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Research Article

LANDMARK-BASED MORPHOMETRIC ANALYSIS FOR SELECTED SPECIES OF INDIAN MAJOR CARP (*CATLA CATLA*, HAM. 1822)

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ABSTRACT
In present study morphological differences or body shape variations (BSV) of Indian major carp *Catla catla* (Hamilton 1822) were studied on the landmark basis of truss morphometric network (TMN) from three different waterbodies. Univariate and multivariate analyses were performed using landmarks of TMN to describe the shape of catla that shows the heterogeneous population in the waterbodies studied. On the basis of 'truss network' and application of ANOVA on variables of body sizes and shapes it was observed that *C. catla* from Mahi bajaj sagar was different from Aasan pond but much close to Surwania dam. The principal component analysis (PCA) of body shape variables provided two important findings (1) all the truss landmarks contributed significantly to the body shape of the fish unlike size variables in which few specific characteristics related to head and body depth and (2) Populations of *C. catla* appear different from each other as order of loading factor to different components in case of same species from different waterbodies. It is, thus, concluded that all the landmarks of 'truss measurements' contribute significantly to the body shape of the fish. These all analysis supports that 'Truss network' is an effective tool to describe the body shape and quantify the intra species variability of carps.

Key Word: *Catla Catla, Truss Network, Multivariate Analysis, Geometric Morphometrix*

INTRODUCTION
Catla is a commercially important cultivable fish species of gangetic origin (Jhingran, 1968) and reported to occur in all the five major river systems of the country which are geographically isolated from each other. According to Jhingran (1968), no distinct races or strains of *C.catla* were known. Reddy (1999) also mentioned that no reports are available whether there exist genetically different populations among the members of a given species of major carp in any of the major river system. However, Sinha and Khan (1989) mentioned that in Rihand dam there are three intra-specific populations within *C.catla* each of which could be distinguishable morphologically by short, medium and long pectorals. The present study was taken up to discriminate the different stocks of *C.catla* found in these different waterbodies of different magnitude located in the southern Rajasthan.

Morphometric and anatomical measurements have been traditional used to differentiate population and fish stock (Reist, 1985). Melvin *et al.*(1992) discriminate among the different populations of American Shad (*Alosa sapidissima*) collected from a common inhabiting marine environment while Joseph and Jayasankar (2001), Jayasankar *et. al.*, (2004) discriminate population on the basis of morphometric variables. Reist (1985) found that size and shape information of a fish population provide different insight into relationship among the organism. Shape at a particular size may vary across samples and thus reflect a fundamentally different similarity or dissimilarity in the organisms. Thus, comparison of samples ideally should be in terms of shape variants free from magnitude, effects of size, as well as in terms of variation in size. Thus, he suggested the transformation of size variables into shape variables, more specifically in case of organisms with indeterminate growth having absence of well defined stages of growth.

MATERIALS AND METHODS

Selection of species in this study was determined by the commercial importance and availability of an adequate size and number of specimens. A total of 180 specimens were randomly collected from fish catch from three different waterbodies namely Mahi bajaj sagar (MBS, 13500 ha), Surwania dam (SD, 100 ha) and Aasan pond (AP, 75 ha) situated in Banswara district of Rajasthan (Fig. 1), during fishing year 2000-2001 and 2001-2002. Measurements were based on a truss network protocol (Strauss and Bookstein, 1982, Bookstein *et al.*, 1985), anchored at 10 homologous anatomical landmarks (Fig. 2). Distance between landmarks refers Mouth tip to pre maxilla (MTPM), Mouth tip to dorsal fin (MTDF), Mouth tip to operculum top (MTOT), Pre maxilla to dorsal fin (PMDF), Operculum tip to pre maxilla (OTPM), Pre maxilla to pectoral fin (PMPC), Pre maxilla to pelvic fin (PMPV), Dorsal fin operculum tip to (DFOT), Pectoral fin operculum tip to (PCOT), Pectoral fin to pelvic fin (PCPV), Dorsal fin to pelvic fin (DFPV), Dorsal fin front to dorsal fin back (DFDB), Dorsal fin to anal fin (DFAF), Pelvic fin to anal fin (PVAF), Dorsal back to anal fin (DBAF), Dorsal fin back to caudal top (DBCT), Dorsal back to caudal bottom (DBCB), Anal fin to caudal top (AFCT), Caudal top to caudal bottom (CTCB), Anal fin to caudal bottom (AFCB) and Dorsal fin back to pelvic fin (DBPV). These distances were measured with help of brass divider to nearest millimeter.

