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PRINCIPAL COMPONENT ANALYSIS OF FISH SPECIES OF DOON VALLEY, DEHRADUN, UTTARAKHAND

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ABSTRACT
The study of fish diversity of Eastern and Western Doon valley streams (March, 2012 – February, 2014) *viz*., Baldi, Song and Suswa in East and Tons and Asan in West has revealed it to be represented by 56 species belonging to 5 Orders, 13 families and 30 Genera. The present research communication highlights the PCA done on these species. Overall 3 situations have become evident while analyzing PCA for species. As many as 18 genera represented by 1 species each placed in circles, are identified as forming Groups A, B, C and D on the basis of their associations in preferential habitats as explained with reference to 'Factors' generated. 30 species belonging to 8 Genera *viz.*, *Puntius*, *Labeo*, *Barilius*, *Tor*, *Schistura*, *Glyptothorax*, *Colisa* and *Channa* arranged themselves in the biplot quadrants according to the Factor coordinate values clearly highlighting their abundance, temporal variability pattern, habitat preferences and infrequent nature. The overall variance analyzed for all the species is indicative of well - established assemblages under the prevalent ecological conditions in the streams of East and West. Also, the results of PCA analyses (both East and West) clearly highlighted the temporal variability pattern and fish species relation with habitat.

KEY WORDS: Fish Genera, Fish Species, Doon Valley, Principal Component Analysis, Multivariate Analysis, Fish Assemblage.

INTRODUCTION
About 21,730 species of fishes have been recorded in the world of which, about 11.7% are found in Indian waters. Out of the 2546 species so far listed, 73 (3.32%) belong to the cold freshwater regime, 544 (24.73%) to the warm fresh waters domain, 143 (6.50%) to the brackish waters and 1440 (65.45%) to the marine ecosystem. The Indian fish fauna is divided into two classes, *viz*., Chondrichthyes (cartilage fishes) and Osteichthyes (bony fishes). The endemic fish families form 2.21% of the total bony fish families of the Indian region. Also 223 endemic fish species are found in India, representing 8.75 % of the total fish species known from the Indian region. Freshwater fishes are a poorly studied group since information regarding distribution, population dynamics and threats is incomplete, and most of the information available is from a few well-studied locations only (Rajashekhar *et al*., 2007; Chaudhuri, 2010). One of the biostatistical tools *i.e.*, multivariate analysis (based on multivariate statistics) has been found useful in authenticating various field data, like those of fish species assemblages, associations and distributional pattern in a particular area of observation. Canonical Correlation Analysis (CCA), Principal Component Analysis (PCA), Factor Analysis (FA) *etc*., are some Multivariate Analyses for evaluating/calculating relationship between fish species and water quality parameters mathematically, to understand the patterns of similarity and variance in the distributional pattern of fish genera and fish species within genera, correlations within fish genera and correlation amongst water quality parameters, respectively. Principal component analysis (PCA) is another mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called Principal Components. The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has as high a variance as possible (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (uncorrelated with) the preceding components (Source: www. wikipedia.org). Ecological applications of multivariate statistics have expanded tremendously (Gauch, 1982), using various methods to observe the aspects like species association analyses, species area relationships, analysis of fish distribution and in defining fish assemblages. All these analyses are suggested (Zar, 1984; Ludwig and Reynolds, 1988; Johnson and Wilchern, 1992) to be done by applying Factor Analysis, Principal Component Analysis, Multivariate Analysis of Variance, Deterended Correspondence Analysis, Canonical Correspondence Analysis, Canonical Correlation Analysis *etc*. As computational power increased in recent decades, there has been an increase in multivariate assessments of distribution of fish species across large geographical or political units (Cross *et al*., 1986; Larson *et al*., 1986; Hughes *et al*., 1987). Distributions of fishes have been linked statistically to individual water-quality variables (*e.g*., Hawkes *et al*., 1986). Principal Component Analysis, a technique that was formerly used in the field of

hydrology, has shown the appropriateness for water quality data, as confirmed by some case studies. The subjects like fish assemblages influenced by environmental factors or fish assemblage variation between geographically defined regions or spatial and temporal characterization of fish assemblages *etc*., have been aptly worked out by wide variety of workers outside India (Zhu *et al*., 2011; Sumith*et al*., 2011; Tololupe, 2011; Anhwange *et al*., 2012; Yidana *et al*., 2012; Cunico *et al*., 2012; Daga *et al*., 2012 *etc.*), who variously used the statistical tools like Principal Component Analysis (PCA), Factor Analysis (FA) to derive correlation between fish diversity and water quality. Using aforesaid statistical tools (=softwares) a comparatively less quantum of work has been initiated in India, except a few (Bhat, 2003, 2004; Sreekantha*et al*.,2007; Johnson and Arunachalam, 2009; Kumar and Singh, 2010; Johnson *et al*., 2012; Gupta *et al*., 2012; Jha *et al*., 2012; Bhatt *et al*., 2012).The objective of the present study was to understand the pattern of distribution of various fish Genera and species (within a Genus) and their occurrence in similar ecological conditions.

MATERIALS & METHODS

Doon Valley, part of district Dehradun (latitude – 29^{o}58′ and 30^{o}32′ N and longitude–77^{o}35′ and 78^{o}20′E) comprises of 2 main river basins, namely, the Ganga river basin and the Yamuna river basin. The present study was carried out on these two river systems comprising of five main rivers- Baldi, Song, Suswa, Tons and Asan. Sampling was regularly/ periodically done for a period of 24 months (March, 2012 –February, 2014) at the 20 sampling stations established along the rivers mentioned above.

