0.81	4.50 ± 0.66	192.71	< 0.001
Dorsal fin height (cm)	4.48 ± 0.50	5.47 ± 0.44	4.62 ± 0.50	2.96 ± 0.85	5.42 ± 0.94	157.61	< 0.001
Anal fin length (cm)	1.42 ± 0.29	1.84 ± 0.19	1.68 ± 0.24	1.16 ± 0.55	1.99 ± 0.24	71.46	< 0.001
Anal fin height (cm)	3.86 ± 0.53	4.79 ± 0.51	4.14 ± 0.56	2.81 ± 1.22	4.07 ± 0.71	63.87	< 0.001
Caudal fin length (cm)	2.56 ± 0.41	2.92 ± 0.41	2.82 ± 0.36	1.96 ± 0.79	2.84 ± 0.42	42.37	< 0.001
Caudal fin height (cm)	5.60 ± 0.75	6.44 ± 0.70	5.86 ± 0.62	4.25 ± 1.54	6.83 ± 1.08	68.77	< 0.001
Max body depth (cm)	4.74 ± 0.75	5.73 ± 0.64	5.24 ± 0.84	3.39 ± 1.30	5.90 ± 0.96	82.59	< 0.001
Min body depth (cm)	1.91 ± 0.42	2.33 ± 0.28	2.17 ± 0.50	1.48 ± 0.60	2.32 ± 0.27	48.45	< 0.001
Pre orbital length (cm)	1.71 ± 0.37	2.64 ± 0.32	2.29 ± 0.35	1.31 ± 0.47	2.00 ±	133.49	<

					0.32		0.001
Inter orbital length (cm)	1.71 ± 0.35	2.15 ± 0.27	2.10 ± 0.42	1.22 ± 0.46	1.92 ± 0.25	77.70	< 0.001
Head length (cm)	4.73 ± 0.73	6.31 ± 0.57	6.66 ± 1.02	3.69 ± 1.14	5.00 ± 0.52	148.28	< 0.001
Pectoral fin rays (score)	16.00 ± 0.66	16.56 ± 1.44	16.70 ± 1.38	15.24 ± 0.79	14.24 ± 0.43	69.61	< 0.001
Pelvic fin rays (score)	10.20 ± 0.50	10.54 ± 0.50	10.10 ± 0.93	9.39 ± 0.82	8.91 ± 0.28	72.06	< 0.001
Dorsal fin rays (score)	9.30 ± 0.46	8.80 ± 0.53	9.47 ± 0.50	10.00 ± 1.14	11.24 ± 0.43	135.96	< 0.001
Anal fin rays (score)	6.00 ± 0.29	6.29 ± 0.46	6.30 ± 0.46	6.97 ± 0.76	6.31 ± 0.47	34.45	< 0.001
Caudal fin rays (score)	20.49 ± 0.86	21.17 ± 0.99	20.74 ± 1.89	18.87 ± 1.15	20.67 ± 0.47	39.85	< 0.001
Lateral line scale (score)	76.57 ± 2.55	70.11 ± 3.42	80.46 ± 4.16	67.06 ± 4.24	41.77 ± 0.71	1490.35	< 0.001

All the mentioned P values (in red) are highly significant (P < 0.001).(SP= Schizothorax plagiostomus,SL=Schizothorax labiatus,SE=Schizothorax esocinus,SR=Schizothorax richardsonii,LB=Labeo boggut)

Table 4: Comparison (P value) of mean difference of morphometric and meristic characteristics between groups (species) by Tukey HSD post hoc test

Variable	SP vs. SL	SP vs. SE	SP vs. SR	SP vs. LB	SL vs. SE	SL vs. SR	SL vs. LB	SE vs. SR	SE vs. LB	SR vs. LB
Total weight	0.000	0.000	0.000	0.002	0.035	0.000	0.002	0.000	0.925	0.000
Total length	0.000	0.000	0.000	0.008	0.026	0.000	0.002	0.000	0.950	0.000
Standard length	0.000	0.000	0.000	0.072	0.024	0.000	0.000	0.000	0.298	0.000
Fork length	0.000	0.000	0.000	0.178	0.088	0.000	0.000	0.000	0.095	0.000
Pre pectoral length	0.000	0.000	0.000	0.753	0.430	0.000	0.000	0.000	0.000	0.000
Pre pelvic length	0.000	0.000	0.000	0.916	0.751	0.000	0.000	0.000	0.000	0.000
Pre dorsal length	0.000	0.000	0.000	0.067	0.964	0.000	0.000	0.000	0.000	0.000
Pre anal length	0.000	0.000	0.000	0.688	0.921	0.000	0.001	0.000	0.013	0.000
Pectoral fin length	0.000	0.001	0.000	0.000	0.591	0.000	0.781	0.000	0.069	0.000
Pectoral fin height	0.000	0.026	0.000	0.008	0.190	0.000	0.372	0.000	0.996	0.000
Pelvic fin length	0.000	0.004	0.000	0.000	0.367	0.000	0.983	0.000	0.711	0.000
Pelvic fin height	0.000	0.016	0.000	0.002	0.000	0.000	0.003	0.000	0.973	0.000
Dorsal fin length	0.000	0.977	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dorsal fin height	0.000	0.738	0.000	0.000	0.000	0.000	0.993	0.000	0.000	0.000
Anal fin length	0.000	0.000	0.000	0.000	0.038	0.000	0.067	0.000	0.000	0.000

Anal fin height	0.000	0.201	0.000	0.472	0.000	0.000	0.000	0.000	0.987	0.000
Caudal fin length	0.000	0.015	0.000	0.008	0.793	0.000	0.881	0.000	1.000	0.000
Caudal fin height	0.000	0.553	0.000	0.000	0.005	0.000	0.139	0.000	0.000	0.000
Max b depth	0.000	0.011	0.000	0.000	0.016	0.000	0.818	0.000	0.000	0.000
Min b depth	0.000	0.003	0.000	0.000	0.169	0.000	0.999	0.000	0.269	0.000
Pre orbital length	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inter orbital length	0.000	0.000	0.000	0.005	0.955	0.000	0.002	0.000	0.022	0.000
Head length	0.000	0.000	0.000	0.311	0.086	0.000	0.000	0.000	0.000	0.000
Pectoral fin rays	0.010	0.000	0.000	0.000	0.927	0.000	0.000	0.000	0.000	0.000
Pelvic fin rays	0.016	0.895	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Dorsal fin rays	0.000	0.551	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Anal fin rays	0.008	0.005	0.000	0.003	1.000	0.000	0.997	0.000	1.000	0.000
Caudal fin rays	0.005	0.693	0.000	0.882	0.194	0.000	0.085	0.000	0.996	0.000
Lateral line scale	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

The mentioned exact P values > 0.05 are not significant (P > 0.05), < 0.05 to 0.01 just significant (P < 0.05), < 0.01 to 0.001 moderate significant (P < 0.01) and < 0.001 highly significant (P < 0.001). The P values marked in red are significant (P < 0.05 or P < 0.01 or P < 0.001). The P values mentioned in black are not significant (P > 0.05).

Morphometric characteristics

The morphometric characteristics (total length, total weight, standard length, fork length, pre pelvic length, pre pectoral length, pre anal length, pre dorsal length, pectoral fin length and height, pelvic fin length and height, dorsal fin length and height, anal fin length and height, caudal fin length and height, maximum body depth, minimum body depth, pre orbital length, inter orbital length and head length) of five different species have been summarized in Table 3.The mean morphometric characteristics differed comparatively among the species. However, the mean of nine morphometric characteristics viz. total weight, total length, standard length, fork length, pre pelvic length, pre anal length, anal fin height, pre orbital length and inter orbital length show similar trend highest in Schizothorax labiatus followed by Schizothorax esocinus, Labeo boggut, Schizothorax plagiostomus and least in Schizothorax richardsonii (SR < SP < LB < SE < SL).Similarly, six morphometric characteristics viz. pectoral fin height, pelvic fin height, pelvic fin length, dorsal fin height, caudal fin length and minimum body depth show similar mean trend highest in SL followed by LB, SE, SP and least in SR (SR < SP < SE < LB < SL). Further, five morphometric characteristics viz. pectoral fin length, dorsal fin length, anal fin length, caudal fin height and maximum body depth have similar mean trend with maximum in Labeo boggut followed by Schizothorax labiatus, Schizothorax esocinus, Schizothorax plagiostomus and minimum in Schizothorax richardsonii (SR < SP < SE < SL < LB).Furthermore, two morphometric characteristics i.e. pre pectoral length and head length have similar mean trend with highest being in SE followed by SL, LB, SP and least in SR (SR < SP < LB < SL < SE). Moreover, the mean of last one morphometric characteristic i.e. pre dorsal length was found highest in Schizothorax labiatus followed by

Schizothorax esocinus, Schizothorax plagiostomus, Labeo boggut and Schizothorax richardsonii (SR < LB < SP < SE < SL).Overall, the mean of most of the morphometric characteristics was highest Schizothorax labiatus in but the mean of all morphometric characteristics was least in Schizothorax richardsonii.This suggests that most of these morphometric characters are environmentally controlled characters showing similar trend of variation in certain species while dissimilar in certain others.

Comparing the mean morphometric characteristics among the five different species, ANOVA showed significantly (P < 0.001) different mean morphometric characteristic among the species (Table 3).

