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Multivariate techniques to *Pomadasys maculatum* (Bloch) of Karachi Coast, Pakistan

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Key words: *Pomadasys maculatum* test of independent, Scree plot factor analysis (FA), Principal component analysis (PCA), Monte carlo PCA for parallel analysis

Abstract

This paper aims to investigate the variability in the morphometric and meristic characteristics in a set of fishery data by applying multivariate statistical techniques; PCA and Factor analysis. Moreover, gender-wise difference in these variables is also investigated via statistical independent t-test. Empirical analysis result obtained from t-test shows that the total length of the body in female is 8.079, whereas male has 8.054 of the whole body length. Furthermore, test of independent result of body displays that weight of female and male are 9.966 and 10.053 respectively. However, head length and snout length are found 9.143 and 10.568 in female and in male 09.145 and 10.557 respectively. To sum up, all the variables are slightly significant in both (Male and Female). In the second phase via applying PCA it is found that the first three variables (total length (TL), Body weight (Bwt), Standard length (SL)) are retained 90.047% of the total variation.

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Introduction

In the recent year, significant development in fisheries typology has enlarged enormously due to their nutritional value and their statistical diversity. In conservation biology and environmental science exploration of fish species distributions has paramount importance. Edible marine fishes Grunts like (*Pomadasys maculatum* (Bloch) (family: Pomadasyidae) are very much famous for their Grunting sounds made at the moment when they are disturbed. *Pomadasys maculatum* is commonly found in Pakistan but limited number of studies available in this regard. Regression analysis was used to study the relationship of weight as function length for *Pomadasys maculatum* (Bloch 1797) by (Khan *et al.,* 2013). In order to compare the gender wise difference test of independence (t-test) was applied. Their result showed that the value of slope has range from 2.843 to 2.93 for the short length and weight whereas the value of slope for the total length and weight was 2.799 to 2.86. In another study, (Amtyaz *et al.*, 2014, Khan *et al.*, 2013) also discussed the length weight relationship. Their studies showed that the total length of female species is greater than male. But still no study was found in multivariate dimension.

Multivariate techniques, such as principle component (PCA), factor analysis (FA) and dendogram etc. are very helpful to analyze multivariate morphometric characteristic and reduce the high dimensionality of data (Jackson 1981, 1991) and (DeCoster 1998). Moreover, several multivariate methods have been used to explain the distribution of fishes, including multivariate analysis of variance (Bendell and McNicol 1987, Jackson and Harvey 1989), factor analysis (Stevenson *et al.*, 1974, Oberdorff *et al.*, 1993), and correspondence analysis by (Hughes and Gammon 1987, Meffe and Sheldon 1988, Pusey *et al.*, 1995).

The primary aim of the study is to explicate the underlying characteristics of the selected data by using multivariate techniques. Different statistical measures were used to study morphometry and meristics characteristics of Pomadasys maculatum by (Siddiqui, S and Fatima, S 2019). Their empirical analysis result exhibited that female total length is more established than male total length.

In Pakistan, study related to *Pomadasys Maculatum* is very rare especially in morphometry and meristics characteristics using multivariate statistical analysis. Although, the taxonomy and its biological aspect of Pomadasys Maculatum was discussed various marine researchers (Ed. Smith, Margaret M, and Heemstra, P 2003, Branch, G.M. Griffiths, C.L. Branch, M.L. Beckley, L.E 2000, Smith & Heemstra, 1986).

The main objective of this study is to investigate the linear structure(s) as well as the variability in the selected variables of *Pomadasys Maculatum* by applying multivariate statistical techniques (Factor/ Component analysis). Furthermore, gender wise test of independence is used to explore difference in the *morphometry and meristics* characteristics.

Material and methods

Study area

For the study the sample was collected from Korangi Creek of Karachi coast and Karachi fish harbour, West Wharf Karachi coast. The study area of Korangi Creek of Karachi coast is located at 24° 47' N latitude 67°5'E longitude whereas the West Wharf Karachi is located at 240° 48' N latitude and 660° 58' E longitude on the north eastern border of the Arabian Sea.