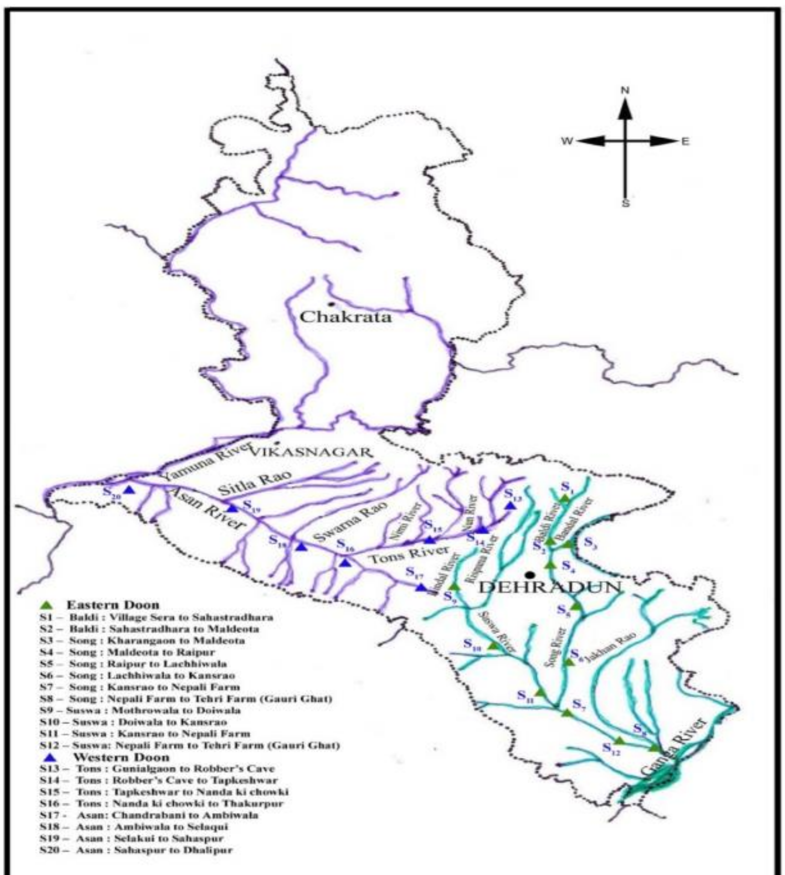


FIGURE 1. Study area showing sampling stretches in Eastern and Western Doon

To understand the pattern of distribution of various fish Genera and species (within a Genus), their occurrence in similar ecological conditions *etc*., Principal Component Analysis was done. For this, the data regarding the number of individuals data was put to software analyses. Genera × locality (Month, River and Station) data matrix consisting of the number of individuals of all Genera were fed to STATISTICA statistical software and results were obtained. Resultantly, the variables (= Genera) underwent fractionation into 'Factors' and each Factor was specified by a set of Genera showing either highest +ve or -ve loadings. The Factors, thus, generated are presented in a Tabular form (Tables 2 - 4) where the scores mentioned against every Genus (variable) figure under the column of 'Factors' generated and correlation biplots (Figs. 2 - 13). Variables with high absolute loadings (either +ve or -ve) concerning with a particular Factor contribute strongly to that Factor. Based on number of individuals (>20 and 20<) reported in a sample, out of 30 Genera recorded from various sampling stations of East and West, 28 Genera were found to be exclusively dominant/frequent throughout the samplings but 2 Genera were exclusively found infrequent althrough the observations. Besides, the species like *Puntius terio*, *Barilius tileo*, *Barilius shacra*, *Lepidocephalichthys annandalei*, *Glyptothorax telchitta*, *Clarias gariepinnus*, *Colisa lalia*, *Colisa labiosus*, *Channa marulius* and *Channa harcourtbutleri*, belonging to Genera of frequent nature were also to be put under exclusively infrequent/rare category as per evaluation of the number of individuals. Therefore, in the forthcoming elaborations of the observations/discussions, particularly with reference to Multivariate Analysis (Factor Analysis, Principal Component Analysis and Pearson Correlation Coefficient), separate references will be made of frquent and infrequent data matrix generated out of random samplings.

RESULTS

The study of fish diversity of Eastern and Western Doon Valley streams (2012-2014) *viz*., Baldi, Song and Suswa in East and Tons and Asan in West has revealed it to be represented by 56 species belonging to 5 Orders, 13 Families and 30 Genera. The results *i.e*., the pattern of distribution of various fish Genera and species (within a Genus) are presented as Factor coordinate values (used to determine the location of fish Genera and species on the Factor plane) [Tables1 - 2] and correlation biplots (Figs. 1-2).Various fish genera and species arrange themselves in the biplot quadrants according to the Factor coordinate values obtained after PCA. In Tables, segregation of species into Factor coordinates show '+ve' or '-ve' loadings, the '+ve' ones indicating the stronger correlation with any individual factor whereas the '-ve' ones indicative of different habitat conditions/associations as compared to those with '+ve' values. On the other hand, some species showed exclusive '-ve' loadings (*e.g*., *Tor*, *Colisa* and *Channa* species) indicative of their habitat preferences quite distinct from rest of the species.Overall 3 situations have become evident while analyzing PCA for species.

