Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(5): 1913 – 1936 (2024)
www.ejabf.journals.ekb.eg

Discriminant Analysis Approach in Morphometric Traits to Differentiate the Thinlip Mullet, *Liza ramada*

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ARTICLE INFO

Article History:
Received: Sept. 14, 2024
Accepted: Oct. 16, 2024
Online: Oct. 30, 2024

Keywords:
Liza ramada,
Morphometric traits,
Multivariate analyses,
Egyptian lakes

ABSTRACT

This study investigated the possibility of using morphometric measurements to differentiate the thinlip mullet, *Liza ramada*. For this purpose, one hundred and fifty specimens were randomly selected from the Qarun, Manzalla, and Burullus lakes in Egypt. Each specimen was assessed for 19 morphometric characteristics. The data were computed using principal component (PCA) and discriminant function analyses. The findings revealed that PC1, PC2, and PC3 accounted for over 76.24% of the observed morphometric variance. PC1 and PC2 accounted for 34.28 and 22.51%, respectively, of the variation. Morphological data from all *L. ramada* populations identified three primary categories. Univariate analysis revealed substantial differences across populations in all characteristics, except body weight and ocular diameter (ED) ratio, allowing separation along PCI and PC2. BW, CPD, PecFL, MBH, and CF ratios were selected using step-wise discriminant function analysis, which revealed three distinct morphotypes. Two canonical functions accounted for 100% of the variation, with the first function accounting for 80.11%. The first function distinguished the Qarun population that scored favorably (greater than zero), while the second function successfully separated the Burullus population that scored unfavorably (less than zero). It can be concluded that morphometric data acquired using PCA and DFA techniques revealed considerable difference amongst the thinlip mullet population morphotypes. The morphometric traits variation will help understand the genetic diversity of the *L. ramada* genotypes and can help to initiate the program for the preservation of the thinlip mullet genetic resources.

INTRODUCTION

Phenotypic characteristics vary greatly amongst populations of the same fish species **(Pakkasmaa & Piironen 2001; Kara *et al.*, 2011)**. Morphological differences can be caused by one of two variables: genetic variations, environmental influences, or their interplay. Genetic variations and reproductive isolation across populations can result in local adaptation, as seen by appearance, behavior, physiology, and life cycle features

(Pakkasmaa & Piironen, 2001). Environmental influences, on the other hand, can cause phenotypic plasticity, which is dependent on a genotype's ability to create distinct phenotypes in different environments **(Scheiner, 1993)**.

Liza sp. is the biggest genus in the Mugilidae family, with 24 species **(Ayo-Olalusi *et al.*, 2010; Doğu *et al.*, 2013)**. The species is still found in fresh waters **(Naama *et al.*, 1986)**, but it has also been observed in brackish water and marine environments **(Nasir & Naama, 1988; Badr El-Bokhty & Amin, 2020)**. The thinlip mullet's was known as *L. ramado* **(Risso, 1810)**, but it's true species name is *Liza ramada* **(Risso, 1827)**. *Ramado*, as used by **Risso (1810)**, is a vernacular name. An earlier new type identification for *M. ramado* is invalid **(Kottelat, 2008)**. *Liza ramada* is found in the Eastern Atlantic, from the beaches of southern Norway to Morocco, as well as the Mediterranean and Black Seas **(Wonham *et al.*, 2000; Saleh, 2008)**.

Saleh (2008) demonstrated that the thinlip mullet, *Liza ramada*, while being the second option in mullet aquaculture, accounts for the majority of Egypt's mullet harvest. This species grows slower than *Mugil cephalus*, but faster than any other Mediterranean mullet species. This species is the main aquaculture species due to its availability and abundance of wild fry in comparison with *Mugil cephalus* **(Sadek & Mires, 2000)**. The thinlip mullets can grow to be 70cm long. The species is distinguished by an elongate fusiform body that is somewhat compressed from side to side, a huge short head flattened above the eyes, and a big terminal mouth with extremely tiny, hardly visible teeth. The top lips are thin and smooth, while the nose is short and pointy. The thinlip grey mullet has two well-defined dorsal fins, the first with 4 to 5 spines. The pectoral fins are located high on the flanks, and the caudal fin is highly forked. There is no visible lateral border, and the scales are big and adhesive.

The scales on the top of the head reach forward to the anterior nostrils, and the eye is not protected by a thick adipose lid. A scaly appendix can be found at the base of the pectoral fin. The color on the back is grey-dark brown, and the belly is whitish-grey with 6-7 longitudinal stripes **(FAO 1973; Rochard & Elie, 1994)**.

The thinlip mullet swims quickly and leaps out of the water when startled. It feeds in estuaries and rivers but spawns at sea. Juveniles often concentrate in the vicinity of freshwater outflows. It feeds on minute bottom living or planktonic organisms (e.g. diatoms and amphipods) and also on suspended organic matter. This study aimed to analyze the discriminant analysis approach in identifying different strains of *Liza ramada*, which is one of the most important aquaculture species in the family Mugilidae, based on a number of morphometric characters.

