



Meristic Variations in Two Congeneric Snow Trouts *Schizothorax niger* (Heckel 1838) and *Schizothorax curvifrons* (Heckel 1838) from Dal Lake, Kashmir

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Abstract

A simple yet useful criterion based on meristics is used to differentiate the two congeneric snow trout fish species *Schizothorax niger* Heckel 1838 and *Schizothorax curvifrons* Heckel 1838 from Dal Lake, Kashmir. Principal component and test of significance were used to investigate meristic differences between these two species. The purpose of this study was to appropriate identification of the two species and assigning them to distinct genetic groups. Eleven meristic traits (dorsal fin spine, dorsal fin rays, pectoral fin spine, pectoral fin ray, ventral fin spine, ventral fin ray, anal fin spine, anal fin ray, caudal fin rays, lateral line scales, number of gill rakers externally on the first gill arch) were studied in 180 fish specimens. The test of significance of meristic traits among *S. niger* and *S. curvifrons* revealed that four meristic characters namely dorsal fin rays, ventral fin rays, lateral line scales, number of gill rakers externally on the first gill arch were significantly different ($p \leq 0.05$) between *S. niger* and *S. curvifrons*. PCA revealed that the first three components together explained 60.51% of total variance. The meristic characters were also counted to draw the fin formula of these fish species. This study provides useful information to support taxonomic identification based on meristic counts.

Key words: *Schizothorax niger*, *Schizothorax curvifrons*, snowtrouts, meristics, PCA, Dal Lake, Kashmir

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Introduction

Fishes form part of a dynamic and versatile aquatic ecosystem influencing the physiology, body form, and genetic makeup in the long term, thus confronting their ability to live, sustain and survive. Meristic characteristics are the serially repeated, countable structures such as the fin rays (spinous ray and soft ray), vertebrae, gill rakers and lateral lines (Turan, Oral, Öztürk, & Düzgüneş, 2006). They can be influenced substantially by environmental factors, especially by temperature during early development (Weisel, 1955) including salinity, light, and dissolved oxygen (Lindsey, 1988). Countable characters vary within and among species, so they are useful in describing or identifying fishes. Variation of this nature has been noted for many species (Hubbs, 1922; Tåning, 1952; Weisel, 1955; Lindsey, 1958, 1962; Fowler, 1970) and should be taken into account in studies involving meristic characters. Meristic features may also be size-dependent within or among species (Strauss, 1985). Poor understanding of the fish and fishery management can lead to dramatic changes in the biological attributes and productivity of a species (Altukhov, 1981).

The schizothoracids, commonly known as snow trouts are members of the family Cyprinidae, (Teleostei: Cypriniformes) one of the richest and most important family of fish, with its members distributed throughout the world (Al-Sabti, 1991). A total of about 1500 species have been recorded in the family worldwide (Gül, Çolak, Sezgin, & Kalođlu, 2004). *Schizothorax* (Cypriniformes: Cyprinidae) comprises many species that inhabit the reservoirs of Central Asia from Turkmenistan and Eastern Persia in the West to the far reaches of Mekong and Yangtzein in the East. They are believed to have migrated into lakes and streams of

Kashmir from Central Asian watersheds bordered by inner and southern slopes of Hindukush, Karakoram and inner ends of the north-western Himalayas and Sulaiman Ranges (Sehgal, 1999). In India, these species are distributed at an elevation of 1180-3000 m above MSL, in the cold waters from Jammu and Kashmir (Sunder & Bhagat, 1979), to Assam and Eastern Himalayas through Bhutan and Sikkim (Jhingran, 1982). The taxonomic status of fishes of the subfamily schizothoracinae has remained highly controversial. Though creditable work has been done by the earlier workers on Kashmir Valley fishes, prominent among them has been that of Heckel (1838); Hora (1934); Silas (1960); Das and Subla (1963); Qadri, Mir, and Yousuf (1983); Yousuf, Balkhi, and Firdous (1990); Yousuf (1996); Kullander, Fang, Delling, and Åhlander (1999) etc.