Further, comparing the difference in mean morphometric characteristics among the species, Tukey test showed significant (P < 0.05 or P < 0.01 or P < 0.001) difference in mean of all morphometric characteristics between Schizothorax plagiostomus and Schizothorax labiatus, Schizothorax plagiostomus and Schizothorax richardsonii, Schizothorax labiatus and Schizothorax richardsonii, and Schizothorax richardsonii and Labeo boggut species (Table 3). The difference in mean of most of the morphometric characteristics also found significant (P < 0.05 or P < 0.01 or P < 0.001) between other species (SP and SE, SP and LB, SL and SE, SL and LB, and SE and LB). In conclusion, all the studied five fish species were found morphometrically different, indicating the major role of interaction of environmental variables (biotic and abiotic) with the fish fauna.

Meristic characteristics

The meristic characteristics (pectoral fin rays, pelvic fin rays, dorsal fin rays, anal fin rays, caudal fin rays, and lateral line scale) of the five different species has also summarized in Table 3. Like, morphometric characteristics, the mean meristic characteristics also showed marked variations among the species. The mean pectoral fin rays were found maximum in Schizothorax esocinus followed by Schizothorax labiatus, Schizothorax plagiostomus and Schizothorax richardsonii and minimum in Labeo boggut (LB < SR < SP < SL < SE). In contrast, the mean pelvic fin rays were found highest in Schizothorax labiatus followed by Schizothorax plagiostomus, Schizothorax esocinus, Schizothorax richardsonii and least in Labeo boggut (LB < SR < SE < SP < SL).Conversely, the mean dorsal fin rays were maximum in Labeo boggut followed by SR, SE, SP and minimum in SL (SL < SP < SE < SR < LB).The mean anal fin rays were maximum in Schizothorax richardsonii followed by Labeo boggut, Schizothorax esocinus, Schizothorax labiatus and minimum in Schizothorax plagiostomus (SP < SL < SE < LB < SR).The mean caudal fin rays were maximum in Schizothorax labiatus followed by Schizothorax esocinus, Labeo boggut, Schizothorax plagiostomus and minimum in Schizothorax richardsonii (SR < SP < LB < SE < SL) whereas lateral line scale (LLS) was maximum in SE followed by Schizothorax plagiostomus, Schizothorax labiatus, Schizothorax richardsonii and Labeo boggut (LB < SR < SL < SP < SE). In contrast of morphometric characteristics, the mean meristic characteristics varied differently among the species i.e. none of the characteristics were found similar among the species.

Comparing the mean meristic characteristics among the five different species, ANOVA showed significantly (P < 0.001) different mean meristic characteristic among the species (Table 3).

Further, comparing the difference among mean meristic characteristics of the species, Tukey test showed significant (P < 0.05 or P < 0.01 or P < 0.001) difference in mean meristic characteristics between the species except pelvic fin rays, dorsal fin rays and caudal fin rays between Schizothorax plagiostomus, Schizothorax esocinus, caudal fin rays between Schizothorax plagiostomus, Labeo boggut, pectoral fin rays, anal fin rays and caudal fin rays between Schizothorax labiatus and Schizothorax esocinus , and anal fin rays and caudal fin rays between both Schizothorax labiatus and Labeo boggut and Schizothorax esocinus and Labeo boggut i.e. were found the same, statistically (Table 4). In conclusion, all the studied five fish species were also found to be meristically different, therefore clearly suggesting that the meristic characters are genetically controlled characters therefore showing marked interspecific and intraspecific variation.

Table 5- Inter-correlation (r value) of morphometric and meristic characteristics of Schizothorax plagiostomus species (n=70) using Pearson correlation analysis

Variable	Total weight	Total length	Standard length	Fork length	Pre pectoral length	Pre pelvic length	Pre dorsal length	Pre anal length	Pectoral fin length	Pectoral fin height	Pelvic fin length	Pelvic fin height	Dorsal fin length	Dorsal fin height	Anal fin length	Anal fin height	Caudal fin length	Caudal fin height	Max b depth	Min b depth	Pre orbital length	Inter orbital length	Head length	Pectoral fin rays	Pelvic fin rays	Dorsal fin rays	Anal fin rays	Caudal fin rays	Lateral line scale
Total weight	1.00																												
Total length	0.93	1.00																											
Standard length	0.96	0.98	1.00																										
Fork length	0.96	0.98	0.99	1.00																									
Pre pectoral length	0.86	0.87	0.88	0.86	1.00																								
Pre pelvic length	0.95	0.94	0.97	0.96	0.90	1.00																							
Pre dorsal length	0.93	0.94	0.97	0.97	0.89	0.97	1.00																						
Pre anal length	0.96	0.96	0.98	0.99	0.87	0.98	0.98	1.00																					
Pectoral fin length	0.70	0.75	0.74	0.73	0.64	0.69	0.74	0.76	1.00																				
Pectoral fin height	0.87	0.90	0.90	0.90	0.79	0.84	0.84	0.89	0.77	1.00																			
Pelvic fin length	0.69	0.73	0.72	0.72	0.77	0.72	0.77	0.72	0.71	0.68	1.00																		
Pelvic fin height	0.95	0.94	0.95	0.95	0.85	0.91	0.90	0.94	0.75	0.93	0.73	1.00																	
Dorsal fin length	0.82	0.81	0.82	0.81	0.74	0.78	0.81	0.81	0.76	0.80	0.68	0.81	1.00																
Dorsal fin height	0.73	0.69	0.71	0.72	0.61	0.66	0.64	0.72	0.65	0.82	0.48	0.76	0.60	1.00															
Anal fin length	0.84	0.85	0.86	0.87	0.84	0.87	0.87	0.86	0.63	0.76	0.71	0.85	0.82	0.49	1.00														
Anal fin height	0.91	0.88	0.89	0.89	0.78	0.85	0.84	0.89	0.75	0.93	0.67	0.96	0.81	0.82	0.77	1.00													
Caudal fin length	0.92	0.92	0.94	0.94	0.82	0.91	0.92	0.94	0.75	0.86	0.72	0.93	0.80	0.67	0.88	0.88	1.00												
Caudal fin height	0.72	0.73	0.76	0.74	0.73	0.70	0.77	0.74	0.69	0.69	0.70	0.72	0.58	0.58	0.59	0.72	0.80	1.00											
Max b depth	0.81	0.83	0.81	0.82	0.79	0.81	0.84	0.82	0.71	0.75	0.69	0.79	0.86	0.43	0.84	0.75	0.78	0.61	1.00										
Min b depth	0.79	0.77	0.80	0.79	0.77	0.84	0.84	0.81	0.58	0.68	0.76	0.73	0.72	0.40	0.81	0.63	0.80	0.61	0.68	1.00									
Pre orbital length	0.78	0.71	0.78	0.77	0.83	0.84	0.84	0.79	0.51	0.64	0.72	0.70	0.66	0.56	0.73	0.65	0.72	0.64	0.63	0.75	1.00								
Inter orbital length	0.89	0.87	0.92	0.91	0.89	0.95	0.94	0.93	0.64	0.81	0.68	0.86	0.73	0.68	0.83	0.81	0.87	0.68	0.73	0.80	0.87	1.00							
Head length	0.91	0.85	0.90	0.90	0.90	0.93	0.93	0.91	0.61	0.79	0.74	0.85	0.71	0.63	0.82	0.81	0.88	0.79	0.75	0.82	0.88	0.92	1.00						
Pectoral fin rays	0.52	0.42	0.48	0.47	0.53	0.55	0.57	0.51	0.38	0.38	0.62	0.50	0.37	0.33	0.40	0.49	0.47	0.44	0.47	0.45	0.58	0.52	0.59	1.00					
Pelvic fin rays	0.47	0.42	0.48	0.47	0.44	0.51	0.52	0.49	0.26	0.36	0.50	0.45	0.22	0.23	0.35	0.39	0.50	0.47	0.33	0.48	0.54	0.54	0.60	0.66	1.00				
Dorsal fin rays	0.46	0.33	0.38	0.38	0.55	0.49	0.51	0.40	0.19	0.26	0.57	0.34	0.45	0.17	0.45	0.36	0.35	0.36	0.47	0.54	0.67	0.50	0.63	0.71	0.49	1.00			
Anal fin rays	0.04	0.20	0.11	0.14	0.16	0.13	0.15	0.13	0.16	0.06	0.06	0.12	0.15	0.01	0.15	0.16	0.00	-0.02	0.30	-0.14	0.00	0.13	0.01	0.00	-0.30	0.00	1.00		
Caudal fin rays	0.28	0.24	0.25	0.27	-0.01	0.25	0.22	0.25	0.24	0.21	0.02	0.26	0.05	0.23	0.16	0.24	0.39	0.26	0.05	0.18	0.12	0.17	0.19	0.15	0.31	-0.15	-0.34	1.00	
Lateral line scale	0.90	0.83	0.85	0.86	0.74	0.84	0.83	0.86	0.60	0.78	0.53	0.84	0.76	0.66	0.75	0.83	0.80	0.60	0.74	0.66	0.67	0.80	0.80	0.38	0.34	0.37	0.08	0.24	1.00

The correlation (r) values marked in red are inter-correlation between morphometric characteristics, in blue between meristic characteristics and in green between morphometric and meristic characteristics. The mentioned r values < 0.24 are not significant (P > 0.05), ≥ 0.24 and < 0.31 just significant (P < 0.05), ≥ 0.31 and < 0.39 moderate significant (P < 0.01) and ≥ 39 highly significant (P < 0.001).

