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Scale Morphology and Population Differentiation in Exotic Fish Tilapia (*Oreochromis mossambicus* P. 1852) from Some Major Water Bodies of Western India

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ABSTRACT

The study was conducted to find out the morphological variations in tilapia (*Oreochrmis mossambicus* P. 1852) samples collected from three different water bodies namely Aanasagar lake (S_1), Jaisamand lake (S_2) and Vallabhsagar dam (S_3) during the March 2012 to April 2022 have been studied in the current research. The standard-length and weight ranged between 17.50 to 38.50 cm and 98.50–932.50 g (S_1), 15.00 to 24.00 cm and 60.00 to 250.00 g (S_2), 15.00 to 33.00 cm and 77.00 to 662.00 g (S_3). Key scales were picked out to accomplish the objective of research. The twelve different morpho-parameters ($L_1, L_2, \ldots L_{12}$) of *Oreochrmis mossambicus* P. 1852 scales were measured and analyzed to find presence or absence of morphological variations among the tilapia populations from three habitats. It was found that between these morphometric parameters of *Oreochromis mossambicus*, L_3 and L_8 in S_1 (0.862), L_7 and L_{12} in S_2 (0.830) and L_{10} and L_{12} in S_3 (0.988) showed very high correlation. Further, the morphological study on measurements was subjected to principal component analysis (PCA) and reported a total 84.98, 89.52 and 93.40 percent of significant variances in scale components (morphometric parameters) for tilapia from S_1, S_2 and S_3 respectively. Variations obtained in morphological (morphometric measurements) data showed four (S_1), five (S_2) and two (S_3) groups of dominant components for the scales of tilapia. It was clearly the formation of disseminated groups in the plot of sheared PCs scores. It is inferred that there was dissimilarity in scale morphological structure of *Oreochromis mossambicus* collected from different water bodies.

KEYWORDS: Correlation, matrix, PCA, population differentiation, tilapia, water bodies

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1. INTRODUCTION

Cichlids are the tropical freshwater fishes well known for their high rates of speciation often resulting in rapid radiation. These fishes exhibit remarkably high levels of genetic and morphological diversity, which affect their morphology, ecology, behavior and genomes (Nelson, 1994; Barlow, 2000; Chakrabarty, 2005). The current study is focused on tilapia (*Oreochromis mossambicus*) which is a teleost fish of the family Cichlidae. That is also known as Mozambique mouth brooder or mud bream. The typical size range (TL) reported for adult male *O. mossambicus* is 30-44 cm from tropical or subtropical regions where conditions are within the normal tolerance ranges of this species. Adult females are smaller and under similar conditions and size ranges approximately from 25–33 cm. Under more extreme conditions at the limits of its range or in stressful environments (eg. shallow drying pools, marginal habitats), the species can mature at a small size (stunting). The maximum size ranges for males can be between 10 to 30 cm. Inhabits of *O. mossambicus* is slow flowing rivers and streams and still waters such as lakes and lagoons and in both fresh and brackish waters. A population has even been established on a marine atoll in the central Pacific (Webb, 2007). In 1990's the occurrence of exotic fish Tilapia (*Oreochromis mossambicus* P.) was noticed in fish catch at Jaisamand Lake, Udaipur (India) probably, on account of accidental entry with seed of Indian major carps (Anonymous, 1995; Ujjania et al., 2008) but it is now reported in the water bodies of entire India (Rose et al., 2018).

Identification of fish populations and connectivity between each other is the major point for the maintenance and management of susceptible fish species (Hanski and Simberloff, 1997). Morphometric is the simplest and most used method of fish species identification and it could be useful for describing fish species into different strains or types (Makeche et al., 2020 and Dwivedi and De, 2023). The population characteristics including biology, abundance, condition factors, and the reproductive biology of cichlids was well studied by Fuerst et al. (2000); Mwanja et al. (2016); Shukla and Bhat (2017) and Natugonza et al. (2022). Thus, phenotypic features of fish like several hard body parts of fish morphology, meristic counts, otolith or scale shape, opercula, vertebrae, frontal bones and fin spines cleithrum are widely used in the identification and discrimination of fish populations (Begg and Brown, 2000; Poulet et al, 2004, Ujjania and Nandita, 2018). Fish scales commonly contain layers of collagen, organic and bony materials (Varma, 1990). Scale characteristics such as overall shape and internal features have proven successful for population identification for many years (Jarvis et al., 1978). Scale morphology discriminates fish populations at relatively large three-dimensional rulers (Jarvis et al., 1978; Casselman et al., 1981). Viertler et al. (2021) and Masood et al. (2022) were study scale morphology and evolution in the adaptive radiation of cichlid. Therefore, current study of scale morphology of *Oreochromis mossambicus* from different water bodies of western part of India was conducted which would be helpful for researchers for the population identification of the fishes and application of appropriate management for better use of water body.