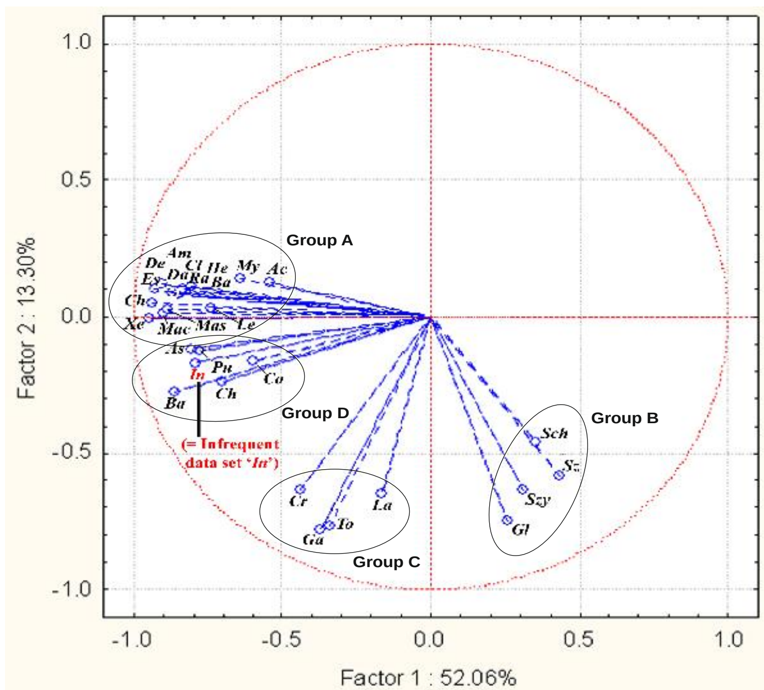


FIGURE 2: Principal Component Analysis of Fish Genera

TABLE 1. Abbreviations used in Principal Component Analyses representation

S. No.	Genus number	Genus	Abbreviation Genus	Species	Abbreviation species
1.	1	*Cyprinus*	*Cy*	*Cyprinus carpio*	*Cyca*
2.	2	*Puntius*	*Pu*	*Puntius chola*	*Puch*
3.				*Puntius conchonius*	*Puco*
4.				*Puntius sarana sarana*	*Pusasa*
5.				*Puntius sophore*	*Puso*
6.				*Puntius ticto*	*Puti*
7.				*Puntius terio*	*Pute*
8.	3	*Chagunius*	*Ch*	*Chagunius chagunius*	*Chch*
9.	4	*Schizothorax*	*Sz*	*Schizothorax richardsonii*	*Szri*
10.	5	*Schizothorachthys*	*Szy*	*Schizothorachthys progastus*	*Szypr*
11.	6	*Labeo*	*La*	*Labeo dyocheilus*	*Lady*
12.				*Labeo pangusia*	*Lapa*
13.				*Labeo dero*	*Lade*
14.	7	*Aspidoparia*	*As*	*Aspidoparia jaya*	*Asja*
15.				*Aspidoparia morar*	*Asmo*
16.	8	*Barilius*	*Ba*	*Barilius barna*	*Baba*

17.				*Barilius bendelisis*	*Babe*
18.				*Barilius vagra*	*Bava*
19.				*Barilius tileo*	*Bati*
20.				*Barilius shacra*	*Bash*
21.	9	*Danio*	*Da*	*Danio rerio*	*Dare*
22.	10	*Devario*	*De*	*Devario devario*	*Dede*
23.	11	*Esomus*	*Es*	*Esomus danricus*	*Esda*
24.	12	*Raiamas*	*Ra*	*Raiamas bola*	*Rabo*
25.	13	*Rasbora*	*Ras*	*Rasbora daniconius*	*Rasda*
26.	14	*Crossocheilus*	*Cr*	*Crossocheilus latius latius*	*Crlala*
27.	15	*Garra*	*Ga*	*Garra gotyla gotyla*	*Gagogo*
28.	16	*Tor*	*To*	*Tor putitora*	*Topu*
29.				*Tor tor*	*Toto*
30.				*Tor chelynoides*	*Toch*
31.	17	*Lepidocephalichthys*	*Le*	*Lepidocephalichthys guntea*	*Legu*
32.				*Lepidocephalichthys annandalei*	*Lean*
33.	18	*Acanthocobitis*	*Ac*	*Acanthocobitis botia*	*Acbo*
34.	19	*Schistura*	*Sc*	*Schistura montanus*	*Scmo*
35.				*Schistura rupecula*	*Scru*
36.				*Schistura savona*	*Scsa*
37.	20	*Amblyceps*	*Am*	*Amblyceps mangois*	*Amma*
38.	21	*Glyptothorax*	*Gl*	*Glyptothorax pectinopterus*	*Glpe*
39.				*Glyptothorax saisii*	*Glsa*
40.				*Glyptothorax telchitta*	*Glte*
41.	22	*Clarias*	*Cl*	*Clarias batrachus*	*Clba*
42.				*Clarias gariepinnus*	*Clga*
43.	23	*Heteropneustes*	*He*	*Heteropneustes fossilis*	*Hefo*
44.	24	*Mystus*	*My*	*Mystus tengara*	*Myte*
45.				*Mystus bleekeri*	*Mybl*
46.	25	*Xenentodon*	*Xe*	*Xenentodon cancila*	*Xeca*
47.	26	*Macrognathus*	*Mac*	*Macrognathus panclaus*	*Macpa*
48.	27	*Mastacembelus*	*Mas*	*Mastacembelus armatus*	*Masar*
49.	28	*Badis*	*Ba*	*Badis badis*	*Baba*
50.	29	*Colisa*	*Co*	*Colisa fasciatus*	*Cofa*
51.				*Colisa lalius*	*Cola*
52.				*Colisa labiosus*	*Colab*
53.	30	*Channa*	*Ch*	*Channa punctatus*	*Chpu*
54.				*Channa gachua*	*Chga*
55.				*Channa marulius*	*Chma*
56.				*Channa harcourtbutleri*	*Chha*
57.		Infrequent Genera/species	In		