Table 6: Inter-correlation (r value) of morphometric and meristic characteristics of Schizothorax Labiatus species (n=70) using Pearson correlation analysis

Variable	Total weight	Total length	Standard length	Fork length	Pre pectoral length	Pre pelvic length	Pre dorsal length	Pre anal length	Pectoral fin length	Pectoral fin height	Pelvic fin length	Pelvic fin height	Dorsal fin length	Dorsal fin height	Anal fin length	Anal fin height	Caudal fin length	Caudal fin height	Max b depth	Min b depth	Pre orbital length	Inter orbital length	Head length	Pectoral fin rays	Pelvic fin rays	Dorsal fin rays	Anal fin rays	Caudal fin rays	Lateral line scale
Total weight	1.00																												
Total length	0.90	1.00																											
Standard length	0.86	0.94	1.00																										
Fork length	0.87	0.95	0.98	1.00																									
Pre pectoral length	0.62	0.70	0.72	0.77	1.00																								
Pre pelvic length	0.77	0.87	0.90	0.93	0.86	1.00																							
Pre dorsal length	0.51	0.62	0.70	0.69	0.59	0.69	1.00																						
Pre anal length	0.55	0.67	0.71	0.68	0.47	0.66	0.66	1.00																					
Pectoral fin length	0.42	0.54	0.46	0.50	0.15	0.36	0.20	0.30	1.00																				
Pectoral fin height	0.43	0.33	0.28	0.29	0.09	0.18	0.20	0.20	0.34	1.00																			
Pelvic fin length	0.49	0.57	0.57	0.56	0.29	0.52	0.30	0.37	0.71	0.01	1.00																		
Pelvic fin height	0.80	0.76	0.69	0.73	0.52	0.56	0.48	0.45	0.50	0.50	0.40	1.00																	
Dorsal fin length	0.81	0.84	0.84	0.84	0.47	0.72	0.57	0.65	0.41	0.39	0.37	0.69	1.00																
Dorsal fin height	0.77	0.74	0.73	0.74	0.50	0.60	0.42	0.52	0.26	0.23	0.25	0.63	0.74	1.00															
Anal fin length	0.78	0.76	0.79	0.78	0.56	0.75	0.56	0.55	0.46	0.54	0.53	0.67	0.79	0.51	1.00														
Anal fin height	0.73	0.71	0.71	0.75	0.72	0.75	0.54	0.41	0.15	0.23	0.28	0.60	0.57	0.67	0.54	1.00													
Caudal fin length	0.53	0.45	0.43	0.44	0.15	0.27	0.22	0.17	0.59	0.89	0.30	0.59	0.48	0.30	0.66	0.22	1.00												
Caudal fin height	0.59	0.63	0.52	0.52	0.23	0.40	0.36	0.49	0.64	0.77	0.47	0.69	0.57	0.42	0.68	0.31	0.79	1.00											
Max b depth	0.75	0.71	0.78	0.78	0.63	0.69	0.48	0.34	0.34	0.07	0.47	0.55	0.58	0.53	0.59	0.52	0.32	0.16	1.00										
Min b depth	0.64	0.65	0.66	0.62	0.27	0.50	0.43	0.57	0.57	0.31	0.56	0.47	0.57	0.42	0.62	0.21	0.51	0.57	0.57	1.00									
Pre orbital length	0.66	0.61	0.64	0.62	0.41	0.53	0.46	0.40	0.52	0.51	0.44	0.60	0.50	0.29	0.75	0.39	0.67	0.57	0.62	0.73	1.00								
Inter orbital length	0.82	0.81	0.85	0.87	0.66	0.79	0.58	0.52	0.59	0.34	0.68	0.76	0.71	0.54	0.80	0.62	0.57	0.55	0.77	0.65	0.72	1.00							
Head length	0.80	0.83	0.82	0.86	0.83	0.82	0.61	0.55	0.49	0.40	0.49	0.83	0.63	0.62	0.74	0.72	0.52	0.56	0.72	0.50	0.66	0.85	1.00						
Pectoral fin rays	-0.22	-0.10	-0.04	-0.06	-0.17	-0.03	-0.06	0.05	0.27	-0.15	0.22	-0.21	-0.06	-0.22	0.05	-0.26	-0.04	-0.05	-0.06	0.11	0.09	-0.09	-0.10	1.00					
Pelvic fin rays	-0.53	-0.44	-0.40	-0.39	-0.23	-0.34	-0.25	-0.39	0.01	0.07	-0.13	-0.35	-0.46	-0.61	-0.20	-0.28	0.03	-0.12	-0.38	-0.42	-0.19	-0.36	-0.23	0.29	1.00				
Dorsal fin rays	0.39	0.46	0.39	0.48	0.56	0.49	0.25	0.14	0.23	0.09	0.13	0.43	0.21	0.47	0.17	0.51	0.16	0.13	0.45	0.12	0.17	0.47	0.58	-0.16	-0.35	1.00			
Anal fin rays	0.55	0.45	0.47	0.43	0.11	0.35	0.30	0.30	0.13	0.33	0.09	0.34	0.64	0.27	0.58	0.18	0.36	0.22	0.50	0.51	0.54	0.44	0.24	-0.09	-0.44	0.00	1.00		
Caudal fin rays	0.06	0.18	0.09	0.14	0.16	0.04	0.02	-0.12	0.15	0.27	-0.17	0.28	0.12	0.33	-0.01	0.34	0.23	0.27	-0.13	-0.16	-0.10	0.02	0.19	-0.24	0.16	0.40	-0.24	1.00	
Lateral line scale	0.83	0.72	0.72	0.71	0.54	0.65	0.49	0.53	0.26	0.22	0.51	0.64	0.59	0.67	0.65	0.63	0.30	0.44	0.62	0.57	0.59	0.69	0.69	-0.11	-0.51	0.32	0.37	-0.09	1.00

The correlation (r) values marked in red are inter-correlation between morphometric characteristics, in blue between meristic characteristics and in green between morphometric and meristic characteristics. The mentioned r values < 0.24 are not significant (P > 0.05), ≥ 0.24 and < 0.31 just significant (P < 0.05), ≥ 0.31 and < 0.39 moderate significant (P < 0.01) and ≥ 39 highly significant (P < 0.001).

Table 7: Inter-correlation (r value) of morphometric and meristic characteristics of Schizothorax esocinus species (n=70) using Pearson correlation analysis

Variable	Total weight	Total length	Standard length	Fork length	Pre pectoral length	Pre pelvic length	Pre dorsal length	Pre anal length	Pectoral fin length	Pectoral fin height	Pelvic fin length	Pelvic fin height	Dorsal fin length	Dorsal fin height	Anal fin length	Anal fin height	Caudal fin length	Caudal fin height	Max b depth	Min b depth	Pre orbital length	Inter orbital length	Head length	Pectoral fin rays	Pelvic fin rays	Dorsal fin rays	Anal fin rays	Caudal fin rays	Lateral line scale
Total weight	1.00																												
Total length	0.97	1.00																											
Standard length	0.97	0.98	1.00																										
Fork length	0.96	0.98	0.99	1.00																									
Pre pectoral length	0.87	0.90	0.92	0.90	1.00																								
Pre pelvic length	0.97	0.96	0.98	0.95	0.95	1.00																							
Pre dorsal length	0.97	0.96	0.99	0.97	0.94	0.99	1.00																						
Pre anal length	0.98	0.97	0.99	0.98	0.90	0.98	0.99	1.00																					
Pectoral fin length	0.74	0.71	0.75	0.74	0.75	0.80	0.79	0.78	1.00																				
Pectoral fin height	0.85	0.87	0.89	0.87	0.93	0.92	0.91	0.88	0.75	1.00																			
Pelvic fin length	0.58	0.57	0.54	0.56	0.51	0.52	0.55	0.57	0.48	0.54	1.00																		
Pelvic fin height	0.76	0.79	0.80	0.79	0.88	0.83	0.83	0.79	0.71	0.94	0.53	1.00																	
Dorsal fin length	0.96	0.94	0.95	0.95	0.84	0.93	0.95	0.95	0.80	0.81	0.63	0.76	1.00																
Dorsal fin height	0.52	0.55	0.60	0.58	0.73	0.62	0.64	0.55	0.50	0.78	0.27	0.80	0.55	1.00															
Anal fin length	0.89	0.87	0.88	0.87	0.87	0.92	0.92	0.91	0.85	0.87	0.58	0.87	0.91	0.61	1.00														
Anal fin height	0.87	0.86	0.88	0.87	0.89	0.90	0.91	0.90	0.74	0.87	0.57	0.82	0.83	0.56	0.89	1.00													
Caudal fin length	0.70	0.68	0.63	0.59	0.53	0.64	0.61	0.63	0.27	0.53	0.31	0.46	0.55	0.21	0.51	0.61	1.00												
Caudal fin height	0.74	0.77	0.78	0.81	0.80	0.78	0.81	0.82	0.72	0.77	0.61	0.79	0.78	0.50	0.85	0.88	0.31	1.00											
Max body depth	0.93	0.88	0.92	0.88	0.82	0.91	0.92	0.91	0.77	0.82	0.55	0.76	0.92	0.53	0.88	0.82	0.57	0.69	1.00										
Min body depth	0.90	0.93	0.93	0.93	0.90	0.90	0.93	0.91	0.67	0.83	0.63	0.81	0.91	0.66	0.86	0.86	0.57	0.80	0.84	1.00									
Pre orbital length	0.75	0.76	0.80	0.76	0.93	0.86	0.84	0.78	0.69	0.90	0.44	0.86	0.70	0.77	0.82	0.85	0.50	0.70	0.74	0.80	1.00								
Inter orbital length	0.89	0.87	0.91	0.88	0.90	0.91	0.93	0.89	0.76	0.89	0.65	0.86	0.91	0.74	0.88	0.89	0.56	0.76	0.89	0.93	0.85	1.00							
Head length	0.87	0.90	0.90	0.89	0.98	0.94	0.92	0.88	0.72	0.93	0.49	0.86	0.82	0.72	0.86	0.89	0.59	0.75	0.79	0.89	0.94	0.88	1.00						
Pectoral fin rays	0.29	0.32	0.33	0.34	0.30	0.31	0.30	0.24	0.29	0.35	-0.21	0.31	0.26	0.30	0.20	0.25	0.23	0.00	0.32	0.19	0.31	0.26	0.33	1.00					
Pelvic fin rays	0.00	-0.07	-0.05	-0.08	0.01	0.04	-0.01	-0.05	0.09	-0.06	-0.03	-0.18	0.01	-0.05	0.00	0.03	-0.05	-0.15	-0.01	-0.08	0.08	0.03	0.08	0.22	1.00				
Dorsal fin rays	0.08	0.03	0.02	0.02	0.13	0.17	0.09	0.12	0.37	0.19	-0.04	0.14	0.05	-0.07	0.22	0.20	0.08	0.21	0.07	-0.14	0.12	0.00	0.14	-0.09	0.05	1.00			
Anal fin rays	0.24	0.28	0.23	0.29	0.22	0.22	0.22	0.24	0.24	0.20	0.08	0.10	0.30	0.16	0.10	0.11	0.17	0.12	0.11	0.15	0.02	0.15	0.23	0.10	-0.07	0.44	1.00		
Caudal fin rays	0.33	0.40	0.41	0.43	0.46	0.38	0.41	0.40	0.40	0.50	0.06	0.61	0.35	0.45	0.44	0.49	0.30	0.50	0.35	0.40	0.41	0.41	0.39	0.23	-0.66	0.28	0.31	1.00	
Lateral line scale	0.93	0.88	0.87	0.87	0.72	0.87	0.87	0.90	0.67	0.71	0.56	0.62	0.91	0.39	0.82	0.73	0.64	0.64	0.84	0.81	0.61	0.78	0.74	0.20	0.04	0.06	0.23	0.20	1.00