The absolute measurements were transformed to size independent shape variables by dividing each of the variables with standard length (Reist and Crossman, 1986). ANOVA was tested on shape variables within inter-species and intra-species. All the morphometric variables were subjected to various analyses. These transformed data were submitted to principal component analysis (PCA) to determine factors (i.e. principal components) in order to explain maximum possible total variations in the data with the use of minimum factors (Dillon and Goldstein, 1984). All the statistical analyses were performed using SPSS 10.0.

RESULTS AND DISCUSSION

The present study indicates the overall performance of the populations of *C.catla* inhabiting MBS (large reservoir), SD (medium reservoir) and AP (small pond) in southern Rajasthan which are different from each other. These variations are possibly manifested in these as a result of genetic and environmental interactions and are visible as variations in shape of the fish body, growth rate, fecundity etc. Melvin *et al.* (1992) have stated that an individual’s process and body form are susceptible to both genetic and environmental variations and it provides the foundation for variations in phenotypic expressions. Slight changes in temperature, salinity, light, and dissolved gasses during ontogeny can be reflected by significant difference in meristic counts for the member of same species. As morphological characters are subject to these factors for an even longer period, greater morphological differences are manifested. The degree of environmental interactions for this species also seems to be different as for few characters from two waterbodies namely MBS and SD depict high similarity while in case of AP the same characters show relatively high degree of variability.

The TMN for *C.catla* from AP seems different from MBS and SD while TMN of catla from MBS and SD appears more or less close (Fig. 3). ANOVA was tested to find the CD in between TMN observations from MBS, SD and AP (Table 1). Szlachciak (1996) differentiated among the four stocks of *Abramis brama* from four lakes of Poland on the basis of meristic and morphometric study following the ‘truss network’ method. It is a better tool to elucidate relationship among populations (Winans, 1984) and to separate physically similar species (Dean *et al.*, 2002). The applicability of TMN to differentiate at intra-species level is well documented. Power and Ni, (1985), Eknath *et al.* (1991), Bronte *et al.* (1999) have estimated the variations in stock of fish species on the basis of body shape through TMN. Mauro *et al.* (1999) studied the morphological differences among the six marine fish species. Bembo *et al.* (1976) differentiated two stocks (Northwestern and Central-southern) of European anchovy, *Engraulis encrasicolus* inhabiting Adriatic Sea on the basis of TMN. Similarly, Velasco *et al.* (1991) differentiated geographically isolated eight strains (Egypt, Ghana, Senegal, Kenya, Israel, Singapore, Taiwan and Thailand) of *Oreochromis niloticus*. These eight strains of O.*niloticus* were not observed similar, they