Heckel (1838) for the first time reported ten species of schizothoracines in the genus *Schizothorax* from Kashmir (*S. plagiostomus*, *S. sinuatus*, *S. curvifrons*, *S. longipinnis*, *S. niger*, *S. nasus*, *S. hugelii*, *S. micropogon*, *S. planifrons* and *S. esocinus*). *Schizothorax* taxonomy is controversial (Mirza, 1991; Talwar & Jhingran 1991; Wu & Wu 1992; Chen, 2000), and the phylogenetic relationships and biogeography of this group are unclear. According to Raina and Petr (1999), it is often difficult to decide whether these are different species, different phenotypes of single species or an intermediate situation between the two extremes. Some species like *S. sinuatus* and *S. nasus* have been treated as synonymous with *S. plagiostomus*. *S. planifrons* has been treated as a synonym of *S. niger*. *S. longipinnis*, *S. hugely* and *S. micropogon* has been treated as synonymous with *S. curvifrons* (Silas, 1960). Each species of the genus *Schizothorax* in Kashmir valley is also identified by its local name (Kullander et al., 1999)

Schizothorax is the most commercially important food fish in Kashmir Himalayas. *S. niger*, locally known as Aelgad, is fusiform, with a short, blunt, somewhat prognathous upper jaw, inferior mouth (upper jaw a little protruding beyond lower jaw), horse-shoe shaped, nearly horizontal, and broader than long. The pigmentation of *S. niger* varies considerably depending upon its habitat. The fishes inhabiting the dense vegetation are darker towards the dorsal side than those inhabiting the open waters. The maximum reported size of this fish is 326 mm SL (Khan & Sabah, 2013). *S. curvifrons*, locally known as Sattar gad, can be recognized by an elongated and streamlined body, somewhat

compressed with its depth 5.1 to 5.8 times in standard length. There are two pairs of barbels (maxillary and rostral), much shorter than eye diameter (Qadri et al., 2015), light brownish colour, and silvery belly (Talwar & Jhingran, 1991). The maximum reported size of this fish is 56 cm in total length (Berg, 1964) and 1.3 kg in weight (Talwar & Jhingran, 1991).

Despite numerous studies addressing the taxonomy and biology of snow trouts (*Schizothorax* spp.), the meristic variation among closely related species inhabiting the same ecosystem remains poorly understood. *S. niger* and *S. curvifrons* both occurring in Kashmir & Himalaya, exhibit significant morphological overlap, leading to misidentification during routine fishery assessments. This study was conducted to explore interspecific meristic differences between *S. niger* and *S. curvifrons* collected from Dal Lake using multivariate statistical analysis. The objective is to identify reliable meristic characters that can effectively discriminate between the two species, thereby improving taxonomic resolution and supporting sustainable management and conservation of snow trout resources in the region.

Materials and Methods

The study was carried out in Dal Lake, Kashmir, India (Fig. 1). Dal Lake is a Himalayan urban Lake, located in the heart of Srinagar (34°18' N latitude and 74°91' E longitude) at an average altitude of 1583 m, which has an immense socio-economic significance. Fisheries and harvesting of food and fodder plants are also important to Dal. It is the second largest lake in Jammu and Kashmir and harbours a variety of fish fauna including both indigenous and exotic species.

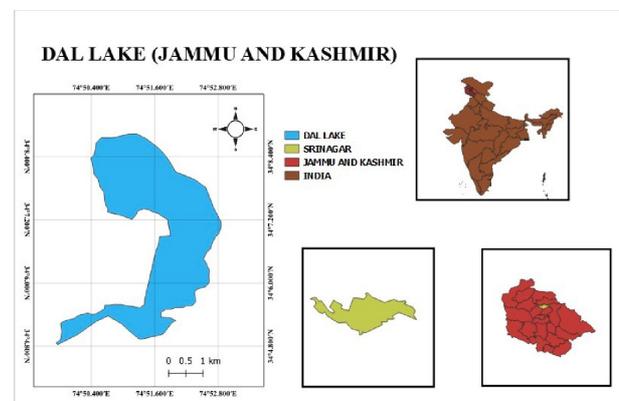


Fig. 1. Study area showing Dal Lake of Jammu and Kashmir, India.