2. MATERIALS AND METHODS

For this study, tilapia (*Oreochromis mossambicus* P.) fishes were collected from three different landing centers that are Anasagar lake, Jaisamand lake and Vallabhsagar (Fig. 1) and referred hereafter as S_1, S_2 and S_3 respectively. The total number of key scales (318, from S_1 47, from S_2 68 and from S_3 203) from tilapia fish specimens were randomly collected during the year 2012–2022. These key scales were preserved in small paper envelopes bearing fish details like total length (cm), weight (g), date of collection etc. (Ujjania et al., 2014).

The scales were dipped in 1% KOH solution for 5 to 10 minutes and gentle wash with tap water was given to remove extraneous matter and mucous and these clean scales were examined under 4P scale reader and twelve different morphological parameters (Figure 2) were measured with the help of measuring tap (±0.01 mm) (Ujjania et al., 2014).

The correlation of morphometric length subtracted by correlation matrix and noted results. Principal components (morphometric parameters) analysis computes a set of uncorrelated composite variables called principal components (PCs) from correlation matrix (Dunn and Everitt, 1982). The first principal component (referred as PC-1) explains the most of the variance in the data set. Geometrically, PC-1 is thought to lie parallel with the largest axis in the hyperdimensional cloud of data (Green, 1976; Campbell and Atchley, 1981). PC-2 is independent of PC-1 and its lies perpendicular to the axis of PC-1, and explains the second largest component of variation in the data set. Each PC is a linear combination of the variables and is defined by a vector (an eigen vector) of coefficients and an eigenvalue. The coefficients are essentially a measure of covariance of the character on that principal component.

The eigenvalue is a measure of variability explained by a particular principal component; the sum of the eigen values equals the total variability in a data set. Since on any component only a few characters have large coefficients, the biological interpretation of a component is based on the magnitude and signs of these supposed important characters. The details of the parameters considered for the morphometric analysis are given in Table 1. The data were analyzed in computer with help of SPSS. The distance dimensions were further subjected to sheared PCA and the PC scores obtained from the analysis were plotted on a graph with PC 1 and PC 2 on X and Y axes, respectively (Figure 4).

3. RESULTS AND DISCUSSION

The collected tilapias (*Oreochromis mossambicus*) size range noted was between 17.50-38.50 cm (S_1), 15.00-24.00 cm (S_2) and 15.00-33.00 cm (S3) standard length and 98.50-932.50 g (S_1), 60.00-250.00 g (S2) and 77.00-662.00 gm (S3) weight (g). A highest mean length 30.90 (±0.66) and weight 554.94 (±28.11) was found in S_1 followed by S3 with 23.60 (±0.33) and 309.95 (±11.56) and S_2 with 17.75 (±0.28) and 123.46 (±4.38), respectively (Table 1 and Figure 1). Similar results for *T. mossambica* (0.5 to 150 cm total length and 3 to 350 g weight) were found by Anni et al. (2016).

Scales different morphometric length were measured to detect variation among the random samples of *Oreochrmis mossambicus* from different water bodies i.e., S_1, S_2 and S_3. Between these twelve variables L_3 and L_8 (0.862) in S1, L_7 and L_{12} (0.830) in S_2 and L_{10} and L_{12} (0.988) in S_3 of *O. mossambicus* scales showed the positive and highest correlation while positive and lowest correlation were found between L_1 and L_6 (0.274) in S_1, L_9 and L_{11} (0.405) in S_2 and L_1 and L_6 (0.715) in S_3 (Table 2).