MATERIALS AND METHODS

Mullet samples

A total of 150 thinlip mullet specimens for three populations of the family Mugilidae were collected at random from commercial landing stations in three different lakes in Egypt: Lake Qarun (29°25`34" N , 30°34`49" E), Lake Manzalla (31°15'36" N, 31°50'54" E), and Lake Burullus (31°28'35" N, 30°51'35" E) (Fig. 1). Each population consisted of 50 specimens. According to **Saleh (2008)**, the samples were recognized using morphological characters (Fig. 2).

Morphometric traits

Characteristics of nineteen morphometric traits recorded in family Mugilidae specimens were as follows: fish body weight (BW) from different populations was measured using balance to the nearest 1-gram, and seventeen morphometric characters were studied according to **Minos *et al.* (1995)**, **Rutten *et al.* (2004)**, **Kara *et al.* (2011)** and **El-Zaeem (2012)**. These morphometric characters were measured to the nearest 0.01mm using a digital caliper connected to a computer. The morphometrics under study were: standard length (SL), total length (TL) fork length (FL), head length (HL), distance of first dorsal fin (Dl), distance of second dorsal fin (D2), distance of ventral fin (DV), distance of the central of anus (DCA), distance of anal fin (DA), maximum body height (MBH), eye diameter (ED), caudal peduncle depth (CPD), dorsal fin length (DFL), snout length (NL), head depth (HD), width (W), pectoral fin length (PecFL) and tail length (TailL) which are illustrated in Fig. (2). In addition, condition factor (CF) was calculated according the following formula: $CF = 100W/L^b$

Where, W= fish body weight (g); L= fish total length (cm), and b= regression coefficient = 3 **(Tudorancea *et al.*, 1988)**. All morphometric measurements were made on the left side of fish. To minimize the effect of fish size, the data were transformed by dividing each measurement by the standard length of each fish **(Allendorf *et al.*, 1987)**.

Statistical analysis

The morphometric measurements from 150 fish specimens (50 specimens from each lake) were performed using the IBM SPSS Statistics version 23.0 software **(SPSS, 2019)**. Data were expressed as means, and significant level differences between means of populations were performed at a 5%.

Analysis of variance

Data findings were systematically analyzed using univariate analysis of variance (ANOVA). The findings obtained were expressed as mean, and significant differences between population’s means were determined using Tukey’s test in each morphometric trait.

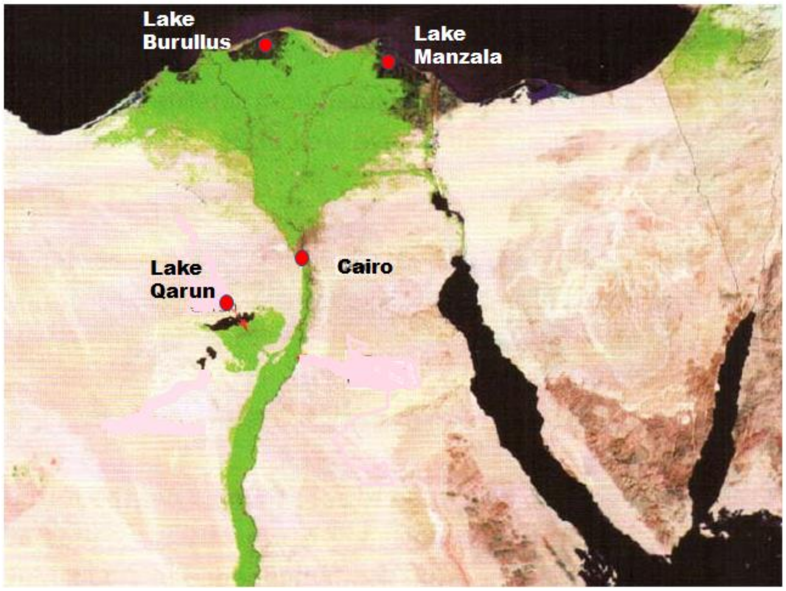

Fig. 1. Sampling sites of the thinlip mullet, *Liza ramada*, from Lake Manzalla, Lake Burullus, and Lake Qarun in Egypt