Fish sampling and data collection

Morphometric variables measurement for the *Pomadasys Maculatum* (Bloch) (family was collected from year 2013, January to 2014, December on monthly basis from different local fish harbour at the Karachi Coastal Area. The measurement collected by the researcher contains 15 variables of a single fish which have been categorically exhibited as under.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T.L (mm)	S.L (mm)	B.Wt (gm)	B.D (mm)	F.L (mm)	H.L (mm)	Sn.L (mm)	E.D (mm)	B.B (mm)	CPL (mm)	P.O (mm)	L.L (mm)	D.S.L (mm)	ASL (mm)	CFRL (mm)

The data collected included 553 female and 503 male fishes. Total of fifteen variables of male and female are studied including morphometry and metrics characteristics, total length (TL), Body weight (Bwt), Head length (HL), Snout length (Sn.L), Eye diameter (ED), Standard length (SL) and, Fork length (FL), Body breath (BB), Pre-orbit length (PO) and Caudal peduncle length (CPL). The Meristic characters like Anal fin rays (ASL), Lateral line scales (LL), Caudal fin rays (CFRL), Dorsal fin rays length (DSL) scales rows above.

Test of independent with split variable (Gender)

In order to compare gender wise difference of the variable independent-samples t-test can be comprehend. Where, the null hypothesis is defined as:

H_0: There is significant difference between male and female for selected variable.

Ha: There is insignificant difference between male and female for selected variable.

Principal Component

Multivariate statistical techniques such as, Factor Analysis (FA) and Principal component analysis (PCA) are commonly used for data reduction which is based on minimum variance of the variables by (Bartholomew, Knott and Moustaki 2011). FA can identify several factors reasonably, but the interpretation of these in terms of actual controlling sources is highly subjective (Gauch 1982). Though, applications of FA have been offered in several areas such as Zoology, Petrography, Geochemistry, Statistics, and Environmental Geology (Saager and Esselaar 1969, Voudouris *et al*., 1997, Morsy 1993) etc.

On the other hand, Principal component analysis (PCA) is a technique mostly used to be the identifying the best part strong patterns which is present in a dataset. If a number of possibly correlated variables are transformed into a smaller number of uncorrelated variables, they are called principal components. Dealing with large number of variables, PCA is found extremely useful in eliminating or reducing dimensions of data set.

Let $X_1, X_2, \ldots, X_p$, is a vector of 'p' random variables whose variance and covariance matrix exists. Principal components are specific linear combinations such that these linear combinations are independent and obtained by applying Eigen analysis on its covariance matrix, which provides new axes. The new axes represent the directions with maximum variability and provide a simpler description of the covariance structure. Therefore, Principal component mainly depends on the covariance/correlation matrix and hence the assumption of multivariate normality is not required.

The linear combinations of 'p' random variables and Eigen vectors is mathematically defined as a system of linear regression equations,

$Y_1 = e_{11}x_1 + e_{12}x_2 + \cdots + e_{1p}x_p$

$Y_p = e_{i1}x_1 + e_{i2}x_2 + \cdots + e_{ipxp}$

Above equations can be represented in matrix notation as follows,

$$y = e^{'}X$$

In this study morphometric variable i.e., p = 15 ($x_1, x_2, \ldots, x_{15}$) is considered for analysis. Where, X_i's are the morphometric variable of the i^{th} series $X=(x_1, x_2, \ldots, x_{15})'$, and the mean of that population is denoted by

$$\mu_x = E(x)$$

Furthermore, the first 'k' principal components out of 'p=15' components are selected in such a way that the proportion of variation explained by those first 'k' principal components is to be as large as possible.

Scree Plot

According to (Cattell 1978) Eigen values and factors are the main components of the scree test. In a scree plot a simple line segment is used to represent the fraction of total variance of the data in descending order of magnitude, of the Eigen values of a correlation matrix. Basically, a scree plot helps us to visualize the relative importance of the factors. The data signifies to be retained. The researcher draws a vertical and horizontal line starting from each end of the curve in order to determine the 'break'. The scree test reliability is based on the

sample size which is at least 200. To set the number of factors manually to extract each time in situations the scree test is hard to interpret (e.g., clustered data points). It is important to repeat the analysis several times to observe the point of inflexion, (Costello and Osborne 2005).

Monte Carlo method

Monte Carlo method is a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. The underlying concept is to use randomness to solve problems that might be deterministic in principle.

Results and discussion

Table 1. Morphometric Independent Samples Test of *Pomadasys Maculatum*.