The twelve scale morphometric measurements taken from sample specimen of *Oreochrmis mossambicus* for S_1, S_2 and S_3 were subjected to principal component analysis. For S_1 tilapias scales, there are four principal components reported which have 84.98% cumulation of total components followed by 23.52, 21.11, 20.44 and 7.55% variance and 8.02, 0.99, 0.62 and 0.55 Eigen value (>0.5 scale is one dimensional) while for S2 tilapias scales, five principal component reported which have 89.52% cumulation of total components followed with 25.17, 17.24, 17.00, 16.16 and 13.94% variance with 7.91, 0.97, 0.67, 0.64 and 0.53

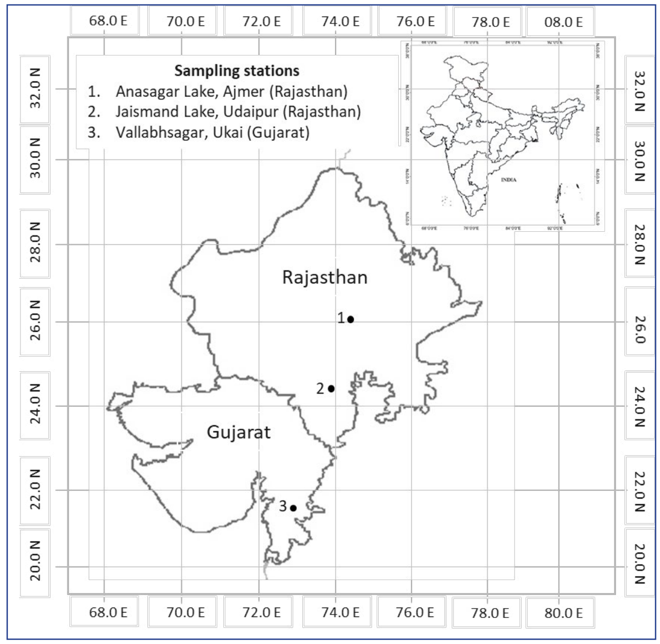

Figure 1: Map showing the locations of study area

Table 1: Observed tilapia fish scale morphological length and standard length and weight collected from different waterbodies

Parameter (cm)	Anasagar (S_1)				Jaisamand (S_2)				Vallabhsagar (S_3)			
	Min	Max	Mean	SE (±)	Min	Max	Mean	SE (±)	Min	Max	Mean	SE (±)
L_1	6.00	16.00	11.52	0.32	4.00	10.20	6.65	0.12	1.50	11.80	8.28	0.15
L_2	6.20	15.80	11.26	0.30	4.00	8.50	6.20	0.13	3.80	11.40	8.09	0.14
L_3	5.50	17.50	13.48	0.33	4.20	12.00	8.38	0.21	1.39	17.00	10.33	0.20
L_4	5.20	16.40	12.05	0.32	4.70	11.50	8.08	0.17	5.50	14.00	10.10	0.16
L_5	6.10	17.20	11.99	0.32	4.90	11.80	7.54	0.17	5.50	15.30	9.86	0.17
L_6	4.80	18.50	13.43	0.35	4.50	12.00	8.48	0.18	5.60	14.50	9.75	0.16
L_7	1.35	20.00	13.62	0.42	5.50	12.00	9.08	0.17	3.50	14.50	10.30	0.17
L_8	5.50	13.50	11.02	0.24	4.50	10.50	7.46	0.16	4.00	11.60	7.93	0.12
L_9	7.50	18.50	14.07	0.31	1.50	12.50	9.22	0.23	5.60	15.30	10.85	0.18
L_{10}	5.90	15.40	11.29	0.26	4.00	9.50	6.68	0.12	5.50	13.80	9.83	0.15
L_{11}	4.70	12.70	9.72	0.23	3.40	8.50	5.55	0.12	4.40	12.90	8.38	0.14
L_{12}	7.00	17.20	12.06	0.30	4.50	9.00	6.71	0.12	5.50	13.70	9.73	0.15
Length	17.50	38.00	30.90	0.66	15.00	24.00	17.75	0.28	15.00	33.70	23.60	0.33
Weight (g)	98.50	932.50	554.94	28.11	60.00	250.00	123.46	4.38	77.00	662.00	309.95	11.56

SE for standard error

Eigen value (>0.5 scale is one dimensional) whereas for S3 tilapias scales, only two principal component reported which have 93.40% cumulation of total components followed by 54.36 and 39.03% variance with 10.66 and 0.54 Eigen value (>0.5 scale is one dimensional) (Table 3, 4 and 5; Figure 3). These significant principal components of the variations in

Table 2: Correlation matrix of *Oreochrmis mossambicus* P. morphological parameters