Genera represented by one species each

As many as 18 genera are represented by 1 species each and therefore their PCA is not done separately but their associations are gathered only by putting the data matrix for PCA of fish Genera only in the form of Factor coordinate Table 1 and correlation bilpot (Fig. 2). The total amount of variability explained by the first 2 eigenvalues corresponding to the first two principal components is 65.36% (Fig. 2). In the Factor biplots (Fig. 1), a total of 16 Genera (*viz*., *Chagunius*, *Schizothorax*, *Schizothorachthys*, *Danio*, *Devario*, *Esomus*, *Rasbora*, *Crossocheilus*, *Garra*, *Acanthocobitis*, *Amblyceps*, *Heteropneustes*, *Xenentodon*, *Macrognathus*, *Mastacembelus* and *Badis*), placed in circles, are identified as forming Groups A, B, C and D on the basis of their associations in preferential habitats as explained with reference to 'Factors' generated after Factor Analysis for Eastern and Western Doon, separately.

The PCA for the remaining 2 Genera *viz*., *Cyprinus* and *Raiamas*, (Fig. 1) indicates their placement in the spot '*In*' (= Infrequent set) placed in the circle of Group D, indicative of their association with other infrequent 10 species on account of their 'infrequency' and restrictive distribution to specific sampling stations. For the 'infrequent set', the total amount of variability explained by the first 2 eigenvalues, corresponding to the first two principal components is 51.05% (Fig. 2).

A total of 12 Genera/ species constituting an infrequent data set were put to PCA separately and it was found that they segregated into 4 groups (identified as A, B, C and D on the circle in the biplot diagram (Fig. 2) on the basis of the corresponding Factor coordinate values [Table 2], with the following associations :

- Group A: *Cyprinuscarpio*, *Raiamas bola* and *Bariliustileo* as Song specific (S_7) forested, pooly - stretch of Rajaji National Park.
- Group B: *Puntiusterio*, *Glyptothoraxtechitta*, *Colisalabiosus*, *Colisalalia*, *Channamarulius* and *Channaharcourtbutleri* as Suswa - specific in the downstream feebly flowing marshy sections (S_{12}).
- Group C: *Lepidocephalichthysannandalei*, as, Suswa - specific, in forested upstream sections (S_{11}).
- Group D: *Clariasgariepinnus* and *Bariliusshacra* as West stream - specific, from Tons (S_{16}) and Asan (S_{20}), respectively.

TABLE 2: Factor Coordinates (values) of fish Genera/species

S. No.	Fish Genera	Factor 1	Factor 2	Factor 3	Factor 4
1.	*Puntius*	-0.84	-0.52	-0.15	0.05
2.	*Chagunius*	-0.89	-0.40	0.17	-0.11
3.	*Schizothorax*	0.27	0.87	0.14	-0.38
4.	*Schizothorachthys*	-0.22	0.89	0.07	-0.39
5.	*Labeo*	-0.87	0.50	0.02	0.05
6.	*Aspidoparia*	-0.98	0.08	0.06	-0.18
7.	*Barilius*	-0.98	-0.09	0.18	0.04
8.	*Danio*	-0.95	0.04	-0.31	-0.04
9.	*Devario*	-0.95	-0.29	-0.10	0.03
10.	*Esomus*	-0.94	0.01	-0.34	-0.04
11.	*Rasbora*	-0.95	-0.29	-0.10	0.03
12.	*Crossocheilus*	-0.88	0.12	0.44	0.09
13.	*Garra*	-0.85	0.38	0.31	0.17
14.	*Tor*	-0.76	0.64	0.13	-0.01
15.	*Lepidocephalichthys*	-1.00	-0.03	0.05	-0.01
16.	*Acanthocobitis*	-1.00	-0.01	0.01	-0.02
17.	*Schistura*	0.71	0.64	0.16	0.22
18.	*Amblyceps*	-0.93	0.12	-0.33	-0.04
19.	*Glyptothorax*	-0.40	0.83	0.18	0.34
20.	*Clarias*	-0.92	0.36	-0.14	0.07
21.	*Heteropneustes*	-0.94	0.33	-0.05	0.06
22.	*Mystus*	-0.75	0.41	-0.51	-0.01
23.	*Xenentodon*	-1.00	0.01	-0.02	0.01
24.	*Macrognathus*	-0.96	0.26	0.10	0.05
25.	*Mastacembelus*	-0.97	-0.10	0.21	-0.06
26.	*Badis*	-0.97	-0.21	-0.12	0.04
27.	*Colisa fasciatus*	-0.53	-0.70	0.45	-0.16
28.	*Channa*	-0.97	-0.24	-0.06	0.01
29.	Infrequent Genera/species (=*In*)	-0.83	-0.40	0.38	-0.05

NOTE : Highest loadings bold.

TABLE 3. Factor Coordinates (values) of Infrequent fish Genera/species

S. No.	Fish Genera/species	Factor 1	Factor 2	Factor 3	Factor 4
1.	*Cyprinus carpio*	0.02	-0.51	0.02	-0.04
2.	*Puntius terio*	-0.39	-0.01	**-0.47**	-0.07
3.	*Barilius tileo*	0.03	**-0.57**	0.001	-0.09
4.	*Barilius shacra*	-0.01	-0.01	0.08	**0.82**
5.	*Raiamas bola*	0.02	**-0.60**	0.01	-0.09
6.	*Lepidocephalichthys annandalei*	-0.18	0.06	**0.60**	-0.25
7.	*Glyptothorax telchitta*	-0.39	-0.01	**-0.47**	-0.07
8.	*Clarias gariepinnus*	0.03	0.06	**-0.12**	-0.02
9.	*Colisa lalia*	**-0.44***	0.001	0.07	0.0002
10.	*Colisa labiosus*	**-0.42**	0.04	0.39	-0.13
11.	*Channa marulius*	-0.30	-0.22	0.15	**0.46**
12.	*Channa harcourtbutleri*	**-0.45**	0.002	0.04	0.001

* Highest loadings boldened.