The correlation (r) values marked in red are inter-correlation between morphometric characteristics, in blue between meristic characteristics and in green between morphometric and meristic characteristics. The mentioned r values < 0.24 are not significant (P > 0.05), ≥ 0.24 and < 0.31 just significant (P < 0.05), ≥ 0.31 and < 0.39 moderate significant (P < 0.01) and ≥ 39 highly significant (P < 0.001).

Table 8: Inter-correlation (r value) of morphometric and meristic characteristics of Schizothorax richardsonii species (n=70) using Pearson correlation analysis

Variable	Total weight	Total length	Standard length	Fork length	Pre pectoral length	Pre pelvic length	Pre dorsal length	Pre anal length	Pectoral fin length	Pectoral fin height	Pelvic fin length	Pelvic fin height	Dorsal fin length	Dorsal fin height	Anal fin length	Anal fin height	Caudal fin length	Caudal fin height	Max b depth	Min b depth	Pre orbital length	Inter orbital length	Head length	Pectoral fin rays	Pelvic fin rays	Dorsal fin rays	Anal fin rays	Caudal fin rays	Lateral line scale
Total weight	1.00																												
Total length	0.91	1.00																											
Standard length	0.92	0.99	1.00																										
Fork length	0.92	1.00	1.00	1.00																									
Pre pectoral length	0.93	0.97	0.97	0.97	1.00																								
Pre pelvic length	0.92	0.99	0.99	0.99	0.98	1.00																							
Pre dorsal length	0.92	0.99	0.99	0.99	0.98	1.00	1.00																						
Pre anal length	0.92	0.93	0.93	0.94	0.95	0.93	0.92	1.00																					
Pectoral fin length	0.91	0.96	0.96	0.97	0.94	0.95	0.94	0.92	1.00																				
Pectoral fin height	0.92	0.98	0.98	0.99	0.95	0.98	0.97	0.93	0.97	1.00																			
Pelvic fin length	0.88	0.96	0.96	0.97	0.92	0.95	0.94	0.90	0.97	0.98	1.00																		
Pelvic fin height	0.89	0.97	0.97	0.98	0.92	0.97	0.96	0.90	0.96	0.99	0.98	1.00																	
Dorsal fin length	0.92	0.98	0.99	0.99	0.95	0.97	0.97	0.94	0.97	0.98	0.97	0.97	1.00																
Dorsal fin height	0.84	0.93	0.93	0.93	0.85	0.91	0.91	0.86	0.92	0.95	0.94	0.97	0.93	1.00															
Anal fin length	0.93	0.96	0.96	0.97	0.93	0.94	0.94	0.94	0.95	0.97	0.96	0.96	0.98	0.92	1.00														
Anal fin height	0.84	0.96	0.96	0.96	0.89	0.95	0.95	0.85	0.93	0.97	0.97	0.98	0.95	0.96	0.92	1.00													
Caudal fin length	0.90	0.97	0.98	0.98	0.95	0.97	0.96	0.93	0.97	0.98	0.98	0.97	0.99	0.92	0.97	0.96	1.00												
Caudal fin height	0.90	0.97	0.97	0.97	0.93	0.97	0.97	0.91	0.97	0.98	0.97	0.98	0.96	0.96	0.94	0.96	0.95	1.00											
Max body depth	0.91	0.97	0.98	0.98	0.95	0.96	0.96	0.93	0.97	0.98	0.98	0.97	0.99	0.93	0.97	0.95	0.99	0.95	1.00										
Min body depth	0.86	0.88	0.88	0.89	0.90	0.88	0.85	0.93	0.91	0.90	0.92	0.88	0.92	0.82	0.92	0.83	0.93	0.85	0.94	1.00									
Pre orbital length	0.91	0.94	0.94	0.94	0.93	0.94	0.93	0.90	0.94	0.96	0.95	0.94	0.94	0.88	0.93	0.92	0.96	0.91	0.97	0.93	1.00								
Inter orbital length	0.92	0.96	0.96	0.96	0.96	0.97	0.96	0.93	0.93	0.96	0.94	0.94	0.96	0.89	0.94	0.93	0.97	0.92	0.97	0.92	0.97	1.00							
Head length	0.91	0.98	0.98	0.98	0.96	0.97	0.96	0.95	0.96	0.98	0.97	0.97	0.98	0.92	0.96	0.95	0.98	0.95	0.98	0.93	0.97	0.98	1.00						
Pectoral fin rays	0.54	0.65	0.65	0.65	0.66	0.66	0.62	0.60	0.68	0.63	0.71	0.64	0.66	0.54	0.62	0.62	0.69	0.64	0.70	0.74	0.67	0.66	0.67	1.00					
Pelvic fin rays	0.46	0.63	0.62	0.62	0.62	0.61	0.59	0.59	0.56	0.58	0.65	0.58	0.65	0.50	0.61	0.61	0.69	0.54	0.67	0.73	0.61	0.65	0.64	0.79	1.00				
Dorsal fin rays	0.46	0.47	0.48	0.46	0.46	0.47	0.50	0.33	0.41	0.39	0.37	0.41	0.47	0.35	0.44	0.40	0.44	0.43	0.44	0.26	0.38	0.45	0.40	0.47	0.29	1.00			
Anal fin rays	0.20	0.18	0.18	0.17	0.19	0.18	0.24	0.06	0.07	0.07	-0.02	0.06	0.13	0.06	0.09	0.08	0.05	0.13	0.07	-0.14	0.01	0.12	0.05	-0.01	-0.12	0.75	1.00		
Caudal fin rays	0.35	0.30	0.31	0.33	0.25	0.28	0.23	0.38	0.40	0.42	0.48	0.42	0.39	0.43	0.45	0.37	0.42	0.34	0.47	0.59	0.50	0.44	0.43	0.43	0.36	-0.12	-0.48	1.00	
Lateral line scale	0.94	0.87	0.88	0.88	0.84	0.86	0.86	0.83	0.88	0.88	0.86	0.87	0.88	0.83	0.90	0.83	0.86	0.87	0.87	0.78	0.86	0.85	0.85	0.51	0.40	0.50	0.22	0.35	1.00

The correlation (r) values marked in red are inter-correlation between morphometric characteristics, in blue between meristic characteristics and in green between morphometric and meristic characteristics. The mentioned r values < 0.24 are not significant (P > 0.05), ≥ 0.24 and < 0.31 just significant (P < 0.05), ≥ 0.31 and < 0.39 moderate significant (P < 0.01) and ≥ 39 highly significant (P < 0.001).