One hundred and eighty samples, comprising ninety individuals each of *S. niger* and *S. curvifrons* were collected from commercial catches of Dal Lake. All fish specimens were transported in insulated boxes to the laboratory and preserved in 10% formalin, and later transferred to 50% ethanol for longer preservation. Since male and female fish could not be differentiated morphologically, sexing of the fish was not carried out.

Data collected were statistically analyzed by using standard statistical packages such as SPSS for windows (version 20) and PAST-3. Since the dataset contained only two species (groups), a single discriminant function was obtained from the LDA model ($DF_1 = \text{number of groups} - 1 = 1$). As a result, the analysis led to univariate bar plots (rather than scatter plots), a statistically anticipated task for two-group examinations, an issue that constrains visualisation. Accordingly, PCA was used to explore the multivariate structure of variation in meristic characters.

Eleven meristic counts were analysed following the conventional method as described by Hubbs and Lagler (1958). All the meristic counts were set against incoming light in the laboratory room using needle and small pins for easy counting. All the counts were taken from the lateral aspect of the fish. The meristic characters studied in the work were (DFS)- Number of spines on the dorsal fin; (DFR)- Number of rays on the dorsal fin; (PFS)- Number of spines on the pectoral fin; (PFR)- Number of rays

on the pectoral fin; (VFS)- Number of spines on the ventral fin; (VFR)- Number of rays on the ventral fin; (AFS)- Number of spine on the anal fin; (AFR)- Number of rays on the anal fin; (CFR)- Number of rays on the caudal fin; (LI)- Number of scales along the lateral line starting from the scale just behind the upper end of the gill opening to the base of caudal fin and (GR)- Number of gill rakers externally on the first gill arch. All the hard and soft rays in all the fins were counted separately including the tiny ones on the inside of ventral fins. When making counts the base of each fin where each fin ray inserts into the body were examined.

Results and Discussion

Knowledge of meristic characteristics of fishes is regarded as one of the most vital means of identifying fish stocks, helping in taxonomic studies, evaluating the evolutionary adaptation of a species with respect to its environment, and most importantly providing information on the precise identification of particular fish species (Pant, Kaur, Lohani, & Ram, 2018). Countable morphological structures (e.g., fin rays, gill rakers, scales) have historically served as an important basis for identifying fish stocks. Count data are discrete, thus facilitating statistical analysis. Out of 11 meristic traits studied, four traits namely, number of dorsal fin spines, pectoral fin spines, ventral fin spines, and anal fin spines did not show any variation in the fishes, and as such were not considered in further analysis. The minimum, maximum, and mean of the

Table 1. Basic statistics for meristic traits of *S. niger* and *S. curvifrons*

Meristic traits	<i>S. niger</i>			<i>S. curvifrons</i>		
	Min	Max	Mean±SE	Min	Max	Mean±SE
DFS	1.00	1.00	1.00±0.00	1.00	1.00	1.00±0.00
DFR	6.00	7.00	6.78±0.04	7.00	9.00	7.42±0.07
PFS	1.00	1.00	1.00±0.00	1.00	1.00	1.00±0.00
PFR	12.00	17.00	13.63±0.10	12.00	18.00	13.42±0.12
VFS	1.00	1.00	1.00±0.00	1.00	1.00	1.00±0.00
VFR	8.00	10.00	8.72±0.07	8.00	11.00	8.99±0.06
AFS	1.00	1.00	1.00±0.00	1.00	1.00	1.00±0.00
AFR	5.00	7.00	5.31±0.06	5.00	7.00	5.39±0.06
CFR	17.00	21.00	19.46±0.10	17.00	21.00	19.51±0.10
LI	80.00	109.00	93.26±0.59	90.00	121.00	105.5±0.91
GR	12.00	17.00	13.61±0.11	20.00	26.00	21.98±0.16