TABLE 4. Factor Coordinates (values) of Frequent Fish Species

S. No.	Fish species	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1.	*Aspidoparia jaya*	0.88*	0.47			
2.	*Aspidoparia morar*	0.88	-0.47			
3.	*Lepidocephalichthys guntea*	0.81	0.58			
4.	*Lepidocephalichthys annandalei*	0.81	-0.58			
5.	*Mystus tengara*	0.93	0.36			
6.	*Mystus bleekeri*	0.93	-0.36			
7.	*Clarias batrachus*	0.74	0.68			
8.	*Clarias gariepinnus*	-0.74	0.68			
9.	*Puntius chola*	0.96	-0.14	-0.19	0.08	
10.	*Puntius conchonius*	0.89	0.02	0.15	-0.43	
11.	*Puntius sarana sarana*	0.96	-0.11	-0.21	0.07	
12.	*Puntius sophore*	0.97	-0.12	-0.19	0.08	
13.	*Puntius ticto*	0.76	0.34	0.62	0.18	
14.	*Puntius terio*	0.34	0.93	-0.11	0.03	
15.	*Labeo dyocheilus*	0.91	-0.30	0.26		
16.	*Labeo pangusia*	0.94	-0.21	-0.27		
17.	*Labeo dero*	0.58	0.81	0.03		
18.	*Barilius barna*	0.75	-0.21	0.18	0.60	0.04
19.	*Barilius bendelisis*	0.87	0.06	0.23	-0.33	0.26
20.	*Barilius vagra*	0.92	0.02	0.14	-0.19	-0.30
21.	*Barilius tileo*	0.61	0.30	-0.73	0.06	0.03

22.	*Barilius shacra*	0.13	-0.95	-0.26	-0.14	0.01
23.	*Tor putitora*	-0.85	-0.21	0.48		
24.	*Tor tor*	-0.86	-0.08	-0.49		
25.	*Tor chelynoides*	0.25	-0.96	-0.06		
26.	*Schistura montanus*	0.95	-0.11	0.29		
27.	*Schistura rupecula*	0.93	-0.22	-0.29		
28.	*Schistura savona*	0.33	0.94	-0.03		
29.	*Glyptothorax pectinopterus*	0.92	0.07	0.37		
30.	*Glyptothorax saisii*	0.93	-0.004	-0.37		
31.	*Glyptothorax telchitta*	-0.06	0.99	-0.03		
32.	*Colisa fasciatus*	-0.96	0.19	0.20		
33.	*Colisa lalius*	-0.90	-0.42	-0.01		
34.	*Colisa labiosus*	-0.96	0.21	-0.19		
35.	*Channa punctatus*	-0.87	-0.03	0.48	-0.08	
36.	*Channa gachua*	-0.89	0.38	-0.05	0.23	
37.	*Channa marulius*	-0.91	0.20	-0.30	-0.20	
38.	*Channa harcourtbutleri*	-0.69	-0.70	-0.14	0.07	

* Highest loadings boldened.