		L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}
S_1	L_1	1.000											
S_2	L_1	1.000											
S_3	L_1	1.000											
S_1	L_2	0.685	1.000										
S_2	L_2	0.792	1.000										
S_3	L_2	0.898	1.000										
S_1	L_3	0.492	0.595	1.000									
S_2	L_3	0.410	0.535	1.000									
S_3	L_3	0.723	0.824	1.000									
S_1	L_4	0.697	0.515	0.544	1.000								
S_2	L_4	0.650	0.594	0.420	1.000								
S_3	L_4	0.918	0.940	0.796	1.000								
S_1	L_5	0.570	0.785	0.687	0.694	1.000							
S_2	L_5	0.582	0.657	0.502	0.776	1.000							
S_3	L_5	0.896	0.899	0.774	0.940	1.000							
S_1	L_6	0.274	0.459	0.664	0.412	0.433	1.000						
S_2	L_6	0.510	0.510	0.749	0.645	0.502	1.000						
S_3	L_6	0.715	0.820	0.905	0.793	0.753	1.000						
S_1	L_7	0.539	0.638	0.627	0.500	0.587	0.482	1.000					
S_2	L_7	0.616	0.662	0.656	0.778	0.757	0.812	1.000					
S_3	L_7	0.865	0.929	0.844	0.921	0.929	0.841	1.000					
S_1	L_8	0.581	0.668	0.862	0.678	0.702	0.639	0.728	1.000				
S_2	L_8	0.525	0.532	0.680	0.674	0.633	0.743	0.779	1.000				
S_3	L_8	0.763	0.845	0.845	0.807	0.847	0.858	0.924	1.000				
S_1	L_9	0.700	0.765	0.801	0.687	0.724	0.626	0.712	0.848	1.000			
S_2	L_9	0.516	0.600	0.547	0.562	0.691	0.534	0.721	0.610	1.000			
S_3	L_9	0.889	0.969	0.883	0.948	0.920	0.898	0.955	0.900	1.000			
S_1	L_{10}	0.645	0.679	0.626	0.632	0.762	0.508	0.457	0.559	0.671	1.000		
S_2	L_{10}	0.573	0.590	0.504	0.704	0.809	0.538	0.662	0.468	0.612	1.000		
S_3	L_{10}	0.907	0.942	0.814	0.980	0.927	0.824	0.929	0.833	0.952	1.000		
S_1	L_{11}	0.625	0.614	0.621	0.701	0.671	0.423	0.488	0.630	0.594	0.604	1.000	
S_2	L_{11}	0.504	0.510	0.585	0.595	0.587	0.518	0.543	0.511	0.405	0.635	1.000	
S_3	L_{11}	0.840	0.904	0.800	0.916	0.834	0.831	0.858	0.769	0.912	0.946	1.000	
S_1	L_{12}	0.743	0.805	0.710	0.709	0.731	0.531	0.597	0.754	0.790	0.636	0.694	1.000
S_2	L_{12}	0.679	0.658	0.660	0.813	0.801	0.695	0.830	0.760	0.688	0.675	0.659	1.000
S_3	L_{12}	0.908	0.937	0.804	0.978	0.932	0.811	0.929	0.834	0.954	0.988	0.931	1.000

Note: S_1: Anasagar; S_2: Jaisamand lake; S_3: Vallabhsagar

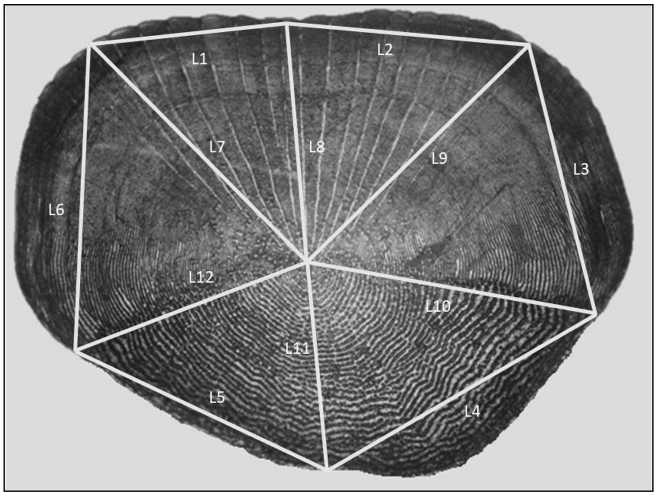

Figure 2: Image of a typical tilapia scale to show morphometric lengths

morphometric parameter measurements data were used to explain the variations. Vincent et al. (2014) reported 89.50 percent of significant principal components for population samples of *P. monodon*.