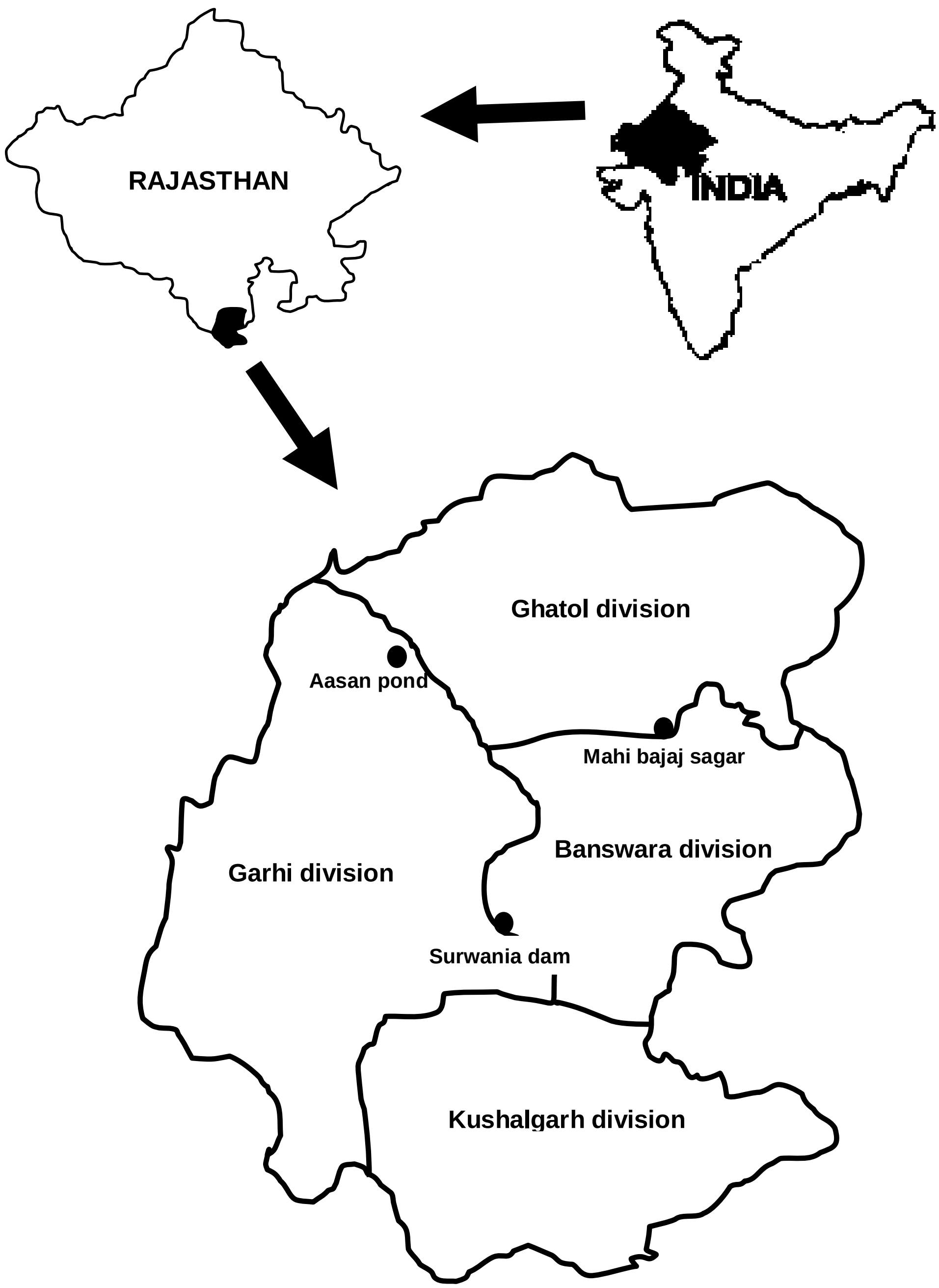

Fig. 1. Map of the study area

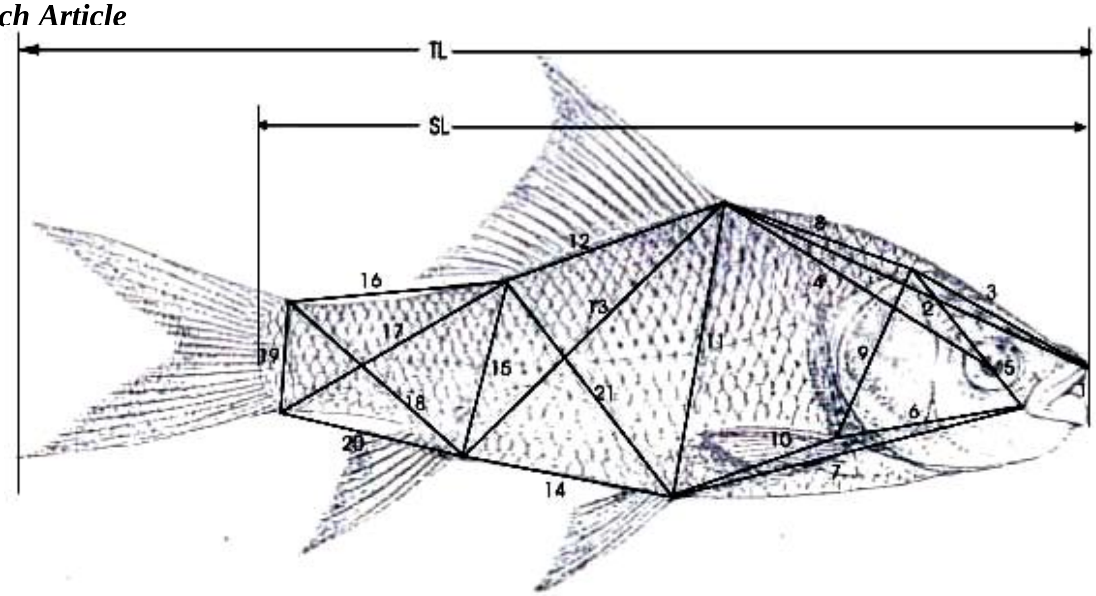

Fig. 2. Typical Truss Morphometric Network (TMN)

1. Mouth tip to premaxilla (MTPM), 2. Mouth tip to dorsal fin (MTDF), 3. Mouth tip to operculum top (MTOT), 4. Pre maxilla to dorsal fin (PMDF), 5. Pre maxilla to operculum tip (PMOT), 6. Pre maxilla to pectoral fin (PMPC), 7. Pre maxilla to pelvic fin (PMPV), 8. Dorsal fin to operculum tip (DFOT), 9. Pectoral fin to operculum tip (PCOT), 10. Pectoral fin to pelvic fin (PCPV), 11. Dorsal fin to pelvic fin (DFPV), 12. Dorsal fin front to dorsal fin back (DFDB), 13. Dorsal fin to anal fin (DFAF), 14. Pelvic fin to anal fin (PVAF), 15. Dorsal back to anal fin (DBAF), 16. Dorsal fin back to caudal top (DBCT), 17. Dorsal back to caudal bottom (DBCB), 18. Anal fin to caudal top (AFCT), 19. Caudal top to caudal bottom (CTCB), 20. Anal fin to caudal bottom (AFCB), 21. Dorsal fin back to pelvic fin (DBPV)