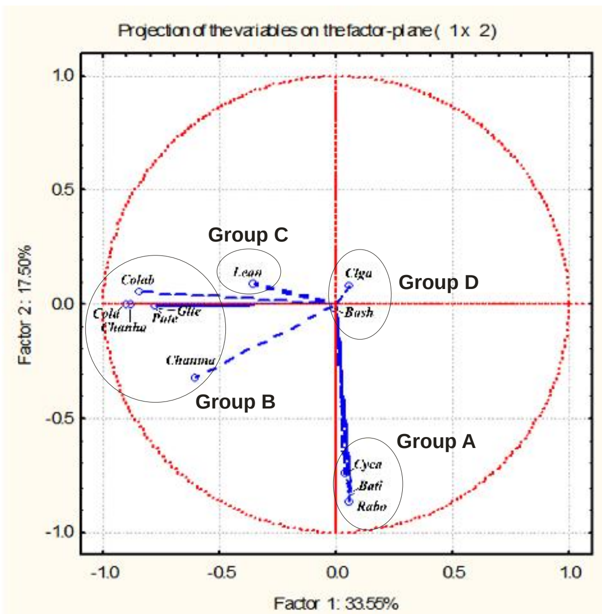


FIGURE 3: Principal Component Analysis of Infrequent Genera/species

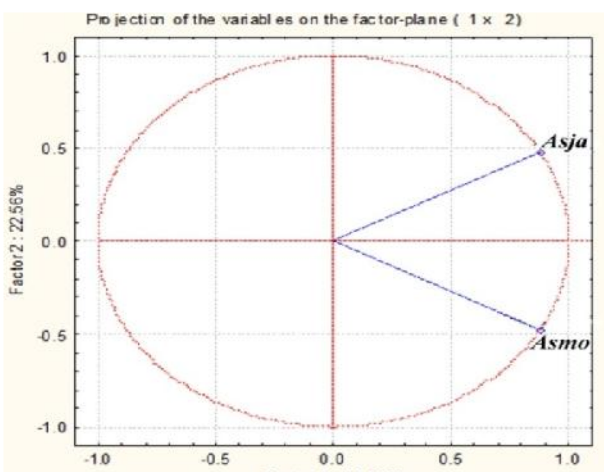


FIGURE 4 Principal Component Analysis of Genus *Aspidoparia*

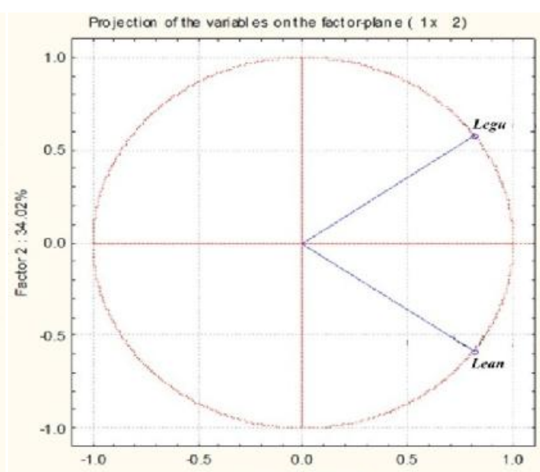
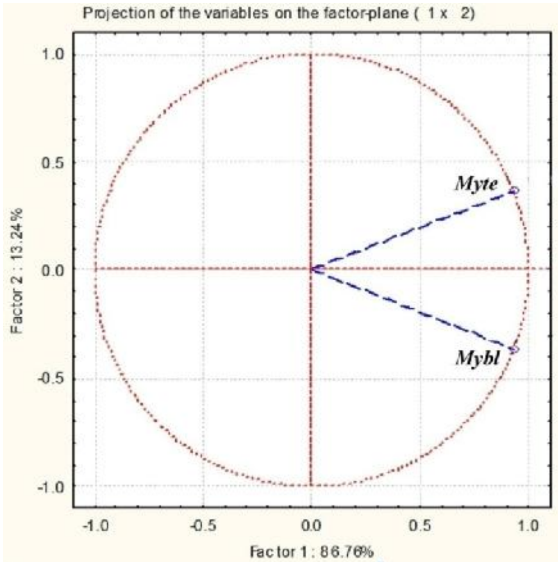


FIGURE 5 Principal Component Analysis of Genus *Lepidocephalichthys*.



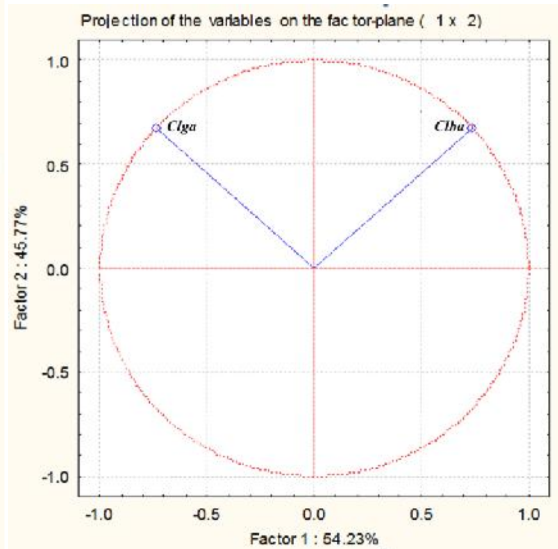
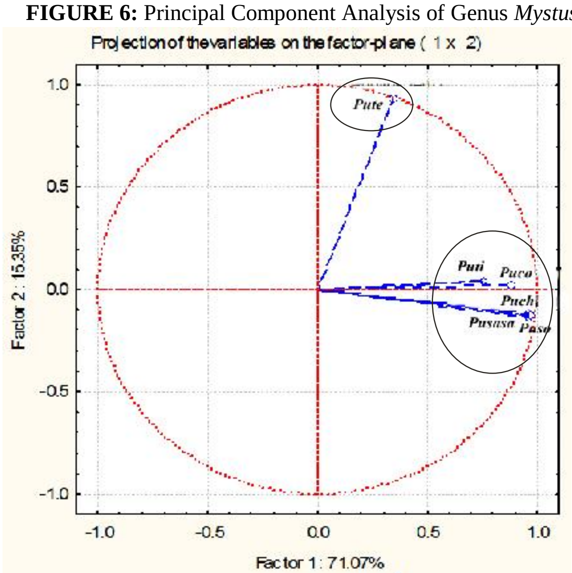


FIGURE 6: Principal Component Analysis of Genus *Mystus*. **FIGURE 7:** Principal Component Analysis of Genus *Clarias*.



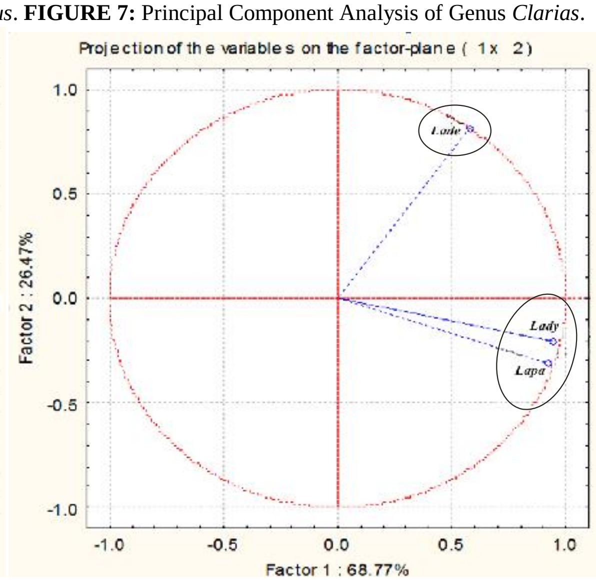
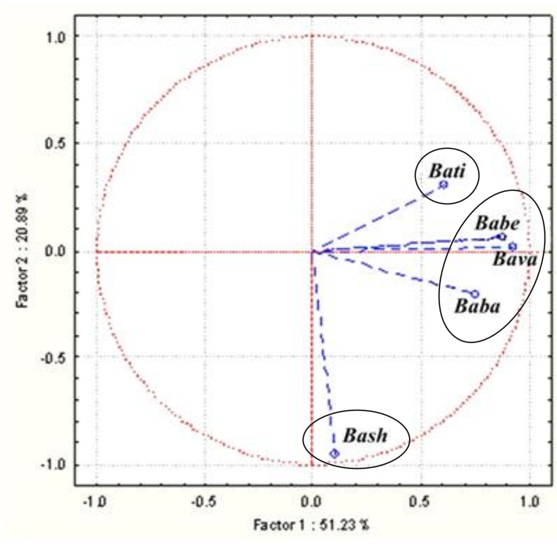


FIGURE 8: Principal Component Analysis of Genus *Puntius* **FIGURE 9:** Principal Component Analysis of Genus *Labeo*.