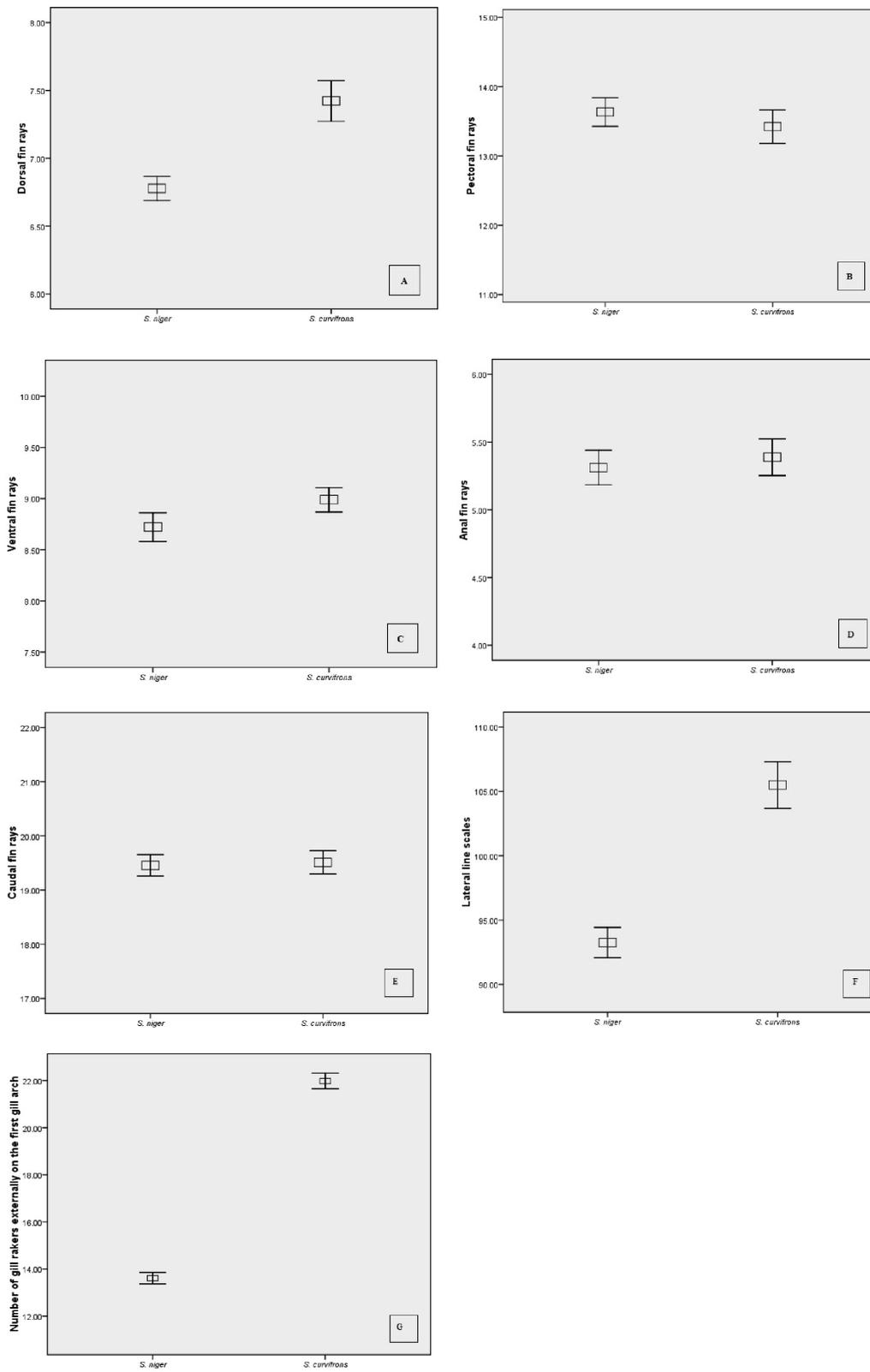


Fig. 2. Box plots (means and 0.95 confidence intervals) of the 7 meristic traits between *S. niger* and *S. curvifrons*

different meristic traits is presented in table 1. *S. niger* and *S. curvifrons* had 6-7 dorsal fin rays and 7-9 dorsal fin rays, respectively. The range of fin rays in the ventral and anal fins was 8-10 and 8-11, respectively. The highest mean was found in the lateral line scale count, which ranged from 93.26 to 105.5 in *S. niger* and *S. curvifrons*, respectively.