Major components were analyzed for S_1, S_2 and S_3 populations of tilapia fish scales morphometric measurements and results showed four group of components, five group of components and two group of components, respectively which were found as PCs with positive "Pearson" correlation between parameters (variables) and component matrix (Tables 3, 4 and 5). For S_1 tilapias scale, among four groups of major components first group of components giving direction probability towards L4 including and followed by L_{11}, L_1 and L_{12} with 2.82 factor loading, 23.52% variances and 23.52% cumulation. Second group of components giving direction probability towards L10 including and followed by L_2 and L_5 with 2.53 factor loading, 21.11% variances and 44.63% cumulation whereas third group of components giving direction probability towards L_7 including and followed by L_9 with 2.45 factor loading, 20.44% variances and 65.08% cumulation and fourth group of components giving direction probability towards L6 including and followed by L_3 and L_8 with 2.48 factor loading, 19.89% variances and 84.98% cumulation (Table 3 and Figure 3), while for S_2 tilapias scale five groups of major components giving direction probability towards L6 including and followed by L_3, L_8, L_7 and L_{12} with 3.02 factor loading, 25.17% variances and 25.17% cumulation, second group of components giving direction probability towards L_1 including and followed by L_2 with 2.06 factor loading, 17.24% variances and 42.41% cumulation, third group of components giving direction probability towards L_9 including and followed by L_5 with 2.04 factor loading, 17.00% variances and 59.42% cumulation, fourth group of only one components giving direction probability towards L_4 with 1.94 factor loading, 16.16% variances and 75.58% cumulation and fifth group of components giving direction probability towards L_{11} including and followed by L_{10} with 1.67 factor loading, 13.94% variances and 89.52% cumulation (Table 4 and Figure 3) whereas for S_3 tilapias

Table 3: Principal components analysis, eigenvalue, loadings and percentage (variance and cumulative) of various components of tilapia in Anasagar lake

Com-ponent	Eigen values	Vari-ance (%)	Cumu-lative (%)	Squared loadings	Variance (%)	Cumu-lative (%)	Component matrix		Rotated component matrix				
							ML	Comp. 1	ML	Component			
										1	2	3	4
1	8.025	66.875	66.875	2.823	23.523	23.523	L_9	0.914	L_4	0.846			
2	0.995	8.294	75.169	2.533	21.111	44.634	L_{12}	0.893	L_{11}	0.741			
3	0.626	5.215	80.384	2.454	20.448	65.082	L_8	0.886	L_1	0.640			
4	0.552	4.596	84.980	2.388	19.898	84.980	L_5	0.857	L_{12}	0.525			
5	0.428	3.563	88.544				L_2	0.842	L_{10}		0.776		
6	0.373	3.108	91.652				L_3	0.842	L_2		0.729		
7	0.328	2.731	94.382				L_4	0.794	L_5		0.677		
8	0.283	2.355	96.737				L_{10}	0.793	L_7			0.818	
9	0.149	1.245	97.983				L_{11}	0.782	L_9			0.582	
10	0.107	0.889	98.872				L_1	0.773	L_6				0.877
11	0.088	0.735	99.607				L_7	0.750	L_3				0.696
12	0.047	0.393	100.000				L_6	0.649	L_8				0.583

Note: ML for morphological length

Table 4: Principal components analysis, eigen value, loadings and percentage (variance and cumulative) of various components of tilapia in Jaisamand Lake

Component	Eigen values	Variance (%)	Cumulative (%)	Squared loadings	Variance (%)	Cumulative (%)	Component matrix		Rotated component matrix					
							ML	Comp. 1	ML	Component				
										1	2	3	4	5
1	7.915	65.959	65.959	3.021	25.177	25.177	L_{12}	0.921	L_6	0.818				
2	0.971	8.090	74.049	2.069	17.240	42.417	L_7	0.911	L_3	0.813				
3	0.677	5.641	79.690	2.041	17.005	59.422	L_5	0.857	L_8	0.743				
4	0.641	5.345	85.035	1.940	16.164	75.586	L_4	0.850	L_7	0.608				
5	0.539	4.494	89.529	1.673	13.943	89.529	L_8	0.816	L_{12}	0.500				
6	0.349	2.905	92.434				L_{10}	0.799	L_1		0.849			
7	0.251	2.095	94.529				L_6	0.798	L_2		0.806			
8	0.192	1.600	96.129				L_2	0.782	L_9			0.806		
9	0.179	1.494	97.623				L_9	0.770	L_5			0.625		
10	0.126	1.048	98.670				L_1	0.754	L_4				0.772	
11	0.082	0.681	99.351				L_3	0.740	L_{11}					0.834
12	0.078	0.649	100.000				L_{11}	0.719	L_{10}					0.580