Table 9: Inter-correlation (r value) of morphometric and meristic characteristics of Labeo boggut species (n=70) using Pearson correlation analysis

Variable	Total weight	Total length	Standard length	Fork length	Pre pectoral length	Pre pelvic length	Pre dorsal length	Pre anal length	Pectoral fin length	Pectoral fin height	Pelvic fin length	Pelvic fin height	Dorsal fin length	Dorsal fin height	Anal fin length	Anal fin height	Caudal fin length	Caudal fin height	Max b depth	Min b depth	Pre orbital length	Inter orbital length	Head length	Pectoral fin rays	Pelvic fin rays	Dorsal fin rays	Anal fin rays	Caudal fin rays	Lateral line scale
Total weight	1.00																												
Total length	0.90	1.00																											
Standard length	0.83	0.90	1.00																										
Fork length	0.89	0.97	0.89	1.00																									
Pre pectoral length	0.86	0.91	0.89	0.92	1.00																								
Pre pelvic length	0.94	0.97	0.85	0.96	0.92	1.00																							
Pre dorsal length	0.92	0.95	0.87	0.96	0.94	0.96	1.00																						
Pre anal length	0.89	0.98	0.91	0.98	0.93	0.96	0.96	1.00																					
Pectoral fin length	0.65	0.77	0.68	0.78	0.71	0.71	0.72	0.74	1.00																				
Pectoral fin height	0.85	0.96	0.86	0.95	0.86	0.93	0.91	0.94	0.88	1.00																			
Pelvic fin length	0.73	0.81	0.80	0.83	0.82	0.77	0.80	0.78	0.86	0.88	1.00																		
Pelvic fin height	0.82	0.98	0.89	0.95	0.84	0.92	0.90	0.95	0.80	0.97	0.82	1.00																	
Dorsal fin length	0.83	0.92	0.80	0.92	0.83	0.89	0.88	0.91	0.86	0.97	0.86	0.93	1.00																
Dorsal fin height	0.76	0.91	0.78	0.91	0.81	0.89	0.85	0.88	0.79	0.91	0.77	0.92	0.86	1.00															
Anal fin length	0.79	0.84	0.68	0.86	0.74	0.83	0.80	0.80	0.90	0.89	0.84	0.85	0.90	0.84	1.00														
Anal fin height	0.86	0.97	0.84	0.96	0.87	0.95	0.94	0.95	0.75	0.96	0.80	0.96	0.93	0.95	0.83	1.00													
Caudal fin length	0.91	0.95	0.84	0.93	0.86	0.92	0.96	0.95	0.77	0.94	0.77	0.92	0.93	0.83	0.82	0.95	1.00												
Caudal fin height	0.73	0.89	0.85	0.91	0.80	0.82	0.85	0.87	0.85	0.91	0.85	0.93	0.84	0.88	0.87	0.86	0.82	1.00											
Max body depth	0.93	0.73	0.65	0.73	0.71	0.83	0.78	0.72	0.51	0.69	0.62	0.63	0.70	0.59	0.71	0.69	0.75	0.57	1.00										
Min body depth	0.86	0.77	0.58	0.73	0.65	0.81	0.79	0.74	0.42	0.67	0.51	0.70	0.72	0.61	0.69	0.77	0.81	0.54	0.83	1.00									
Pre orbital length	0.79	0.89	0.78	0.86	0.82	0.85	0.90	0.88	0.76	0.92	0.77	0.88	0.91	0.80	0.74	0.92	0.95	0.78	0.61	0.70	1.00								
Inter orbital length	0.95	0.92	0.85	0.87	0.81	0.92	0.90	0.89	0.64	0.88	0.71	0.87	0.84	0.76	0.74	0.89	0.94	0.74	0.84	0.83	0.86	1.00							
Head length	0.75	0.92	0.81	0.93	0.91	0.88	0.92	0.93	0.74	0.91	0.80	0.90	0.88	0.84	0.75	0.91	0.89	0.85	0.55	0.63	0.90	0.77	1.00						
Pectoral fin rays	-0.56	-0.41	-0.20	-0.35	-0.23	-0.49	-0.41	-0.36	-0.28	-0.39	-0.15	-0.38	-0.41	-0.44	-0.51	-0.43	-0.44	-0.32	-0.65	-0.63	-0.36	-0.51	-0.16	1.00					
Pelvic fin rays	0.26	0.21	0.15	0.06	-0.05	0.15	0.12	0.09	0.03	0.14	-0.05	0.22	0.09	0.21	0.11	0.25	0.25	0.07	0.19	0.36	0.24	0.37	-0.05	-0.54	1.00				
Dorsal fin rays	-0.17	-0.01	-0.15	-0.08	-0.14	-0.08	-0.06	0.02	-0.23	-0.07	-0.40	0.00	-0.06	-0.11	-0.28	0.02	0.08	-0.21	-0.35	0.04	0.15	-0.01	0.09	0.15	0.17	1.00			
Anal fin rays	-0.40	-0.67	-0.55	-0.72	-0.62	-0.64	-0.59	-0.68	-0.48	-0.65	-0.62	-0.72	-0.65	-0.74	-0.58	-0.71	-0.53	-0.68	-0.23	-0.41	-0.54	-0.40	-0.77	-0.02	0.21	-0.02	1.00		
Caudal fin rays	0.36	0.61	0.67	0.55	0.45	0.46	0.46	0.55	0.37	0.53	0.48	0.68	0.47	0.64	0.39	0.62	0.47	0.59	0.12	0.33	0.49	0.45	0.52	-0.03	0.44	0.04	-0.64	1.00	
Lateral line scale	-0.16	-0.21	-0.29	-0.27	-0.20	-0.18	-0.24	-0.28	-0.14	-0.24	-0.17	-0.24	-0.21	-0.22	-0.08	-0.25	-0.25	-0.24	-0.07	-0.06	-0.22	-0.19	-0.25	-0.01	0.05	-0.10	0.18	-0.18	1.00

The correlation (r) values marked in red are inter-correlation between morphometric characteristics, in blue between meristic characteristics and in green between morphometric and meristic characteristics. The mentioned r values < 0.24 are not significant (P > 0.05), ≥ 0.24 and < 0.31 just significant (P < 0.05), ≥ 0.31 and < 0.39 moderate significant (P < 0.01) and ≥ 39 highly significant (P < 0.001)

Correlation

The inter-correlation and correlation between morphometric and meristic characteristics of each of the five species have been summarized in Table 5 to 9, respectively.

In Schizothorax plagiostomus, a highly significant (P < 0.01 or P < 0.001) and positive (direct) correlation has been found between all the morphometric characters. The highest correlation has been found between the standard length and fork length (r=0.99, P < 0.001) while least was found between dorsal fin height and minimum body depth (r=0.40, P < 0.01) (Table 5). In contrast, most of the meristic characteristics show significant (P < 0.05 or P < 0.01 or P < 0.001) positive and/or negative correlation with each other. Conversely, a positive and highly significant (P < 0.05 or P < 0.01 or P < 0.001) correlation was also found between most of the morphometric and meristic characteristics. The meristic characteristics viz. lateral line scale showed highest positive and significant correlation with all morphometric characters.

Similarly, in Schizothorax labiatus, a positive and highly significant (P < 0.05 or P < 0.01 or P < 0.001) correlation was also found between most of the morphometric characteristics with highest between standard length and fork length (r=0.98, P < 0.001) (Table 6). In contrast, meristic characteristics showed significant (P < 0.05 or P < 0.01 or P < 0.001) positive and/or negative correlation with each other. Between morphometric and meristic characteristics also, most of the characteristics showed significant (P < 0.05 or P < 0.01 or P < 0.001) positive or negative correlation with each other. The meristic characteristics viz. lateral line scale showed a positive and significant (P < 0.05 or P < 0.01 or P < 0.001) correlation with all the morphometric characteristics except pectoral fin height (r=0.22, P > 0.05).

In Schizothorax esocinus also, a positive and highly significant (P < 0.05 or P < 0.01 or P < 0.001) correlation was found between all the morphometric characteristics except dorsal fin height and caudal fin length (r=0.21, P > 0.05) (Table 7). The meristic characteristics viz. dorsal fin rays and anal fin rays (r=0.44, P < 0.001), dorsal fin rays and caudal fin rays (r=0.28, P < 0.05), and anal fin rays and caudal fin rays (r=0.31, P < 0.01) showed a positive and significant correlation with each other whereas pelvic fin rays and caudal fin rays (r=-0.66, P < 0.001) showed significant and negative correlation with each other. Between morphometric and meristic characteristics, most of the characteristics showed either positive or negative significant (P < 0.05 or P < 0.01 or P < 0.001) correlation with each other. The meristic characteristics viz. lateral line scale showed significant (P < 0.01 or P < 0.001) correlation with all the morphometric characteristics; highest with total weight (r=0.93, P < 0.001) and least with dorsal fin height (r=0.39, P < 0.01).

In Schizothorax richardsonii, a positive and highly significant (P < 0.001) correlation was found between all the morphometric characteristics with highest/perfect correlation (r=1.00, P < 0.001) between total length and fork length, standard length and fork length, and pre pelvic length and pre dorsal length and least between dorsal fin height and min b depth (r=0.82, P < 0.001) (Table 8). The meristic characteristics showed a significant positive correlation and/or negative correlation with each other. Between morphometric and meristic characteristics, most of the meristic characteristics showed a significant (P < 0.05 or P < 0.01 or P < 0.001) and positive correlation with morphometric characteristics except anal fin rays. Among meristic characteristics, the lateral line scale again showed significant correlation with all the morphometric characteristics; highest with total weight (r=0.94, P < 0.001) and least with min b depth (r=0.78, P < 0.001).

In Labeo boggut, a positive and high significant (P < 0.001) correlation was also found between all the morphometric characteristics with highest correlation (r=0.98, P < 0.001) between total length and pre anal length, total length and pelvic fin height, and fork length and pre anal length and least between pectoral fin length and min b depth (r=0.42, P < 0.001) (Table 9). The meristic characteristics viz. pelvic fin rays and caudal fin rays (r=0.44, P < 0.001), showed a positive and significant correlation whereas pectoral fin rays and pelvic fin rays (r=-0.54, P < 0.001), and anal fin rays and caudal fin rays (r=-0.64, P < 0.001) showed a significant and negative correlation. Between morphometric and meristic characteristics, most of the meristic characteristics showed a significant (P < 0.05 or P < 0.01 or P < 0.001) either positive or negative correlation with most of the morphometric characteristics; highest positive correlation between pelvic fin height and caudal fin rays (r=0.68, P < 0.001) and highest negative between head length and anal fin rays (r=-0.77, P < 0.001).

In conclusion, all species showed significant and higher association with morphometric characteristics than meristic characteristics and it was found highest in Schizothorax richardsonii followed by Labeo boggut, Schizothorax esocinus, Schizothorax plagiostomus and least in Schizothorax labiatus. Moreover, in all species, lateral line scale showed significant association with most of the morphometric characteristics.