The test of significance of meristic traits among *S. niger* and *S. curvifrons* is presented in Table 2. Four meristic characteristics namely, dorsal fin rays, ventral fin rays, lateral line scales, and number of gill rakers (externally) on the first-gill arch were significantly different between the two fish species ($p \leq 0.05$) whereas the characters of pectoral fin rays, anal fin rays, and caudal fin rays showed non-significant variations between the two fish species. The difference in the numbers of fin rays among the species assessed might be explained to some extent by genetic diversity. However, some individuals exhibit varied numbers of fin rays, suggesting that non-genetic factors such as developmentally stochastic events and environmental cues affect variation in fin ray anatomy (Hubbs, 1922; Lindsey, 1988). An investigation of the skeletal morphology of the fins in individuals should be performed to establish the extent to which non-genetic variables contribute to this variation (Hamada et al., 2019). Fish show variation in meristic attributes between species when compared to other vertebrates and are more disposed to ecological changes (Wimberger, 1992). El-Dahhar, Fernandes, and El-Saidi (2017) reported significant differences in most of the meristic counts among the three different strains of common carp. Similar results were obtained by Mahmoud, Mehanna, and Mohammad (2016) for *Mullus sermuletus* and *M. barbatus*. Simon, Bakar, Temple,

Table 3. Eigenvalues and proportion of variance contribution to the total variance of meristic traits in *S. niger* and *S. curvifrons*

Components	Eigenvalue	Proportion%	Cumulative%
PC1	2.02	28.83	28.83
PC2	1.20	17.12	45.95
PC3	1.02	14.56	60.51

and Mazlan (2010) investigated the meristic variation in two congeneric archer fishes, *Toxotes chatareus* and *T. jaculatrix*, and discovered that *T. chatareus* had more lateral line scales, less pectoral fin rays, and more anal fin rays. Robson, King, and McGrath (2005) reported meristic variation between *Lepidorhombus whiffiagonis* and *L. boscii*.

The fin formula for *S. niger* was devised as D: I, (6-7); P: I,(12-17); V: I,(8-10); A: I,(5-7); C: I,(17-21); Ll: (80-109); Gr: (12-17) and for *S. curvifrons* as D: I,(7-9); P: I,(12-18); V: I,(8-11); A: I,(5-7); C: I,(17-21); Ll: (90-121); Gr: (20-26). Box plots representing the seven meristic traits (A to G) between *S. niger* and *S. curvifrons* are depicted in Fig. 2. The range of values of the meristic characters estimated in the present study is similar to the findings of Gharaei (2012) for *S. zarudnyi*, Vasave and Saxena (2013) for *S. richardsonii*, Ahmed, Shah, Qadri, Abubakr, and Qadir (2017) for *S. curvifrons*, Ashraf, Bashir, A., and Bakhtiyar (2018) for *S. niger*, Jha (2020) for *S. sikusirumensis*, Jan and Ahmed (2021) for *S. labiatus* and, Shafi, Mushtaq, Bano, Shah, and Mushtaq (2021) for *S. esocinus*. Inter-specific variations of meristic characters have been observed in many fish species including *Osmerus mordax* (Copeman, 1977),

Table 2. Test of Significance of meristic traits between *S. niger* and *S. curvifrons* of Dal Lake

Meristic trait	<i>S. niger</i> Mean±SD	<i>S. curvifrons</i> Mean±SD	Z- value	p- value
DFR	6.78±0.41	7.42±0.71	7.35	<0.01*
PFR	13.63±0.98	13.42±1.15	1.32	>0.05
VFR	8.72±0.67	8.99±0.57	2.88	<0.05*
AFR	5.31±0.61	5.39±0.64	0.83	>0.05
CFR	19.46±0.94	19.51±1.01	0.37	>0.05
Ll	93.26±5.62	105.5±8.67	11.24	<0.01*
GR	13.61±1.11	21.98±1.56	41.32	<0.01*