Independent Samples Test										
Independent Samples Test	Levene's Test for Equality of Variances		t-test for Equality of Means							P-value ("Sig.")<.05
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Interval of the Lower	Upper	Results
T.L (mm)	.012	.911	8.079 8.054	1054 1027.674	.000	11.718	1.450 1.455	8.872 8.863	14.564 14.573	Significant
S.L (mm)	.499	.480	8.689 8.651	1054 1018.507	.000	9.977	1.148 1.153	7.724 7.714	12.230 12.240	Significant
B.Wt (gm)	9.413	.002	9.966 10.035	1054 1051.299	.000	17.535	1.759 1.747	14.082 14.106	20.987 20.963	Significant
B.D(mm)	.147	.702	7.593 7.569	1054 1026.964	.000	3.917	.516 .518	2.905 2.902	4.99930 4.933	Significant
F.L(mm)	.341	.559	8.393 8.339	1054 1001.811	.000	11.758	1.401 1.410	9.009 8.991	14.507 14.525	Significant
H.L(mm)	.430	.512	9.143 9.145	1054 1045.329	.000	3.651	.399 .399	2.867 2.867	4.434 4.434	Significant
Sn.L(mm)	.054	.816	10.568 10.557	1054 1039.828	.000	1.534	.145 .145	1.249 1.249	1.819 1.819	Significant
E.D(mm)	1.406	.236	8.261 8.339	1054 1042.604	.000	1.042	.126 .125	.795 .797	1.290 1.287	Significant
B.B(mm)	.606	.436	7.756 7.766	1054 1049.364	.000	1.842	.126 .125	1.376 1.376	2.308 2.307	Significant
CPL(mm)	3.206	.074	6.481 6.497	1054 1051.821	.000	1.167	.237 .237	.813 .814	1.520 1.519	Significant
P.O(mm)	.196	.658	8.165 8.158	1054 1040.803	.000	1.711	.180 .180	1.299 1.299	2.122 2.122	Significant
L.L(mm)	.001	.981	6.478 6.489	1054 1050.069	.000	6.829	.209 .210	4.761 4.764	8.898 8.894	Significant
D.S.L(mm)	.057	.811	8.940 8.932	1054 1040.367	.000	4.599	1.054 1.052	3.589 3.588	5.608 5.609	Significant
ASL(mm)	.001	.981	8.155 8.128	1054 1026.352	.000	6.681	.819 .822	5.073 5.068	8.288 8.293	Significant
CFRL(mm)	2.478	.116	7.949 7.927	1054 1029.712	.000	2.895	.364 .365	2.181 2.179	3.610 3.612	Significant

*Equal variances assumed (Female)

*Equal variances not assumed (Male)

Note: In the above table 1st column represents selected variables corresponding to this columns of t',df, standard error, lower and upper interval are divided as male and female. Author's calculation using SPSS software.

Table 1, presents the output of independent t-test obtained by SPSS software. The result shows that the full length of body in female is 8.079, whereas, in male it is 8.054. The body weight in female is 9.966 whereas male has 10.053. The measurement of head length and snout length are 9.143 and 10.568 consecutively in female. The eye diameter is 8.261 and the length of caudal peduncle is 6.481 in female, whereas in male these lengths are 8.339 and 6.497 respectively. The other length of meristic characters; anal fin rays, dorsal fin rays, caudal fin rays and lateral line scales in female are 8.155, 8.940, 7.949

and 6.478 but male has 8.128, 8.932, 7.927 and 6.489 respectively. To put in nutshell, the contemporary study demonstrates that no significant difference is found between the total lengths of females (8.079) and males (8.054) as the p-value is less than the level of significance at 5% level of significance.

Table 2. Morphometric KMO and Bartlett's Test *in Pomadasys Maculatum*.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.974
Bartlett's Test of Sphericity	Approx. Chi-Square	28805.025
	Df	105
	Sig.	.000

This measure varies between 0 to 1 and value closer to 1 suggested adequacy of sampling (Field 2009). In this analysis sampling adequacy KMO=0.974. Furthermore, Bartlett's Test of Sphericity describes the variation between the gender under the null hypothesis that identity matrix is the correlation matrix. This suggested that the null hypothesis of (equal variances) rejected. Taken together, these tests provide a minimum standard which support the implementation of factor analysis (or a principal components analysis).

Table 3. Morphometric Communalities *in Pomadasys maculatum*.