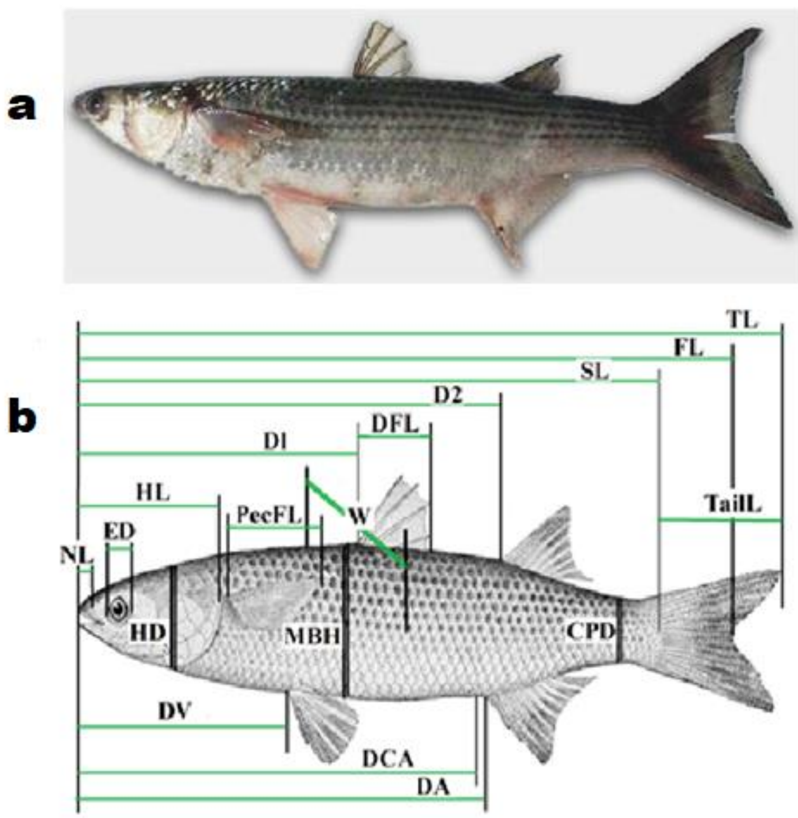

Fig. 2. (a) Photomicrograph of *Liza ramada* used in the current study; (b) Illustration of morphometric measurements

Principal component analysis (PCA)

PCA is a linear aspect reduction technique which can be used to reduce a wide variety of variables to a smaller number but also retains much of the original details **(Jolliffe & Cadima, 2016)**. Most of the variability in the results appear through the first principal component (PC1), while the second principal component (PC2) is orthogonal to the first and incorporates as many as possible of the residual variance, etc. **(Rombaut *et al.*, 2009)**. The dimensions' number to be retained for data analysis was estimated by the competent eigen values (which should be more than one), the Cronbach's alpha parameter (that must be positive), and the percentage of total variance (that should be as higher as possible).

Discriminant function analysis (DFA)

The discriminant analysis describes a set of variables such that the first function provides the most general distinction between classes; the second set the second-most, and so on **(El-Deeb, 2015)**. DFA was used to classify mullet species according to their morphometric measurements. It is a stepwise method, using the Wilks' λ method with the F- to-remove statistic, to apply for variable selection. The Wilks' λ test was applied in order to verify which discriminant functions were significant. To avoid over-optimistic modulation of data, a cross-validation leave-out procedure was performed to evaluate model performance. Moreover, the discriminant model output was tested for the ability to an index to classify the specimens using the Jackknife classification **(El-Deeb, 2015)**.

RESULTS

Fish stocks developed in a variety of environments have distinct biometric connections and development patterns. Morphometric features are a vital fisheries evaluation tool since fish growth is continuous and dependent on genetic and environmental variables **(Houeto, 2024)**. The present study aimed to to analyze the discriminant analysis approach in identifying different strains of *Liza ramada,* which is one of the most important aquaculture species in the familyMugilidae, based on a number of morphometric traits

Univariate analysis and morphometric polymorphism

To determine the significance of morphometric data for species identification, a univariate analysis of 19 measurements, represented as percentages of fish standard length, was performed (Table 1). All characters exhibited significant differences among populations except BW ($P< 0.05$).

Factor analysis

The principal component analysis (PCA) loadings on PC1 were large and positive for longitudinal measurements, and this component accounted for 34.28% of the variance. PC1 values were highly positively correlated with TL, FL, DV and TailL, and negatively correlated with MBH and CF ratios. PC2 explained 22.51% of the variance. PC2 was highly positively correlated with BW and ED and highly negatively correlated with PecFL and ED ratios. PC3 explained an additional 19.45% of the variance. Cumulative variance of PC1, PC2 and PC3 was 76.24% of the variance (Table 2). According to this study, the loadings on the first three components identified in the analysis showed an appreciable variation among populations.

Morphometric variations among populations

The scatter of standardized scores of PC1 against PC2 for populations examined is given in Fig. (3). The plot of PCA scores for 19 morphometric variables showed that all of *Liza ramada* Qarun wild specimens were located on the positive sector of the first component, and most of *Liza ramada* Burullus and Manzala wild specimens were located on the negative sector of the first component PC1. While, most of *Liza ramada* Burullus wild specimens were situated on positive sector, and all of *Liza ramada* Manzala wild were situated on the negative sector of the second component PC2 (Fig. 3). The first component PC1 is defined by TL, FL, DV and TailL and the second component PC2 is defined by BW, PecFL and ED ratios as percentage of total length. Most characters differences between geographic locations may represent local adaptations to differing lakes ecology **(Jerry & Cairns, 1998)**.