*= significant difference

three *Synodontis* species (Mahmoud & Mekkawy, 1991), *Labeo horie* and *L. forskalii* (Mahmoud, 1991), *Alestis nurse* (Mekkawy, 1991), four Tilapiine species namely, *Oreochromis niloticus*, *O. ismailiaensis*, *Sarotherodon galilaeus* and *Tilapia zillii* (Mekkawy, 1995), four species of genus *Epinephelus* (Mekkawy, Saber, Shehata, & Osman, 2002), three Epinephaline species namely, *Cephalopholis argus*, *Cephalopholis miniata* and *Variola louti* (Mekkawy & Mohammad, 2011), *Trachurus mediterraneus* (Turan, 2004), *Carangoides bajad* and *Caranx melampygus* (Mahmoud et al., 2016) and *Acanthopagrus bifasciatus* (Mahmoud, El-Gammel, Mehanna, & El-Mahdy, 2013). Meristic characters studied was within the reported ranges of other authors who conducted research on different fish species like *B. birdi* (Sharma, Mir, Pandey, & Singh, 2014), *Crossocheilus latius* (Hamilton) (Brraich & Akhter, 2015a), and *Garra gotyla* (Gray) (Brraich & Akhter, 2015b) except for lateral line count. The difference in lateral line count indicates that different locations and environments have a considerable impact on meristic characters. Various authors also reported variations in meristic characters (Al-Hassan, 1987; Watanabe, 1998; Jaiswar, Parida, Chakraborty, & Palaniswamy, 2004; Koshy et al., 2008; Paunikar & Panwar, 2021). The basis of variation is the varying extent to which a fin plays role in locomotion and manoeuvring (Srivastava, 1999). Variations reported for meristic characters can be caused by many factors including temperature (Al-Hassan, 1987; Sfakianakis, Leris, Laggis, & Kentouri, 2011), genetics (Yousefian, 2011), nutrient availability, and seasonal variations.

In the present study, Principal Component Analysis (PCA) was performed to understand the variation between the two fish species. PCA is a multivariate technique used for studying higher dimensional data and presenting it in fewer dimensions. In the PCA, the first three components together explained 60.51% of total variance with eigenvalues of 2.02, 1.20, and 1.02 respectively (Table 3). The proportion of variance explained by each principle component is depicted as a scree plot (Fig. 3). The PCA loadings of seven meristic traits are listed in Table 4. The PC1 explained 28.83% of the total variance with significant loading on number of gill rakers (externally) on the first-gill arch, lateral line scales, and dorsal fin rays. This is an indication that the differences between the two fish populations resulted mainly from first gill arch, lateral line scales, dorsal fin rays, and ventral fin rays. Such meristic variation is determined partially by genetics and partially by

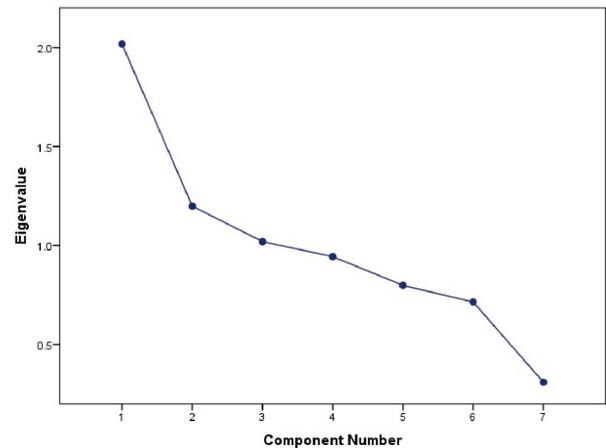


Fig. 3. Scree plot representing eigenvalues for meristic traits

environmental conditions (Swain, Hutchings, & Foote, 2005). Similar results were found by Simon et al. (2010) for distinctions between two closely related archer fishes, using multivariate techniques. Many workers have also reported comparable results for some other marine vertebrates and invertebrates (Fridriksson, 1958; Boetius, 1980; Pierce et al., 1994a, 1994b; Bolles & Begg, 2000). The bivariate plot of PC1 and PC2 extracted from the PCA for meristic traits of *S. niger* and *S. curvifrons* depicted a slight overlap of meristic characters between the two species. Along the X-axis, *S. curvifrons* had positive scores while *S. niger* had negative scores (Fig. 4).