Length-weight relationship

The length-weight relationship of all the five species has been summarized in Table 10 and also shown graphically in Fig.11-15, respectively. The Pearson correlation analysis showed highly significant and positive (direct) association between total length and total weight in all species with highest being in Schizothorax esocinus (r=0.96, P < 0.001), followed by both Schizothorax plagiostomus (r=0.94, P < 0.001) and Schizothorax richardsonii (r=0.94, P < 0.001), Labeo boggut (r=0.91, P < 0.001) and Schizothorax labiatus (r=0.89, P < 0.001) indicating that total length may estimate total weight of the species.

The simple linear regression analysis found a best fit regression equation to estimate total weight from total length with high coefficient of variation (R2) with highest being for Schizothorax esocinus (R2=0.9252), followed by Schizothorax plagiostomus (R2=0.8914), Schizothorax richardsonii (R2=0.8763), Labeo boggut (R2=0.8195) and Schizothorax labiatus (R2=0.7915) indicating that total length may account for 92.52, 89.14, 87.63, 81.95 and 79.15% total variations of total weight alone in these species respectively.

Table 10: Length-weight relationship of five different species using simple Pearson correlation and linear regression analyses

Species	**n**	**Correlation (r)**	**Intercept (a)**	**Slope (b)**	**Equation (y=a + bx)**	**Coefficient of determination (R^2)**
SP	70	0.94***	-2.0233	2.9571	y=-2.0233 + 2.9571x	0.8914
SL	70	0.89***	-2.3233	3.1523	y=-2.3233 + 3.1523x	0.7915
SE	70	0.96***	-2.8632	3.5208	y=-2.8632 + 3.5208x	0.9252
SR	70	0.94***	-1.4390	2.4975	y=-1.4390 + 2.4975x	0.8763
LB	70	0.91***	-1.8350	2.8372	y=-1.8350 + 2.8372x	0.8195

***-P < 0.001.)(SP= Schizothorax plagiostomus,SL=Schizothorax labiatus,SE=Schizothorax esocinus,SR=Schizothorax richardsonii,LB=Labeo boggut)

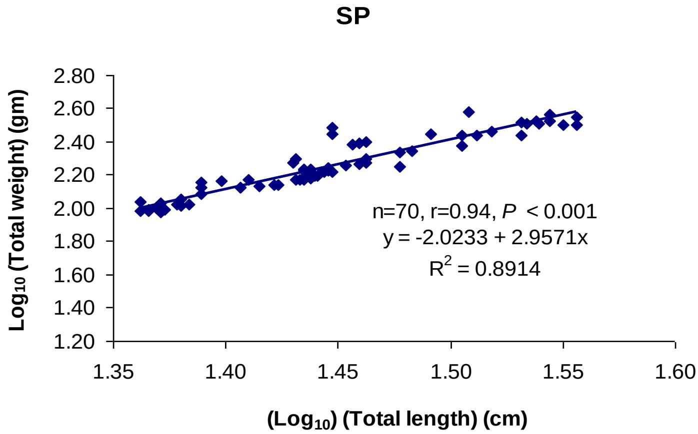

Fig. 11. Linear regression equation between total length and total weight in Schizothorax plagiostomus.

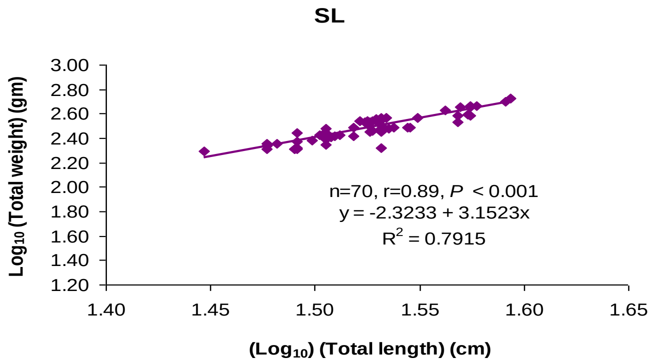

Fig. 12. Linear regression equation between total length and total weight in Schizothorax labiatus

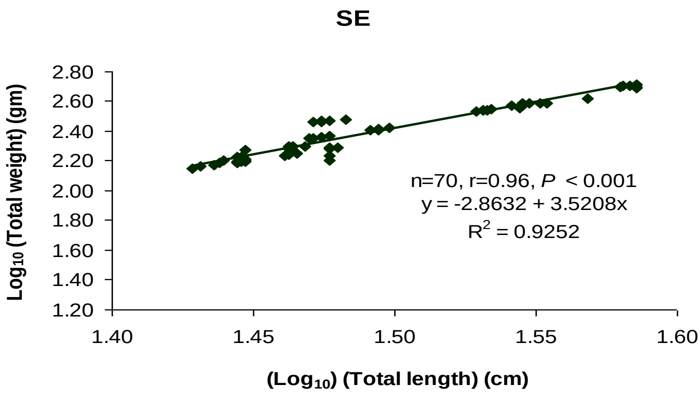

Fig.13.Linear regression equation between total length and total weight in Sichzothorax

esocinus

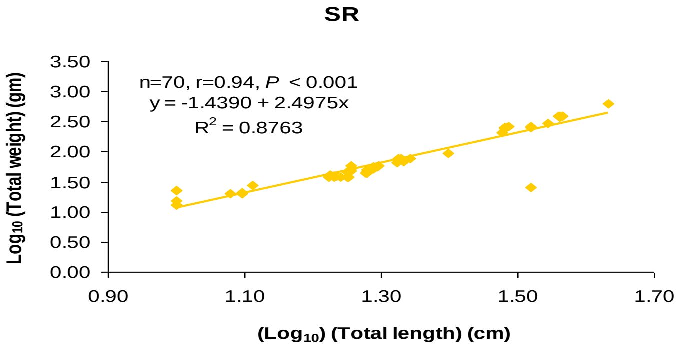

Fig. 14. Linear regression equation between total length and total weight in Schizothorax richardsonii

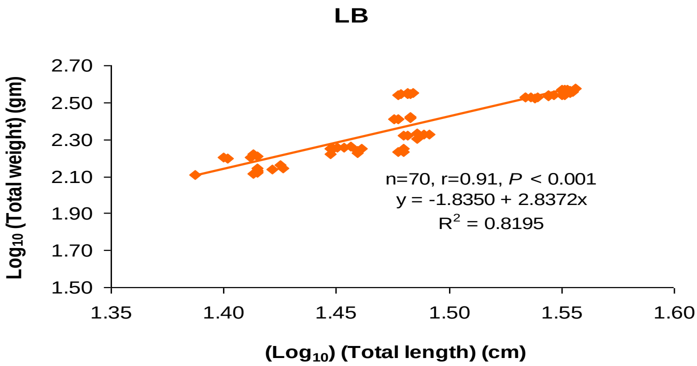

Fig. 15. Linear regression equation between total length and total weight in Labeo boggut.

Condition factors

The condition factor (KTL) which assesses the overall health (survival and growth), physiology and productivity of a fish population has been calculated for all the five species and summarized in Table 10 and also its mean value been represented in fig 16. The condition factor of Schizothorax plagiostomus, Schizothorax labiatus, Schizothorax esocinus, Schizothorax richardsonii and Labeo boggut ranged from 0.66-1.40, 0.53-0.95, 0.59-1.12, 0.07-2.30 and 0.62-1.29 gm/cm3 respectively with mean (± SD) 0.83 ± 0.13, 0.82 ± 0.09, 0.83 ± 0.11, 0.86 ± 0.31 and 0.85 ± 0.15 gm/cm3 respectively and median 0.79, 0.83, 0.85, 0.79 and 0.81 gm/cm3 respectively. The mean condition factor was highest for Schizothorax richardsonii followed by Labeo boggut, Schizothorax plagiostomus, Schizothorax esocinus and Schizothorax labiatus (SL < SP = SE < LB < SR), indicating that the midstream and downstream regions have been more negatively impacted by anthropogenic activity than the upstream area. Additionally, a lower Condition Factor value is a clear sign of unfavourable environmental factors (biotic and abiotic) impacting fish growth.

Comparing the mean condition of factor of five different species, ANOVA showed similar condition factor among the species (F=0.56, P = 0.688) (Table 11).Further, comparing the difference in mean condition factor between the species, Tukey test also showed similar (P > 0.05) condition factor between the species i.e. did not differ significantly (Table 12).

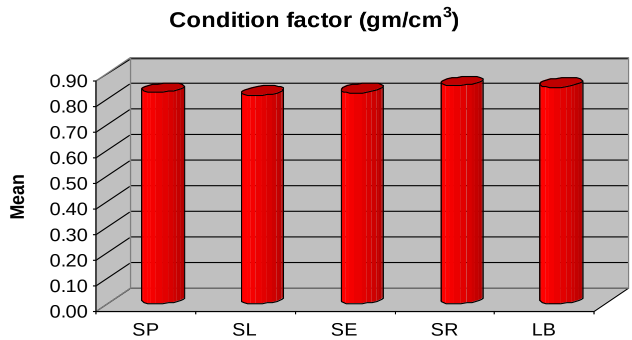

Fig.16. Mean condition factor of five different species.

Table 11: Summary Statistics (Mean ± SD) and comparisons of condition factors among five species using ANOVA

Species	Condition factor (Mean ± SD, n=70)	F value	*P* value
SP	0.83 ± 0.13	0.56	0.688[ns]
SL	0.82 ± 0.09		
SE	0.83 ± 0.11		
SR	0.86 ± 0.31		
LB	0.85 ± 0.15		

ns- P > 0.05.