Note: ML for morphological length

Table 5: Principal components analysis, eigen value, loadings and percentage (variance and cumulative) of various components of tilapia in Vallabhsagar

Component	Eigen values	Variance (%)	Cumulative (%)	Squared loadings	Variance (%)	Cumulative (%)	Component matrix		Rotated component matrix		
							ML	Comp. 1	ML	Component	
										1	2
1	10.664	88.869	88.869	6.524	54.369	54.369	L_9	0.989	L_1	0.875	
2	0.544	4.531	93.400	4.684	39.031	93.400	L_{10}	0.978	L_4	0.864	
3	0.271	2.256	95.655				L_{12}	0.975	L_{12}	0.844	
4	0.134	1.120	96.776				L_4	0.969	L_{10}	0.838	
5	0.108	0.902	97.677				L_7	0.966	L_5	0.826	
6	0.087	0.723	98.400				L_2	0.966	L_2	0.788	
7	0.068	0.563	98.963				L_5	0.943	L_{11}	0.761	
8	0.046	0.385	99.348				L_{11}	0.933	L_9	0.730	
9	0.038	0.314	99.662				L_1	0.914	L_7	0.722	
10	0.018	0.153	99.815				L_8	0.903	L_6		0.865
11	0.015	0.124	99.939				L_6	0.887	L_3		0.853
12	0.007	0.061	100.000				L_3	0.883	L_8		0.776

Note: ML for morphological length

scale only two group of major components giving direction probability towards L1 including and followed by L_4, L_{12}, L_{10}, L_5, L_2, L_{11}, L_9 and L_7 with 6.52 factor loading, 54.36% variances and 54.36% cumulation and second group of components giving direction probability towards L_6 including and followed by L_3 and L_8 with 4.68 factor loading, 39.03% variances and 93.40% cumulation (Table 5 and Figure 3).

On the basis of above analysis it could be concluded that for S_1 tilapias (*O. mossambicus*) scales four groups of principal components are strong enough or sufficiently able to explain the variability of morphometric parameters while for S_2 tilapias (*O. mossambicus*) scales, five groups of principal components were strong enough or sufficiently able to explain the variability of morphometric parameters whereas for S_3 tilapias (*O. mossambicus*) scales, only two groups of principal components were strong enough or sufficiently able to explain the variability of morphometric parameters.

The first principal component (PC 1) explains the most of the variance in the data set and second principal component (PC 2) is independent of PC 1 and explains the second largest component of variation in the data set (Green, 1976; Campbell and Atchley, 1981). The distance dimensions were further subjected to sheared PCA and the PC scores got from the analysis were plotted on a graph with PC 1 and PC 2 on X and Y axes, respectively (Figure 4). The PC-1 and PC-2 scores were computed for each of the samples and PC-1 scores were plotted against PC-2 scores to observe scale morphometric variations between tilapia population different water bodies. From the plot it was found that samples from S_1, S_2 and S_3 formed a separate cluster from within other samples, though there is mixing up of samples. The plotting of PC-1 scores against PC-2 scores of each sample on a graph produced three clustering and there was separate cluster formation in the plot of sheared PC scores (Figure 4) which indicated that the morphological outlines of *O. mossambicus* scales of all (S_1, S_2 and S_3) water bodies are different from each other (Lester, 1983). Horton (1982) reported significantly different morphometric variations in population samples of *P. stylirostris* and *P. vannamei* while Vincent et al. (2014) reported no significantly different morphometric variations in population samples of *P.monodon*. The observed morphological differentiation in tilapia may be attributed by environmental and geographical isolation similarly it was reported by Radkhah et al. (2017) and Shukla and Bhat (2017).

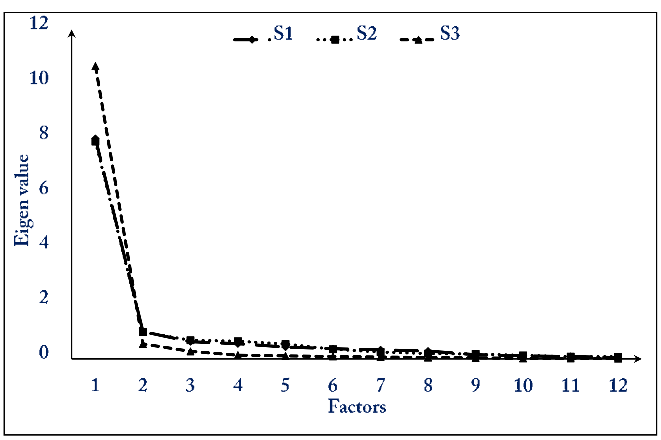

Figure 3: Eigen value plot of scale morphometric parameters for different water bodies (S_1 for Anasagar, S_2 for Jaisamand lake and S_3 for Vallabhsagar) populations of tilapia