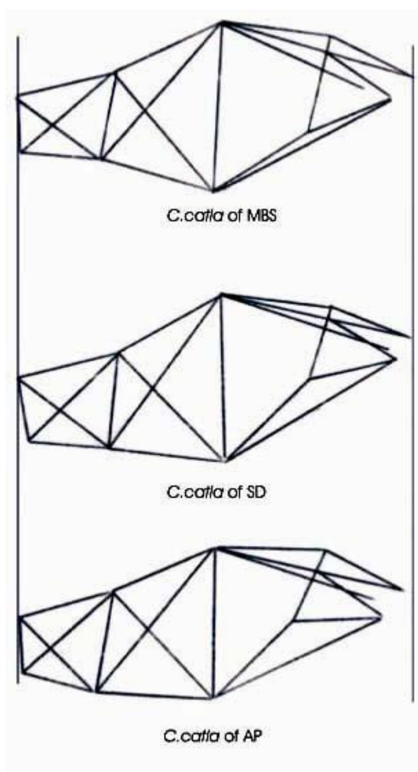

Figure. 3. Truss morphometric network of *C.catla* from MBS, SD and AP

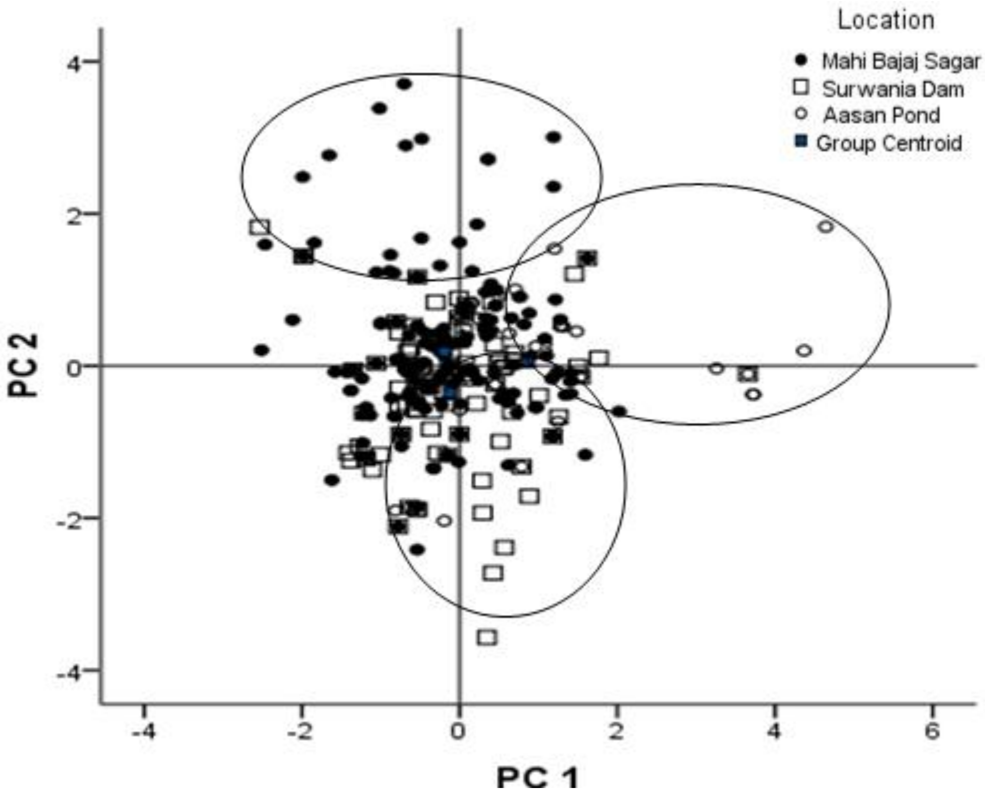

Figure 4: Scatter plots of truss network land marks of Indian major carps (*Catla catla*) from Mahi Bajaj Sagar, Surwania Dam and Aasan pond.

were found different from each other only for few truss morphometric characters (Velasco *et al.*, 1991). A high degree of correlation of all the truss landmarks with the standard body length in the present study confirms the applicability of Truss landmarks to study the shape variations of a fish species. Univariate analysis of truss morphometric landmarks of phenotypically similar specimens, helps to know the variability and similarity of the populations of *C. catla*, (MBS, SD and AP), but most significant morphometric features differentiating these populations could not be identified. Hence, body size variables were converted into shape variables as large variations of size in samples may give erroneous result and poor conclusion. Reist and Crossman (1986) have recommended the use of body shape variables as the basis of distinguishing the different populations of fishes. Jain (2000) has also recommended the use of body shape variables in quantifying the variability of Catla-Rohu hybrid from the parental species *C. catla* and *L. rohita*.