Table 12: Comparison (P value) of mean difference of condition factors between groups (species) by Tukey HSD post hoc test

Comparison	*P* value
SP vs. SL	0.996[ns]
SP vs. SE	1.000[ns]
SP vs. SR	0.898[ns]
SP vs. LB	0.962[ns]
SL vs. SE	0.998[ns]
SL vs. SR	0.712[ns]
SL vs. LB	0.835[ns]
SE vs. SR	0.881[ns]
SE vs. LB	0.953[ns]
SR vs. LB	0.999[ns]

ns- P > 0.05.

The correlation of morphometric and meristic characteristics with condition factor of each of the five species has also been evaluated and summarized in Table 13. Schizothorax plagiostomus showed significant and direct (positive correlation) association of total weight (r=0.30, $P < 0.05$), dorsal fin height (r=0.25, $P < 0.05$), pre orbital length (r=0.27, $P < 0.05$), head length (r=0.26, $P < 0.05$), pectoral fin rays (r=0.32, $P < 0.01$), dorsal fin rays (r=0.37, $P < 0.01$) and lateral line scale (r=0.26, $P < 0.05$) whereas significant inverse (negative correlation) association of anal fin rays (r=-0.51, $P < 0.001$) with condition factor.

In contrast, Schizothorax labiatus showed significant and positive correlation of total length (r=0.51, $P < 0.001$), pectoral fin height (r=0.30, $P < 0.05$), pelvic fin height (r=0.34, $P < 0.01$), dorsal fin height (r=0.30, $P < 0.05$), anal fin length (r=0.34, $P < 0.01$), caudal fin length (r=0.34, $P < 0.01$), maximum body depth (r=0.31, $P < 0.01$), minimum body depth (r=0.25, $P < 0.05$), pre orbital length (r=0.34, $P < 0.01$), inter orbital length (r=0.30, $P < 0.05$), anal fin rays (r=0.32, $P < 0.01$) and lateral line scale (r=0.49, $P < 0.001$) whereas significant negative correlation of pelvic fin rays (r=-0.34, $P < 0.01$) and caudal fin rays (r=-0.29, $P < 0.05$) with condition factor.

Conversely, Schizothorax esocinus showed a significant ($P < 0.05$ or $P < 0.01$ or $P < 0.001$) and direct association of most of the morphometric and meristic characteristics with the condition factor except pelvic fin length, caudal fin height, pectoral fin rays, anal fin rays and caudal fin rays.

In contrast to Schizothorax esocinus, Schizothorax richardsonii also showed a significant ($P < 0.05$ or $P < 0.01$ or $P < 0.001$) but inverse association of most of the morphometric and meristic characteristics with the condition factor except total weight, dorsal fin rays, anal fin rays, caudal fin rays and lateral line scale.

The Labeo boggut showed significant and direct association of total weight (r=0.31, $P < 0.01$), maximum body depth (r=0.53, $P < 0.001$), minimum body depth (r=0.30, $P < 0.05$) and anal fin rays (r=0.50, $P < 0.001$) whereas significant and inverse association of pelvic fin height (r=-0.28, $P < 0.05$), caudal fin height (r=-0.30, $P < 0.05$), head length (r=-0.28, $P < 0.05$), pectoral fin rays (r=-0.36, $P < 0.01$), dorsal fin rays (r=-0.39, $P < 0.001$) and caudal fin rays (r=-0.49, $P < 0.001$) with condition factor.

These findings demonstrate that there is no direct relationship between condition factor and morphometric features (apart from overall length and weight), and that the association of condition factor with various variables varies significantly between species.

Table 13: Correlation (r value) of morphometric and meristic characteristics with condition factors of each of five species using Pearson correlation analysis (n=70)

Variable	**SP**	**SL**	**SE**	**SR**	**LB**
Total weight	0.30^{*}	0.51^{***}	0.59^{***}	-0.13^{ns}	0.31^{**}
Total length	-0.04^{ns}	0.10^{ns}	0.42^{***}	-0.42^{***}	-0.13^{ns}
Standard length	0.09^{ns}	0.14^{ns}	0.53^{***}	-0.40^{***}	-0.11^{ns}
Fork length	0.09^{ns}	0.13^{ns}	0.43^{***}	-0.40^{***}	-0.10^{ns}
Pre pectoral length	0.08^{ns}	0.03^{ns}	0.44^{***}	-0.38^{**}	0.00^{ns}
Pre pelvic length	0.14^{ns}	0.04^{ns}	0.58^{***}	-0.40^{***}	0.04^{ns}

Pre dorsal length	0.12^{ns}	-0.08^{ns}	0.57^{***}	-0.41^{***}	0.03^{ns}
Pre anal length	0.14^{ns}	-0.02^{ns}	0.54^{***}	-0.35^{**}	-0.12^{ns}
Pectoral fin length	0.09^{ns}	-0.03^{ns}	0.55^{***}	-0.27^{*}	-0.22^{ns}
Pectoral fin height	0.12^{ns}	0.30^{*}	0.46^{***}	-0.35^{**}	-0.18^{ns}
Pelvic fin length	0.09^{ns}	0.10^{ns}	0.22^{ns}	-0.35^{**}	-0.09^{ns}
Pelvic fin height	0.16^{ns}	0.34^{**}	0.32^{**}	-0.37^{**}	-0.28^{*}
Dorsal fin length	0.22^{ns}	0.21^{ns}	0.56^{***}	-0.34^{**}	-0.13^{ns}
Dorsal fin height	0.25^{*}	0.30^{*}	0.31^{**}	-0.40^{***}	-0.22^{ns}
Anal fin length	0.11^{ns}	0.34^{**}	0.53^{***}	-0.28^{*}	-0.04^{ns}
Anal fin height	0.22^{ns}	0.21^{ns}	0.49^{***}	-0.43^{***}	-0.13^{ns}
Caudal fin length	0.17^{ns}	0.34^{**}	0.41^{***}	-0.35^{**}	-0.01^{ns}
Caudal fin height	0.10^{ns}	0.16^{ns}	0.23	-0.37^{**}	-0.30^{*}
Max body depth	0.08^{ns}	0.31^{**}	0.69^{***}	-0.33^{**}	0.53^{***}
Min body depth	0.20^{ns}	0.25^{*}	0.40^{***}	-0.30^{*}	0.30^{*}
Pre orbital length	0.27^{*}	0.34^{**}	0.47^{***}	-0.28^{*}	-0.16^{ns}
Inter orbital length	0.15^{ns}	0.30^{*}	0.59^{***}	-0.35^{**}	0.14^{ns}
Head length	0.26^{*}	0.23^{ns}	0.44^{***}	-0.38^{**}	-0.28^{*}
Pectoral fin rays	0.32^{**}	-0.21^{ns}	0.23^{ns}	-0.37^{**}	-0.36^{**}
Pelvic fin rays	0.19^{ns}	-0.34^{**}	0.38^{**}	-0.49^{***}	0.10^{ns}
Dorsal fin rays	0.37^{**}	-0.09^{ns}	0.24^{*}	0.01^{ns}	-0.39^{***}
Anal fin rays	-0.51^{***}	0.32^{**}	0.05^{ns}	-0.01^{ns}	0.50^{***}
Caudal fin rays	0.19^{ns}	-0.29^{*}	0.00^{ns}	0.00^{ns}	-0.49^{***}
Lateral line scale	0.26^{*}	0.49^{***}	0.56^{***}	-0.08^{ns}	0.12^{ns}

ns-P > 0.05, *-P < 0.05, **-P < 0.01, ***-P < 0.001

Similarity among species

The cluster analysis was used to investigate nearest neighbor among five species (SP, SL, SE, SR and LB) based on their morphometric and meristic characteristics and condition factors summarized graphically in Fig.17. The cluster analysis found both SE and LB nearest neighbor (i.e. demographically similar) followed by SP, LB and SR the farthest neighbor (i.e. demographically different).

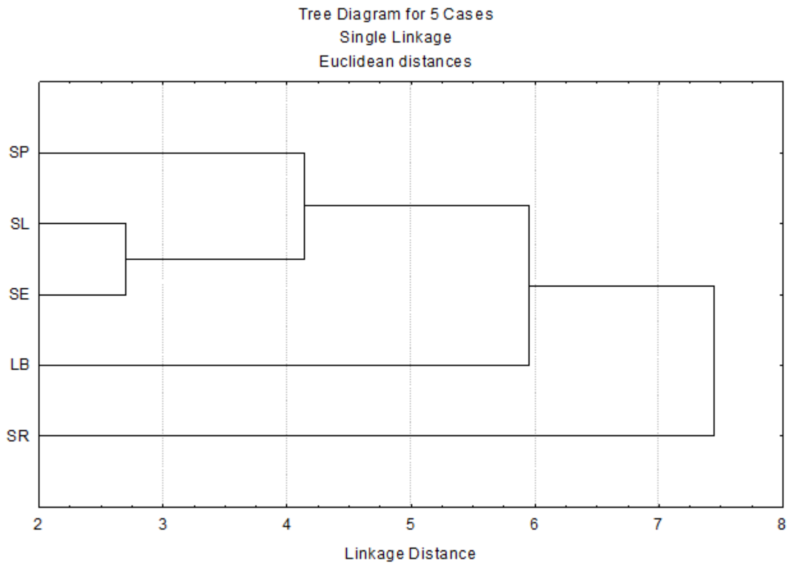

Fig.17. Tree diagram of five fish species based on their morphometric and meristic characteristics and condition factors using cluster analysis.