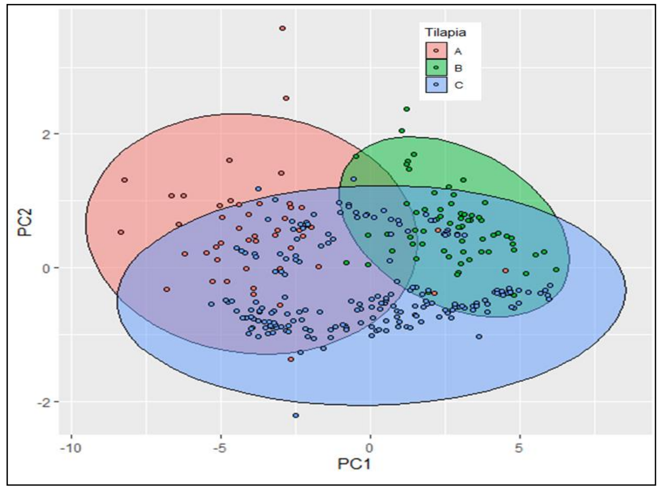

Figure 4: Scatter plot with sheared PC scores of morphometric parameters for different populations of tilapia in various water bodies (A for Anasagar, B for Jaisamand lake and C for Vallabhsagar)

4. CONCLUSION

The studied scale specimens of tilapia form Aanasagar, Jaisamand Lake and Vallabhsagar reservoir indicated that the scales morphological outlines of studied fish in all water bodies were different from each other that could be considered as three different stocks arbitrated by hydrological difference and isolated geographical condition.

5. REFERENCES

Anni, J.A.M.D., Christina, A.P., Jeyaseeli, A., 2016. Length-weight relationship and condition factor of freshwater fish *tilapia mossambica.* Journal of Biological Innovations 5(5), 758–763.

Anonymous, 1995. Afriki machhali phailaw se jaisamand jheel ki desi machhalion par sankat, Rajasthan Patrika. 11.12.1995.

Barlow, G., 2000. The cichlid fishes: the natures grand experiment in evolution. Persuus publishing Cambridge, Massachusetts.

Begg, G.A., Brown, R.W., 2000. Stock identification of haddock *Melanogrammus aeglefinus* on Georges Bank based on otolith shape analysis. Transactions of the American Fisheries Society 129, 935–945.

Campbell, N.A., Atchley, W.R., 1981. The geometry of canonical variant analysis. Systematic Zoology 30, 268–280.

Casselman, J.M., Collins, J.J., Crossman, E.J., Ihssen, P.E., Spanger, G.R., 1981. Lake whitefish (Coregonus clupeaformis) stocks of the Ontario waters of Lake Huron. Canadian Journal of Fisheries and Aquatic