Univariate analysis of shape variables revealed that though, *C. catla* from MBS, SD and AP were different from each other but the variability was more among *C. catla* (MBS and SD) as compared to MBS and AP. Use of shape variables could also define the landmarks of 'Truss network' on the basis of which two populations could be differentiated. It was noted that diagonal measurements of 'Truss network' was more useful to describe the different populations of a species than the vertical and horizontal measurements. As no such studies are available on Indian major carps where shape variables of truss landmarks have been used to identify specific population or strains, the comparisons are not possible but the trends of above results are in conformity with the studies of Bookstein *et al.* (1985), Cavarcanti *et al.* (1990) and Eknath *et al.* (1991). However, the existence of different strains of Indian major carps

Table 1. Means of different morphometric characteristics and significance level of critical difference for *Catla catla* of three different waterbodies

Morphometric characteristics	Mahi (I)	Surwania (II)	Aasan (III)	CD 5 %	CD 1%	Significance
MTPM	1.485 ± 0.026	1.536 ± 0.027	1.499 ± 0.025	0.051	0.067	(I,II)** (I,III)* (II,III)*
MTDF	26.419 ± 0.201	26.576 ± 0.213	26.750 ± 0.218	0.394	0.519	(I,II)NS (I,III)* (II,III)*
MTOT	12.547 ± 0.111	12.533 ± 0.116	12.741 ± 0.114	0.3415	0.450	(I,II)NS (I,III)* (II,III)*
PMDF	22.695 ± 0.186	22.744 ± 0.196	22.977 ± 0.197	0.859	1.132	(I,II)NS (I,III)* (II,III)*
PMOT	12.714 ± 0.114	12.015 ± 0.520	11.985 ± 0.109	0.859	1.132	(I,II)** (I,III)* (II,III)NS
PMPC	11.222 ± 0.108	11.365 ± 0.134	11.315 ± 0.120	0.253	0.333	(I,II)NS (I,III)NS (II,III)NS
PMPV	25.285 ± 0.192	25.276 ± 0.181	25.371 ± 0.199	0.343	0.452	(I,II)NS (I,III)* (II,III)*
DFOT	14.547 ± 0.136	12.804 ± 0.119	15.088 ± 0.147	0.246	0.324	(I,II)** (I,III)NS (II,III)NS
PCOT	12.622 ± 0.101	12.720 ± 0.107	12.655 ± 0.119	0.194	0.256	(I,II)NS (I,III)* (II,III)*
PCPV	14.875 ± 0.128	15.035 ± 0.124	15.028 ± 0.131	0.247	0.325	(I,II)NS (I,III)* (II,III)*
DFPV	21.158 ± 0.190	21.226 ± 0.182	21.503 ± 0.187	0.362	0.477	(I,II)NS (I,III)NS (II,III)*
DFDB	14.587 ± 0.122	14.755 ± 0.121	14.735 ± 0.120	0.232	0.306	(I,II)NS (I,III)* (II,III)*
DFAF	23.849 ± 0.252	23.988 ± 0.237	24.360 ± 0.226	0.449	0.591	(I,II)NS (I,III)* (II,III)*
PVAF	16.195 ± 0.122	16.358 ± 0.125	16.508 ± 0.127	0.223	0.294	(I,II)NS (I,III)* (II,III)*
DBAF	13.438 ± 0.106	13.419 ± 0.101	13.503 ± 0.099	0.189	0.249	(I,II)NS (I,III)* (II,III)*
DBCT	13.513 ± 0.096	13.590 ± 0.097	13.587 ± 0.098	0.177	0.233	(I,II)NS (I,III)* (II,III)*
DBCB	16.556 ± 0.102	16.663 ± 0.101	16.747 ± 0.104	0.193	0.254	(I,II)NS (I,III)* (II,III)*
AFCT	14.398 ± 0.093	14.468 ± 0.108	14.510 ± 0.094	0.179	0.236	(I,II)NS (I,III)* (II,III)*
CTCB	7.992 ± 0.059	8.008 ± 0.057	8.001 ± 0.058	0.116	0.153	(I,II)NS (I,III)* (II,III)*
AFCB	10.066 ± 0.089	10.219 ± 0.076	10.278 ± 0.080	0.165	0.217	(I,II)NS (I,III)* (II,III)*
DBPV	19.987 ± 0.177	19.839 ± 0.173	20.151 ± 0.189	0.354	0.466	(I,II)NS (I,III)* (II,III)*