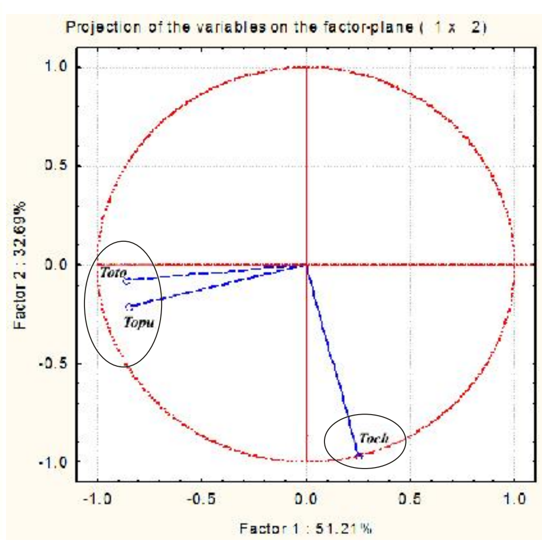
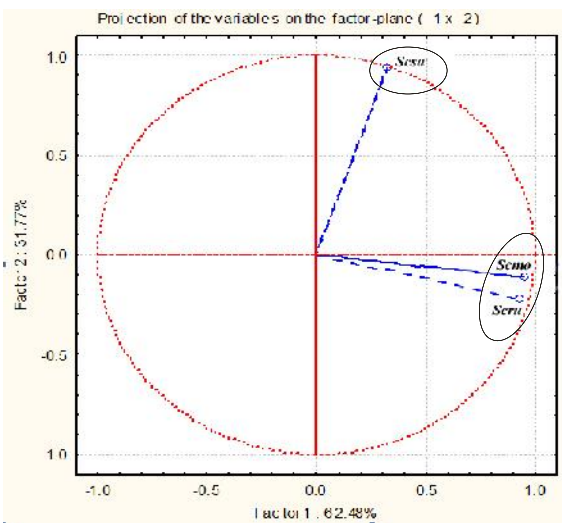


FIGURE 10: Principal Component Analysis of Genus *Barilius* **FIGURE 11:** Principal Component Analysis of Genus *Tor*.



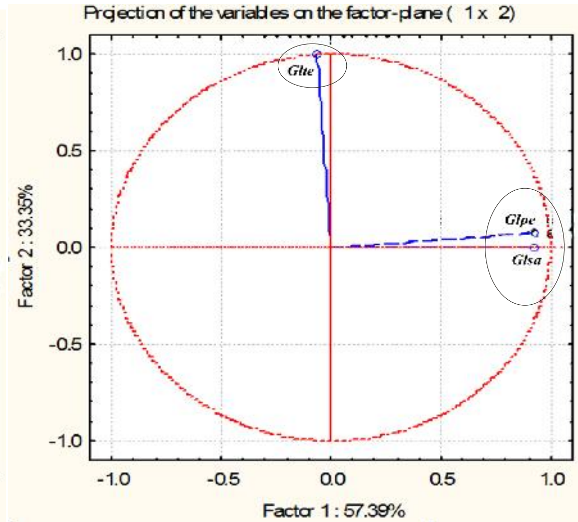
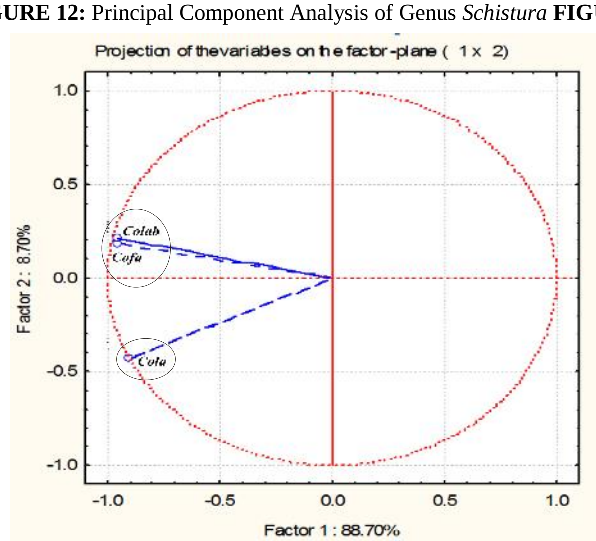


FIGURE 12: Principal Component Analysis of Genus *Schistura*

FIGURE 13: Principal Component Analysis of Genus *Glyptothorax.*



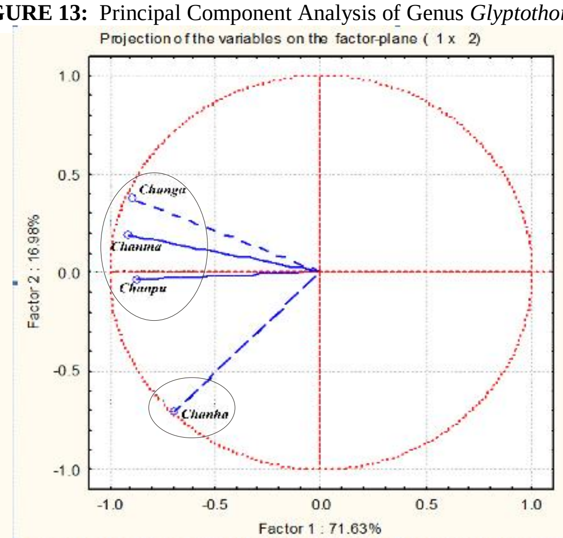


FIGURE 14: Principal Component Analysis of Genus *Colisa*.