Sciences 38, 1772–1789.
Chakrabarty, P., 2005. Testing conjectures about morphological diversity in cihlids of Lakes Malawi and Tanganyika. Copeia 2, 359–373.
Dunn, G., Everitt, B.S., 1982. An introduction to mathematical taxonomy. Cambridge, MA, Pp. 152.
Dwivedi, A.K., De, K., 2023. Role of morphometrics in fish diversity assessment: status, challenges and future prospectus. National Academy Science Letters 46(3), 3–7.
Fuerst, P.A., Mwanja, W.W., Kaufman, L., 2000. The genetic history of the introduced Nile tilapia of Lake Victoria (Uganda–E. Africa): The population structure of *Oreochromis niloticus* (Pisces: Cichlidae) revealed by DNA microsatellite markers. In Tilapia Aquaculture in the 21st Century Proceedings from the Fifth International Symposium on Tilapia in Aquaculture; Panorama da Aquicultura Magazine: Rio de Janeiro, Brazil, pp. 30–40.
Green, P.E., 1976. Mathematical tools for applied multivariate analysis. Academic Press, N.Y., Pp. 376.
Hanski, I., Simberloff, D., 1997. The metapopulation approach, its history, conceptual domain, and application to conservation. In: Hanski, I., Gilpin, M.E. (Eds), Metapopulation biology, ecology, genetics, and evolution. Academic press, San Diego, 5–26.
Horton, S.E., 1982. Intra-specific variation in the marine shrimps *Penaeus* (*Litopenaeus*) *stylirostris* and *Penaeus* (*Litopenaeus*) *vannamei*. Unpublished M.S. Thesis, Texas A & M University.
Jarvis, R.S., Klodowski, H.F., Sheldon, S.P., 1978. New method of quantifying scale shape and an application to stock identification in Walleye (Stizostedion vitreum vitreum). Transactions of the American Fisheries Society 107, 528–534.
Makeche, M.C., Muleya, W., Nhiwatiwa, T., 2020. Characterization of *Oreochromis niloticus* strains of Lake Kariba culture fisheries using morphological and meristic methods. American Scientific Reserch Journal of Engineering and Technological Science 74, 31–40.
Masood, Z., Habib Ul, H., Shahid Mahboob, M.F., Aid, A.A., Safia, M., Naseem, R., Yasmeen, G., Halima, J., Mehtab, I., Saeed, 2021. Relationship between different linear dimensions of scale parameters of four species of mugilidae from Karachi Coast, Pakistan. Egyptian Journal of Aquatic Biology & Fisheries, 25(4), 871–881.
Mwanja, M., Ondhoro, C., Sserwada, M., Achieng, P., Ddungu, R., Mwanja, W., 2016. Morphological variation of nile tilapia populations from major water bodies of Uganda. Uganda Journal of Agricultural Science 17, 21–32.
Natugonza, V., Nyamweya, C., Sturludóttir, E., Musinguzi, L., Ogutu-Ohwayo, R., Bassa, S., Mplaponi, E., Tomasson, T., Stefansson, G., 2022. Spatiotemporal variation in fishing patterns and fishing pressure in Lake Victoria (East Africa) in relation to balanced harvest. Fisheries Research 252, 106–355.
Nelson, J.S., 1994. Fishes of the world, 3rd Edn. Wiley, New York.
Poulet, N., Berrebi, P., Crivelli, A.J., Lek, S., Argillier, C., 2004. Genetic and morphometric variations in the pikeperch (*Sander lucioperca* L.) of a fragmented delta. Archiv for Hydrobiologie 159, 531–554.
Radkhah, A.R., Poorbagher, H., Eagderi, S., 2017. Habitat effects on morphological plasticity of Sawbelly (*Hemiculter leucisculus*) in the Zarrineh river (Urmia Lake basin, Iran). Journal of BioScience and Biotechnology 6, 37–41.
Rose, S., Ujjania, N.C., Soni, N., Rathore, A.S., Sharma, L.L., 2018. Preliminary observations on age and growth of exotic fish tilapia (*Oreochromis mossambicus* P.) from Ana Sagar Lake, Ajmer (India). International Journal of Zoological Stdudy 3(4), 01–05.
Shukla, R., Bhat, A., 2017. Morphological divergences and ecological correlates among wild populations of zebrafish (Danio rerio). Environmental Biology of Fishes 100, 251–264.
Ujjania, N.C., Kohli, M.P.S., Sharma, L.L., 2008. Managing tilapia in large reservoirs – a case study from Jaisamand Lake, Udaipur (India). Conference: 8th International Seminar on Tilapia in Aquaculture.
Ujjania, N.C., Nandita, S., 2018. Use of scale for the growth study of Indian major carp (*Cirrhinus mrigala* Ham., 1822) in tropical freshwater. Indian Journal of Experimental Biology, 56, March 2018, 202–206.
Ujjania, N.C., Soni, Nandita, Sharma, L.L., 2014. Determination of Age and Growth of Cyprinid Fish of tropical Environment using Scale- A Protocol. Fishing Chimes 34(4), 51–56.
Varma, K.B.R., 1990. Morphology and dielectric properties of fish scale. Current Science 59(8), 420–422.
Viertler, A., Salzburger, W., Ronco, F., 2021. Comparative scale morphology in the adaptive radiation of cichlid fishes (Perciformes: Cichlidae) from Lake Tanganyika. Biological Journal of the Linnean Society XX, 1–16.
Vincent, T.R., George, M.K., Paulton, M.P., Sathianandan, T.V., 2014. Morphometric structure of the jumbo tiger prawn, *Penaeus monodon* Fabricius, 1798 from southeast and southwest coasts of India. Journal of the Marine Biological Association of India 55(2), 11–15.
Webb A.C., 2007. Status of the Mozambique tilapia, Oreochromis mossambicus, in the Ross Dam, Townsville, in Tropical northern Queensland. A report for NQ Water. School of Marine and Tropical Biology, James Cook University, Douglas, Qld, Australia.