Communalities		
	Initial	Extraction
T.L (mm)	0.977	0.977
S.L (mm)	0.956	0.954
B.Wt (gm)	0.916	0.897
B.D (mm)	0.906	0.866
F.L (mm)	0.931	0.9
H.L (mm)	0.927	0.927
Sn.L (mm)	0.884	0.883
E.D (mm)	0.643	0.612
B.B (mm)	0.693	0.653
CPL (mm)	0.564	0.498
P.O (mm)	0.879	0.875
L.L (mm)	0.808	0.805
D.S.L (mm)	0.885	0.882
ASL (mm)	0.957	0.948
CFRL (mm)	0.793	0.769

In the factor Analysis: the principal factor axis factoring method is used, the proportion in each variable's variance can be explained.

The values in the column (Table 3) indicate the proportion of each variable's variance which can be explained by the retained factors. Variables with low values are not well represented is not considered.

Table 4. Morphometric Total Variance Explained *in Pomadasys maculatum*.

Total Variance Explained						
Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.594	83.960	83.960	12.444	82.963	82.963
2	.538	3.587	87.547			
3	.375	2.500	90.047			
4	.334	2.226	92.273			
5	.227	1.511	93.784			
6	.194	1.291	95.075			
7	.148	.986	96.061			
8	.135	.901	96.962			
9	.116	.776	97.738			
10	.102	.682	98.420			
11	.081	.539	98.959			
12	.063	.418	99.377			
13	.040	.270	99.647			
14	.033	.222	99.869			
15	.020	.131	100.000			

*Extraction Method: Principal Axis Factoring.

From Table 5, a value of 90.047 can be shown in the third row. This means that the first three factors together account 90.047% of the total variance.

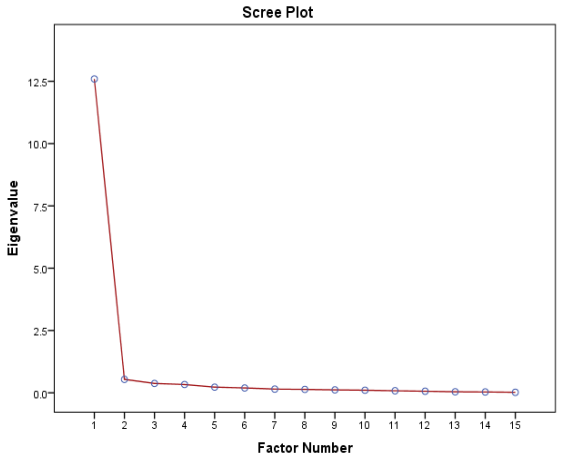

Fig. 1. Morphometric variable Scree plot.

The Eigen value against the factor number is graphed by the scree plot. These values can be seen in the first two columns (Table 4). The line is almost flat of the third factor which indicates that each successive factor is accounted smaller and smaller in the total variance.

This shows that first three factor together account of the total variance of total length (TL), Body weight (Bwt),), Standard length (SL).

Table 5. Morphometric Factor Scores *in Pomadasys maculatum*.

Factor Matrix		Factor Score Coefficient Matrix
	Factor-1	Factor-1
T.L (mm)	.989	.348
S.L (mm)	.977	.149
B.Wt (gm)	.947	.068
B.D (mm)	.930	.027
F.L (mm)	.949	.013
H.L (mm)	.963	.081
Sn.L (mm)	.940	.106
E.D (mm)	.782	.008
B.B (mm)	.808	.024
CPL (mm)	.705	.002
P.O (mm)	.935	.064
L.L (mm)	.897	.038
D.S.L (mm)	.939	.043
ASL (mm)	.973	.052
CFRL (mm)	.877	.015
Extraction Method: Principal Axis Factoring. Factors extracted. 3 iterations required.		

From Table 5, it is observed that one factor explain only 84% variation in total but according to the thumb rule maximum variation is consider therefore three variable is consider that 90% variation at all variables (Table 6).

Table 6. Morphometric Total Variance Explained *in Pomadasys maculatum*.

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.594	83.960	83.960	12.594	83.960	83.960
2	.538	3.587	87.547	.538	3.587	87.547
3	.375	2.500	90.047	.375	2.500	90.047
4	.334	2.226	92.273			
5	.227	1.511	93.784			
6	.194	1.291	95.075			
7	.148	.986	96.061			
8	.135	.901	96.962			
9	.116	.776	97.738			
10	.102	.682	98.420			
11	.081	.539	98.959			
12	.063	.418	99.377			
13	.040	.270	99.647			
14	.033	.222	99.869			
15	.020	.131	100.000			

The Eigen value as shown in the fifth column of Table 6 (Extraction Sums of Squared Loadings) is 12.594 greater than 1 (rule of thumb). All basic difference is the essential supposition about Principal segment examination works accordingly; the communalities are each of the one preceding extraction. In every factor, the measure of fluctuation can be depicted by the held variables spoke to by the shared traits.