FIGURE 15: Principal Component Analysis of Genus *Channa.*

Genera represented by 2 species each:

4 Genera *viz*., *Aspidoparia, Mystus, Lepidocephalichthys* and *Clarias*are represented by 2 species each. The PCA for both species under each Genus shows characteristically heavy '+ve' loadings of equal amount on Factor 1 *viz.*, 0.88 for *Aspidopariajaya*and *Aspidopariamorar*; 0.93 for *Mystustengara* and *Mystusbleekeri*; 0.81 for *Lepido cephalichthysguntea* and *Lepidocephalichthy sannandalei* and 0.74 for *Clariasbatrachus* whereas -0.74 for *Clarias gariepinnus*. On account of equal heavy loadings they come to lie at similar coordinates in the biplot diagram (Figs. 3 – 6) giving an indication about their occurrence in similar type of ecological conditions (S_5, S_6, S_7, S_8, S_{11} and S_{12}).

Genera represented by more than 2 species

30 species belonging to 8 Genera *viz*., *Puntius* (represented by 6 species), *Labeo* (represented by 3 species), *Barilius* (represented by 5 species), *Tor* (represented by 3 species), *Schistura* (represented by 3 species), *Glyptothorax* (represented by 3 species), *Colisa* (represented by 3 species) and *Channa*(represented by 4 species) are included under this category exhibited well - established assemblages according to the ecological conditions.

DISCUSSION

Various multivariate methods have been used to explain the distribution of fishes including multivariate analysis of variance (Bendell and MacNikol, 1987) and cluster analysis (PCA) that sorts fish species into groups or clusters based upon their overall resemblance to one another (Ludwig and Reynolds, 1988). In the present findings, the PCA ordination (Pielou, 1984) has broken down or partitioned a resemblance matrix (variance–covariance or correlation) into a set of orthogonal (perpendicular) axes or PCA 'components' (Ludwig and Reynolds, *op. cit*.). The PCA components of first 2 orders have explained the largest percentage of variation in the data set (Gauch, 1982) and ordination of sampling units provided information about the ecological relationships between them.

For the present observations, the PCA had to be analyzed with the given 3 situations *i.e*., Genera represented by 1 species each, 2 species each and more than 2 species.

After putting the data for PCA for these 3 situations, the results obtained as factor coordinate values [Tables 1 - 2] were diagrammatically expressed in the correlation biplot diagrams (Figs. 1 –2) where the Genera/species segregated into groups (clusters) on the circle in the biplots [Sabates, 1990; Cantu and Winemiller, 1997; Maes*et al*., 1998; Fleiutz and Armitowz, 2005; Sreekantha*et al*., 2007] on the basis of their habitat preferences, *e.g*., Groups A, B, C and D on the circle in the biplot diagram (Fig. 2) identify the fishes (*Raiamas bola* and *Bariliustileo*) as Song – specific (S_7), forested and pooly stretch of Rajaji National Park; *Lepidocepahlichthysannandalei*, *Channamarulius*, *Channaharcourtbutleri*, *Colisalalia* and *Colisalabiosus* as Suswa – specific (S_{12}) in forested and andpooly stretch of Rajaji National Park and Asan (S_{20})- specific (*Bariliusshacra*), respectively.

The placement of the Genera/species in various group assemblages in the circles on the biplot is also according to strong '+ve' and '-ve' loadings of Factor coordinate values [Tables 1-2]. The variable with high absolute loadings (either +ve and –ve) on a given axis contributes strongly to the axis of the correlation biplot (Matthews *et al*., 1992). The PCA of Genera having 2 or more than 2 species have categorically revealed 5 interpretations on the basis of their '+ve' and '-ve' Factor coordinate values on any component (= Factor):

The aggregation of majority of fish species under 1 component and rest under Factor (component) 2 or 3 has been explained in terms of percentage of total amount of variability explained by the first 2 eigenvalues corresponding to first 2 principal components (Cantu and Winemiller, 1997; Maes*et al*., 1998; Fleiutz and Armitowz, 2005). The amount of variability observed ranged differently between sets of fish samples identified on the basis of number of species under a Genus, their abundance and infrequent nature.

The overall variance analyzed is indicative of well-established assemblages under the prevalent ecological conditions in the streams of East and West. A special emphasis may be made here of *Barilius* species which showed a total variance of 51.05% on the first 2 components, leading to the conclusion that their combination fluctuates in the East with the addition of *Bariliustileo* and in the West with the addition of *Bariliusshacra* (where *Bariliustileo* is not found), *Bariliusbendelisis*>*Bariliusvagra*>*Bariliusbarna* remaining the other component species in the separate combinations of East and West.

The results of PCA analyses (both East and West, Tables 1 – 2) clearly highlighted the temporal variability pattern and fish species relation with habitat as also observed by Cantu and Winemiller (1997) and Sreekantha*et al*. (2007).

The assemblage pattern observed here through the PCA of fish Genera [Table 1, Fig. 1] also clearly highlighted the importance of biological variables, including predator–prey intensity and competition, a fact also highlighted by Matthews *et al*., (1992).

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