4. Discussion:

River Chenab one of the of five major tributaries of Indus river system, has historically served as a cradle for civilization. It is the most vibrant, economically and socially celebrated river, enjoys a special place amongst the major riverine systems in India. Both India and Pakistan depend heavily on the river (Fotedar et al., 2010), which has a tremendous impact on both nations.In pursuance of the terms of the Indus Water Treaty, Pakistan is given access to the Chenab River's waters, while India is given access to the Ravi, Beas, and Sutlej rivers' waters.

The aforementioned observations on the Icthyofauna of the river shows that

1.The River inhabits rich Icthyofaunal diversity with Cyprinidae as the dominating family. Also, in the upper catchment region, Kishtwar (Temperate zone) diversity is lowest. Whereas due to favourable topographical and climatic factors, it is highest in the downstream region (fig 2,3).

2.Schizothorax sps. (native cold water trout), which are widely distributed in the main river and hardly ever ascend to the tributaries, are the predominant occupants at higher altitudes.

3.Reasi is the breeding ground for Tor sps. (locally known as Mahseer).

4.Mahseer (Tor) is the second largest contributor in river only upto Salal dam and expectedly uses river for ascending tributaries for both breeding & feeding.

5.Both Mahseer and Schizothorax, undertake migration. Schizothorax sps. migrates within the river in hunt of food / to overcome extreme low temperatures in upper reaches and Mahseer use the river as a transit route to reach tributaries which are their feeding and breeding grounds.

6.Most of the species disappeared altogether during winter (especially December). It seems that these fishes in order to tide over the unfavourable conditions i.e. low winter temperature migrate to such zones along the river course where water is simulating more or less to lentic conditions (particularly at depths). These areas serve as ideal winter habitats both from point of view of avoidance of thermal stress and availability of allochthonus food supply.

7. The majority of species inhabiting the water body fall to the conservation category LC (least concern), but a few are vulnerable or endangered.

The "b" values of the five species recorded ranged from 2.9571 to 3.5208, with the highest 'b' values estimated for Schizothorax esocinus (3.5208), Schizothorax labiatus (3.1523), and Schizothorax plagiostomus (2.9571), and the lowest "b" values for Schizothorax richardsoni (2.4975) and Labeo boggut (2.8372) (Table 9). The values of b for Schizothorax labiatus, and Schizothorax esocinus are greater than 3, signifying positive allometric growth. Similar patterns of growth have also been reported earlier as well (Chatta et al., 2010; Ujjania et al., 2012). While Schizothorax richardsoni, Schizothorax plagiostomus and Labeo boggut showed, negative allometric growth, similar to the previous reports by Gupta et al., 2005.

Population dynamics research have demonstrated that Fulton factor signals rise and decline in favourable environmental conditions (Blackwell et al., 2000). A K value near to 1 implies that environmental conditions are optimal for fish growth. The mean value of condition factor of SP, SL, SE, SR and LB is 0.83 ± 0.13, 0.82 ± 0.09, 0.83 ± 0.11, 0.86 ± 0.31 and 0.85 ± 0.15 gm/cm3 respectively. The mean condition factor was highest for Schizothorax richardsoni. Variations in conditioning factors are regarded as illustrative of diverse biological characteristics, such as fitness or environmental adaptability (Le Cren, 1951b).In the present study, a drop in the "K" value of species can be interpreted as a degradation of feeding habits or a reduction in the overall quality of the environment, Interestingly these findings are consistent with the results of Awas et al., 2020 and Kırankaya et al., 2014.

Remarkably, variations in morphological characteristics can be attributed to a wide variety of environmental conditions, such as food abundance resulting from climatic conditions that fluctuate (Sidiq et al., 2021).Despite size differences, meristic counts remained constant (within species) indicating that meristic counts are independent of fish body size. The results are coinciding with those of other researchers who observed identical changes in various fish species (Ahmad et al., 2019; Bashir et al., 2015).

Future research into the Ichthyofauna of Jammu's most significant body of water can be grounded on the findings of this study. As the study is the first of its kind, an attempt was made not only to investigate the current status of the Ichthyofauna but also to assess their morphometric characteristics and length-weight relationship in order to deduce the Condition factor so that the current status of health of the dominant species can be deduced.This can serve as a baseline for analysing the ecology and productivity of the water body as well as revealing the impact of invasive species on its native Fish fauna, which can greatly aid in planning conservation strategies.

Comparative analysis revealed a decline of Catch per unit effort (Baba et al. 2014). Most likely, the aquatic ecosystem is not getting sufficient time to re-establish its natural community structure, due to overexploitation. During the tenure of present investigations, it was established that majority of the fish habitats are continuously exposed to sand and shingle mining, construction of crushers at the bank of the river besides leaching of detergents into the water (especially in the downstream region of Pargwal and Akhnoor) which are deteriorating the ecology of riverine system. Moreover, fish in the river and its tributaries suffer because of illegal methods of fish capture used by people living in and around the aquatic ecosystem. Most of these methods pertain to over exploitation, illegal fishing methods like dynamiting, use of bleaching powder, chemicals like insecticides, pesticides, electro-fishing and use of small meshed nets, besides, a native method of fish capture through 'fundha' (galloping).Based on the findings and observations specific recommendations have been formulated for the scientific management of the body of water exploited for fisheries development.

1. Since over-fishing is among the major concerns leading to depletion of the fishery resource in the river, especially in the midstream and down stream region, therefore regular monitoring needs to be carried out to keep a check on illegal/unethical local methods of fish catch, so that the fauna gets enough time to recover and re-establish.

2. As a result of numerous point and non-point pollution sources being poured into its water, the river is progressively losing its purity. The river is widely utilised as a disposal site, especially close to plain inhabited areas, therefore entry of sewage and agricultural wastes into the river needs to be carefully monitored in order to manage the fish fauna. Regulation of sand extraction and capture, especially during the breeding season, is crucial because it has a significant impact on the developing larval stages and poses a threat to the fish population at the very beginning of its life cycle.

3.Developing strategies to deal with the annoyance of invasive species (Carp) by analysing their impact on native fauna, in terms of competition for food and habitat exploitation. The introduction of exotic species such as Common Carp has a significant impact on the native fish population. Despite being introduced for a specific reason, Carp are currently prevalent in several waterbodies around the region, including Mansar-Surinsar Lake (dominant species) Common carps are resilient fish that can withstand pollution and changing biological conditions in the region's waters and thrive in such shifting environments, posing a serious threat to becoming a dominant species in the coming decades if left unchecked. Snow trout and Tor, on the other hand, are extremely vulnerable to environmental changes and face a risk of population decline.

Similar to this, strategies for halting the future spread of Nile Tilapia must be developed before the fish invades the main river channel and spreads farther.

Invasive species can be managed directly by using biological control measures and also monitoring the activities of humans that spread these fish into new locations, such as accidental release of fish seed into body of water. Restoration of natural processes within the River will also provide a type of indirect control, particularly in areas dealing with the effects of human disturbance. It would be based on the concept that restoring part of the natural ecosystems' resistance and resilience would restrict the successful Invasion of Exotic species, as any type of disruption in the ecology directly impacts the endemic fishes of the region, which the Carp can endure, providing it with better prospects for niche expansion.

4.The river's Reasi region should be designated as a hotspot region for Tor conservation, and also the effects of adventure tourism (done widely in the Reasi waters) on breeding of Tor needs to be researched.

5.There is a considerable research deficit in molecular characterisation of morphologically ambigious species that needs to be addressed, which has left the correct identification of many economically important species in peril and thus their genepool unexplored.

5. Conclusion:

The results show that the River inhabits rich Ichthyofaunal diversity with Cyprinidae as the dominating family. The current investigation successfully examined alterations in the spatial and temporal dynamics of fish assemblages by leveraging environmental data.The findings illuminated significant variations in fish communities within the Chenab region across different spatial and temporal scales. Moreover, it was inferred that distinct environmental factors exerted diverse influences on fish populations. The morphometric analysis of the five studied fish species revealed significant differences, underscoring the influential role of environmental variables, both biotic and abiotic, in shaping their distinct characteristics. Additionally, the meristic examination established notable differences among the species, strongly indicating a genetic basis for meristic traits and highlighting pronounced variations both within and between species. These findings emphasize the complex interplay of genetic and environmental factors in shaping the morphological attributes of fish populations, contributing valuable insights to our understanding of the intricate dynamics within aquatic ecosystems.

Further more analysis of length weight relationship of the economically important dominant species indicate a lower K value. Additionally, this is the first time report of length-weight relationship and the Fulton factor therefore, the information can be used to improve and exploit the existing fish fauna in the best possible way, and moribund species may also be looked after. The study recommends regulating the over exploitation and Illegal fishing as well as more intensive studies on the impacts of aquatic toxicology and exotic species on native fauna to be executed for development of conservation plans of indigenous fishes under the changing circumstances. The insights gained from this research have valuable implications for monitoring the well-being of fauna of the River. The knowledge derived can contribute to informed decision-making in areas such as preservation, restoration, and adaptation, essential for effective economic planning and execution. Creating informative documents detailing the distribution of rare and endangered fish species is crucial for supporting and maintaining aquatic ecosystem diversity and ecological balance. This study lays the groundwork for future research endeavors, emphasizing the importance of a holistic understanding of the intricate relationships between environmental variables and fish assemblages for sustainable ecosystem management.

CRediT authorship contribution statement

Anchal Chib: Investigation, Formal analysis, Writing – original draft, Shvetambri, Sharma K.K. :Writing – review & editing.

Ethical statement: As no live animal has been harmed or experimented with, in the laboratory, therefore ethical approval was not required.

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