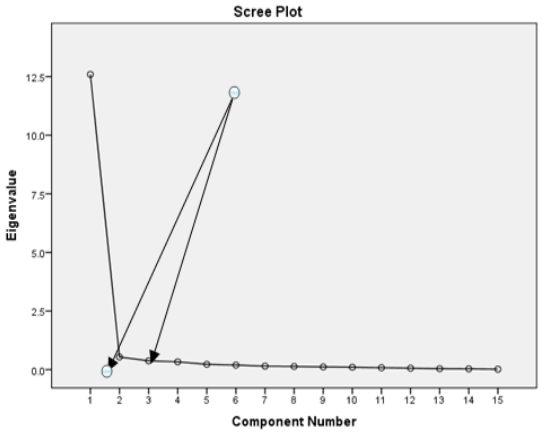

Fig. 2. Morphometric variable Scree plot.

Finally the scree plot of three PCA is plotted. There was slightly ambiguity scree plot and inflexions are showed so that the retaining components 1, 2 and 3 would be justified.

Table 7. Morphometric Component Matrix *in Pomadasys maculatum*.

Component Matrix			
	Component		
	1	2	3
T.L (mm)	0.984	0.001	-0.031
S.L (mm)	0.974	0.028	-0.003
B.Wt (gm)	0.949	-0.12	-0.115
B.D (mm)	0.935	-0.065	-0.065
F.L (mm)	0.951	-0.01	-0.027
H.L (mm)	0.963	-0.027	-0.01
Sn.L (mm)	0.943	-0.046	0.02
E.D (mm)	0.802	-0.224	0.546
B.B (mm)	0.826	-0.226	-0.089
CPL (mm)	0.73	0.631	0.156
P.O (mm)	0.939	0.014	-0.114
L.L (mm)	0.906	0.069	-0.04
D.S.L (mm)	0.942	-0.011	-0.01
ASL (mm)	0.972	-0.025	-0.019
CFRL (mm)	0.888	0.102	-0.098

Furthermore, for the 15 morphometric variables PCA using orthogonal rotation (VARIMAX) method is conducted. Sampling adequacy for the analysis KMO is 0.974 also verified adequacy of sampling.

Table 8. Monte Carlo method of PCA for Parallel Analysis Version.

Eigen	Random Eigen Value	Standard Dev
1	1.2071	0.0245
2	1.165	0.0199
3	1.1286	0.0176
4	1.099	0.0132
5	1.0724	0.0138
6	1.0452	0.0122
7	1.0195	0.0108
8	0.9944	0.0135
9	0.9722	0.113
10	0.9494	0.0114
11	0.9253	0.0115
12	0.8994	0.0125
13	0.8738	0.0146
14	0.8436	0.015
15	0.805	0.0207

Above Table 8, shows irregular Eigenvalues are more prominent than 1 according to rule of thumb. Therefore, for deciding noteworthy head parts that show that base standard deviation Monte Carlo test is used. This test is used to parallel analysis as a method for determining the "correct" number of factor. Below table shows the output of Monte Carlo.

Table 9. Decision Table of Monte Carlo.

Actual Eigen Value	Parallel Eigen value	Decision
12.594	1.2071	Accept
0.538	1.165	Accept
0.375	1.1286	Accept
0.334	1.099	Reject

The output of Monte Carlo displays only three main factors total length (TL), Body weight (Bwt), Standard length (SL) are accepted and retained 12.594, 0.538, 0.375 a total of 90.047% variance.

Conclusion

This study investigates inconstancy in the morphometric and meristic qualities in fishery data by applying multivariate statistical analysis such as PCA and factor analysis. Furthermore, paired t-test is used to study gender wise difference in the morphometric and meristic characteristics. The empirical analysis shows that all the factors are marginally significant in both (Male and Female). Moreover, according to PCA first three factors (all out length (TL), Bodyweight (Bwt), Standard length (SL)) are contains 90.047% of the total variance. This research will be helpful for the fishery department and the marine research.

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