* P<0.01; ** P<0.05 and NS, Non-significant, CD, Critical Difference

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Table 2. Eigen values, percentage of variables and cumulative percentage of various components of PCA for *Catla catla* from three waterbodies

Comp.	Mahi Bajaj Sagar			Surwania dam			Aasan pond		
	Eigen.	% varb	Cum. %	Eigen.	% varb	Cum. %	Eigen.	% varb	Cum. %
1	17.895	85.213	85.213	18.078	86.088	86.088	19.133	91.110	91.11
2	0.470	2.237	87.450	0.518	2.467	88.555	0.560	2.665	93.775
3	0.456	2.170	89.620	0.437	2.251	90.806	0.360	1.715	95.490
4	0.405	1.931	91.551	0.398	1.895	92.701	0.218	1.040	96.530
5	0.289	1.376	92.927	0.307	1.460	94.161	0.183	0.870	97.400
6	0.260	1.236	94.163	0.273	1.299	95.460	0.127	0.606	98.006
7	0.220	1.047	95.210	0.184	0.877	96.337	0.109	0.519	98.525
8	0.186	0.886	96.096	0.145	0.692	97.029	0.100	0.477	99.002
9	0.149	0.708	96.804	0.127	0.603	97.632	0.056	0.267	99.269
10	0.135	0.644	97.448	0.109	0.521	98.153	0.052	0.246	99.515
11	0.113	0.539	97.987	0.097	0.460	98.613	0.034	0.162	99.677
12	0.081	0.386	98.373	0.066	0.312	98.925	0.023	0.110	99.787
13	0.074	0.352	98.725	0.057	0.293	99.218	0.015	0.071	99.858
14	0.063	0.300	99.025	0.044	0.209	99.427	0.011	0.052	99.910
15	0.049	0.233	99.258	0.034	0.162	99.589	0.008	0.037	99.947
16	0.049	0.233	99.491	0.027	0.128	99.717	0.006	0.028	99.975
17	0.033	0.157	99.648	0.019	0.091	99.808	0.002	0.010	99.985
18	0.028	0.134	99.782	0.018	0.075	99.883	0.001	0.005	99.990
19	0.019	0.090	99.872	0.012	0.056	99.939	0.001	0.005	99.995
20	0.016	0.076	99.948	0.009	0.043	99.982	0.001	0.005	100.00
21	0.011	0.052	100.00	0.004	0.018	100.00	0.000	0.000	100.00

Comp. Components, Eigen. Eigen values, % varb. % of variables, cum. % cumulative %

Table 3. Component loading of first two pooled principal components of truss morphometric characters of Indian major carp (*Catla catla*) from three water bodies.

Morphometric characteristics	Principal component	
	1	2
MTPM	-0.033	-0.166
MTDF	-0.314	-0.279
MTOT	0.692	0.380
PMDF	0.001	0.054
PMOT	-0.866	-0.130
PMPC	0.465	0.132
PMPV	-0.491	0.924
DFOT	0.540	-0.172
PCOT	-0.289	0.053
PCPV	-0.506	-0.292
DFPV	0.430	0.048
DFDB	0.273	-0.489
DFAF	0.153	-0.038
PVAF	-0.014	-0.513
DBAF	-0.334	0.987
DBCT	0.022	-0.673
DBCB	0.621	-0.134
AFCT	0.392	-0.028
CTCB	-0.091	0.401
AFCB	-0.186	-0.324
DBPV	0.210	0.223
Percentage of variance explained	71.6	28.4

owing to complete geographical isolation without any intermixing has been reported (Anon, 2001) but the variability of shape in the population of MBS, SD and AP can not be attributed to genetic variability but only to environmental variability as all the three waterbodies in the present study are connected to Mahi River. Hence, continuous intermixing of population is unavoidable.