In the present study, *S. curvifrons* were having high lateral line scale count compared to *S. niger*. The

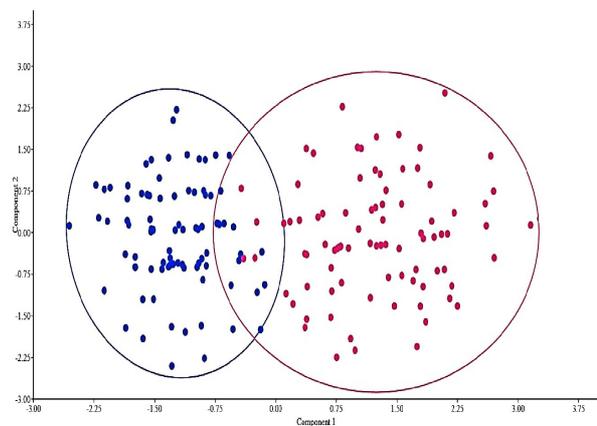


Fig. 4. Bivariate plot scores of the two components (PC1 and PC2) extracted from meristics of *S. niger* (●) and *S. curvifrons* (●)

Table 4. Variable loadings in Principal Component Analysis (PCA) of meristic traits in *S. niger* and *S. curvifrons*

Meristic traits	PC1	PC2	PC3
DFR	0.067	0.106	0.099
PFR	-0.078	0.726	-0.076
VFR	0.370	0.004	-0.694
AFR	0.134	-0.390	0.583
CFR	0.033	0.697	0.415
LI	0.784	0.140	0.010
GR	0.887	0.052	0.096

lateral line scale count is related to the fish habitat (Brraich & Akhter, 2015a, 2015b). The higher count of *S. curvifrons* may be due to the fact that the fish is migratory (Nasreen, Reyaz, Jan, Shah, & Mir, 2017) and can adapt to different local conditions. The present finding is supported by Watanabe (1998), who reported that fish having higher lateral scale count have better adaptability in changing localities. The present study also revealed a significant difference in number of gill rakers (externally) on the first gill arch between *S. niger* and *S. curvifrons* with higher numbers of gill rakers in *S. curvifrons*. These differences may be attributed to the different feeding habit of these fishes, as *S. niger* has been categorized as herbi-omnivorous fish (Ahmed & Sheikh, 2017; Wani et al., 2018), and *S. curvifrons* as phytophagous (Kausar, 2008; Naik, Rashid, Balkhi, & Bhat, 2015). Similar results were reported by Kullander et al. (1999) for *S. niger* and *S. curvifrons* and, Jahan (2021) for *S. niger*. The gills form an important characteristic feature of fishes and their presence has a marked effect on their physiological functioning. The primary function of the gill is to act as the main respiratory site for gas exchange while its secondary function is related to the feeding habits of the fish. The gill rakers act as a sieve retaining only the food particles that are greater in size than the inter raker spaces (Drenner, 1977). Number, shape as well as spacing of gill rakers gives insight about the food and feeding habit of different fishes (Durbin, 1979). Species possessing fewer and short rakers tend to be omnivorous in comparison to the filter feeding fishes possessing numerous long rakers (Sanderson, Cech, & Patterson, 1991). Zayed and Mohammad (2004), while studying the gills of tilapia and catfish reported short and widely spaced

gill rakers in tilapia and long and narrow spaced gill rakers in catfish. Srekanth et al. (2013) reported the number of gill rakers on upper limb of the first gill arch to range from 5 to 8 while on the lower limb from 7 to 12 in *N. japonicas*. Mahmoud et al. (2016) reported the total number of gill rakers on the first gill arch from 21-26 in *M. sermuletus* and 22-26 in *M. barbatus*. Soliman, Mehanna, Soliman, and Baker (2018) reported the total number of gill rakers on the first gill arch from 13-16 in *L. quinqelineatus*.

In summary, the present study establishes a set of reliable meristic traits that effectively discriminate between the two congeneric snow trouts, *S. niger* and *S. curvifrons*, inhabiting Dal Lake. The findings help in enhancing taxonomic resolution by demonstrating that *S. niger* can be distinguished from *S. curvifrons* through comparatively fewer dorsal fin rays, ventral fin rays, lateral line scales, and gill rakers. These diagnostic characters will help in simple and more accurate species identification and will serve as valuable reference points for fisheries professionals, biologists, and taxonomists involved in the management and conservation of snow trout resources in the Kashmir Himalaya.

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