C.catla from MBS, SD and AP were found to be different from each other at various levels of significance. All the variables of *C.catla* of MBS and SD were observed non-significantly different form each other except body depth related parameters (MTPM and PMLL) and body length related parameter (DSL), these variables were observed to be different from each other at the (0.05) level of significance. While, *C.catla* of MBS and AP were found different from each other at 0.01 level of significance, except body depth related parameter (DPF) and body length related parameter (PMPC and DSL) these parameters showed the similarity between *C.catla* of MBS and AP. Whereas, *C.catla* of SD and AP were observed different from each other at 0.01 level of significance except body depth related parameter (PMPC) and body length related parameter (PMLL) which shows the similarity. A network of various morphometric characteristics on the basis of landmarks of Truss network on the body of fish was developed for catla from all the three types of waterbodies. On the basis of both 'Truss network' and application of ANOVA on variables of body sizes and body shapes, it was observed that *C.catla* of MBS was different from that of AP but much close to *C.catla* of SD. Further, all the landmarks of the 'Truss network' were observed to have a strong correlation with each other and also with standard length of fish body.

Body shape of *C.catla* was contributed by 21 components in MBS and SD while in AP it was contributed by 20 components. About 90% of total variability of body shape of *C.catla* (MBS) was contributed by first 3 components, while next 4 components contributed only 5.59% to the total variability of the body shape. The remaining 14 components contributed even $< 1\%$ in descending order. In case of *C.catla* (SD) the contribution of various components to the variability of body shape was almost similar to that of *C.catla* (MBS). In case of *C.catla* (AP) the first component alone contributed about 91% of the body shape variability. The next 3 components explained about 7.4% of body shape variability and remaining 16 components were contributing less then 1% variability to the body shape (Table 2). The transformed truss morphomrtric data of selected fish species were analyzed for pooled PCA in that first two PCs explained about 100 % variance of the morphometric characters (Table 3). Principal Component 1 (PC1) represent the size that explained 71.6 % of variance and represent the loading of component that exhibited differ in respect of characters. Positive loading were associated with Mouth tip to operculum top (MTOT), Pre maxilla to dorsal fin (PMDF), Pre maxilla to pectoral fin (PMPC), Dorsal fin operculum tip to (DFOT), Dorsal fin to pelvic fin (DFPV), Dorsal fin front to dorsal fin back (DFDB), Dorsal fin to anal fin (DFAF), Dorsal fin back to caudal top (DBCT), Dorsal back to caudal bottom (DBCB), Anal fin to caudal top (AFCT), and Dorsal fin back to pelvic fin (DBPV) characters while negative loading were associated with Mouth tip to pre maxilla (MTPM), Mouth tip to dorsal fin (MTDF), Pre maxilla to operculum tip (PMOT), Pectoral fin operculum tip to (PCOT), Pectoral fin to pelvic fin (PCPV), Pelvic fin to anal fin (PVAF), Dorsal back to anal fin (DBAF), Caudal top to caudal bottom (CTCB), and Anal fin to caudal bottom (AFCB) characters. The PC2 represents size correlated shape variables explained 28.4 % of variance. In this the positive and negative loading were associated with Mouth tip to operculum top (MTOT), Pre maxilla to dorsal fin (PMDF), Pre maxilla to pectoral fin (PMPC), Pre maxilla to pelvic fin (PMPV), Pectoral fin operculum tip to (PCOT), Dorsal fin to pelvic fin (DFPV), Dorsal back to anal fin (DBAF), Caudal top to caudal bottom (CTCB), Dorsal fin back to pelvic fin (DBPV) and Mouth tip to pre maxilla (MTPM), Mouth tip to dorsal fin (MTDF), Pre maxilla to operculum tip (PMOT), Dorsal fin operculum tip to (DFOT), Pectoral fin to pelvic fin (PCPV), Dorsal fin front to dorsal fin back (DFDB), Dorsal fin to anal fin (DFAF), Pelvic fin to anal fin (PVAF), Dorsal fin back to caudal top (DBCT), Dorsal back to caudal bottom (DBCB), Anal fin to caudal top (AFCT), Anal fin to caudal bottom (AFCB) characters respectively. The scatter plot of PCs (Fig. 3) exhibits morphological variations among the Indian major carp from different location viz. Mahi Bajaj Sagar, Surwania Dam and Aasan pond. All these analyses support that 'Truss network' could be used as an effective tool to describe the body shape of carps and also to quantify the intra species variability which may be manifested due to environmental variability as in the present study.

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REFERENCES

Anonymous. (2001). Annual report of National Bureau of Fish Genetics Research, Lucknow (2001-2002).

Bembo, D.G., Carvalho, G. R., Cingolani, N. Arneri, E., Glannetti, G. and Pitcher, T. J. 1976. Allozyme and morphometric evidence for two stocks of the European anchovy *Engraulis encrasicolus* in Adriatic waters. *Marine Biol.* Berlin Heidelberg 126 (**3**): 529 - 538.

Bookstein, F.L., Chernoff, B., Elder, R., Humphrier, J., Smith, G. and Strauss, R. (1985). Morphometric in evolutionary biology. *Spl. Pub. 15*. The Academy of Natural Science of Philadelphia, Philadelphia.

Bronte, C.R., Fleischer, G.W., Maistrenko, S.G. and Pronin, N.M. (1999). Stock structure of Lake Baikal omul as determine by whole-body morphology. *J. fish. Biol.* (**54**): 787-798.

Cavarcanti, M.J. and Durate, Lopes, P. R. (1990). Comparative morphology of the Sciaenidae. *Rev. Zool.* 7 (**4**): 627 -635.

Dean, G.F., Jeffrey, W.N., Thomson, N.T. and Bruce, M.D. (2002). Application of truss analysis for the quantification of changes in fish condition. *Journal of Aquatic Ecosystem Stress and Recovery* 9: 115-125

Dillon, William R. and Matthew Goldstein (1984) Multivariate Analysis: Methods and Applications, John Wiley, New York.

Eknath, A.E., Macaranas, J. M., Augstin, L. Q., Velasco, R. R., Ablan, M. C. A., Pante, M. J. R. and Pullin, R. S. V. (1991). Biochemical and morphometric approaches to characterize farmed Tilapia. *ICLARM, NAGA*, Vol. 2: 7-14.

Hamilton, B. 1822. An account of the fishes found in the Ganga and its branches. Edinburgh. 405.

Jain, A.K. (2000). Studies on catla-rohu hybrid in relation to its parents *Catla catla* and *Labeo rohita*. Ph. D. thesis, South Gujarat University, Gujarat.

Jhingran, V. G. (1968). Synopsis of biological data on *Catla catla* (Hamilton, 1822). FAO, fisheries synopsis No. 32 rev 1, FAO, Rome.

Joseph, J and Jayasankar, P. (2001). Morphometric and genetic variation in the threadfin bream *Nemipterus mesoprion*. *J. Mar. Bio. Ass. India*, 42 (**1&2**): 217-221.

Jayasankar, P, Thomas, P.C., Paulton, M.P. and Mathew, J.(2004). Morphometric and genetic analysis of Indian Mackerel (*Restrelliger kanagurta*) from Indian peninsular. *Asian Fisheries Science* (**17**): 201-215

Mauro, T.C., Leandro, R.M. and Paulo, R.D.L. (1999). Landmark-based morphometric analysis in selected species of Serranid fishes (Peciformes: Teleostei). *Zoological Study*. 38(**5**): 287-294

Melvin, G.D., Dadswell, M. J. and McKenzie, A. (1992). Usefulness of meristic and morphometric characters in discriminating populations of American shad (*Alosa sapidissima*) (Ostreichthys: Clupeidae) inhabiting a marine environment. *Can. J. Fish. Aquat. Sci*. 49: 266-280.

Power, D.J. and Ni, I.H. (1985). Morphometric differences between golden redfish (*Sebastes marinus*) and beaked redfishes (*S. mentella* and *S. fasciatus*). *J. Northw. Atl. Fish. Sci*., (**6**): 1-7.

Reddy, P. V. G. K. (1999). Genetic resources of Indian major carps. Fisheries Technical Paper 387, FAO, Rome: 11.

Reist, J.D. (1985). An empirical evaluation of several univariate methods that adjust for size variation in morphometric data. *Can. J, Zool*. 64: 1363-1368.

Reist, J.D. and Crossman, E. J. (1986). Genetic basis of variation in morphometric characters as implied by hybrids between species of *Esox americanus* (Pieces: Escoidae). *Can. J. Zool*. 65: 1224-1229.

Sinha, V. R. P. and Khan, H. A. (1989). In: Genetic improvement of Indian major carps for aquaculture industry, pp 141-146. *In* Das and Jhingran (ed), Fish genetics in India. Today and Tomorrow's Printers and Publisher, New Delhi-110 005 (India).

Strauss, R.E. and Bookstein, F.L. (1982). The truss: Body forms reconstruction in morphometrics. Syst. Zool. 31(**2**): 113-135.

Szlachciak, J. (1996). Meristic and morphometric study of *Abramis brama* (Pisces, Cypriniformes). Symposium on uses of the database of selected species. Vilnis (Lithuania, 28 Sep. 1996), 24.

Velasco, R.R., Pante, M. J. R., Macaranas, J. M., Janagap, C. C. and Eknath, A. E. (1991). Truss morphometric characterization of eight strains of Nile Tilapia (*Oreochromis niloticus*). 3rd International symposium on Tilapia in Aquaculture. Abidjan, 16 Nov. 1991, 11.

Winans, G.A. (1984). Multivariate morphological variability in Pacific Salmon: Technical demonstration. *Can. J. Fish. Aquat. Sci*. (**41**): 1150-1158.