The Duncan test indicated that mean standardized PC1 scores for specimens of *Liza ramada* from Qarun lake (6.406) are significantly higher than those from Burullus Lake (-3.078) and Manzalla Lake (-3.389) (Table 3).

A plot of PC1 and PC2 scores, for all fish, indicated that the three *Liza ramada* lakes wild populations were separated along PC1 and PC2 (Fig. 3). The overall pattern of spacing of the samples on the PC1 and PC2 co-ordinates (Fig. 3) can be explained by differentiation between (Qarun, Manzalla and Burullus) lakes' samples. Qarun samples tended to display higher values of PC1 compared with Burullus and Qarun lakes' samples. When standard scores for the PC1 specimens of *Liza ramada* from different geographical localities were graphed as a multidimensional distribution (Fig. 3), there was a clear separation between the fish from lakes.

Table 1. Univariate analysis for *Liza ramada* in Qarun, Manzala and Burullus lakes

Trait	Lake Qarun	Lake Manzala	Lake Burullus
BW	-0.004^{ns}	-0.192^{ns}	0.196^{ns}
TL	0.315^{a}	-0.189^{b}	-0.335^{c}
FL	0.821^{a}	-0.356^{b}	-0.458^{b}
CPD	1.139^{a}	-0.851^{c}	-0.291^{b}
DFL	1.070^{a}	-0.488^{b}	-0.572^{b}
PecFL	0.441^{a}	0.372^{a}	-0.829^{b}
HL	0.107^{a}	-0.531^{b}	0.435a
DV	0.799^{a}	-0.317^{b}	-0.493^{b}
DCA	0.351^{a}	-0.942^{b}	0.583^{a}
DA	0.368^{a}	-0.906^{b}	0.533^{a}
NL	0.673^{a}	-0.344^{b}	-0.322^{b}
ED	0.153^{ns}	-0.008^{ns}	-0.157^{ns}
D1	0.167^{a}	-0.614^{b}	0.437^{a}
D2	0.318^{b}	-1.138^{c}	0.826^{a}
HD	-0.870^{b}	0.297^{a}	0.414^{a}
MBH	-0.656^{b}	0.357^{a}	0.297^{a}
W	-0.968^{c}	0.049^{b}	0.911^{a}
TailL	0.867^{a}	-0.257^{b}	-0.610^{c}
CF	-1.051^{c}	0.014^{b}	1.039^{a}

Means within the same row bearing different superscript differ significantly ($P < 0.05$).

Morphometric characters separated the samples of *Liza ramada* from Manzala Lake clearly from Qarun Lake samples and clearly from Burullus Lake samples. Most fish, including salmonids, have a limited understanding of how genetic and environmental variables influence morphometric variation **(Taylor & McPhail, 1985; Hard *et al*, 1999)**.

Table 2. Component matrix and eigen values of morphometric traits for *Liza ramada* collected from Qarun, Manzala and Burullus lakes in Egypt

Trait	Component				
	1	2	3	4	5
BW	-0.245	0.820	-0.312	0.256	-0.196
TL	0.735	0.335	-0.336	0.144	0.373
FL	0.784	0.349	-0.222	0.084	0.397
CPD	0.580	0.374	-0.235	0.377	-0.393
DFL	0.653	-0.015	-0.232	0.466	-0.408
PecFL	0.372	-0.789	-0.077	0.357	0.137
HL	0.441	-0.392	0.729	-0.078	-0.010
DV	0.750	-0.380	0.163	0.117	-0.086
DCA	0.590	0.517	0.552	-0.163	-0.036
DA	0.565	0.582	0.498	-0.143	-0.055
NL	0.672	-0.596	0.256	0.166	-0.114
ED	0.407	-0.690	0.443	0.259	0.060
D1	0.477	0.435	0.599	-0.018	0.114
D2	0.432	0.525	0.587	-0.070	-0.226
HD	-0.549	0.028	0.494	0.443	0.418
MBH	-0.654	0.331	-0.010	0.624	-0.014
W	-0.515	0.387	0.607	0.254	0.152
TailL	0.750	0.382	-0.352	0.104	0.365
CF	-0.618	0.030	0.712	0.189	-0.084
Eigen values	**6.513**	**4.277**	**3.695**	**1.443**	**1.106**
% of variance	**34.280**	**22.512**	**19.446**	**7.597**	**5.820**
Cumulative %	**34.280**	**56.793**	**76.238**	**83.836**	**89.655**

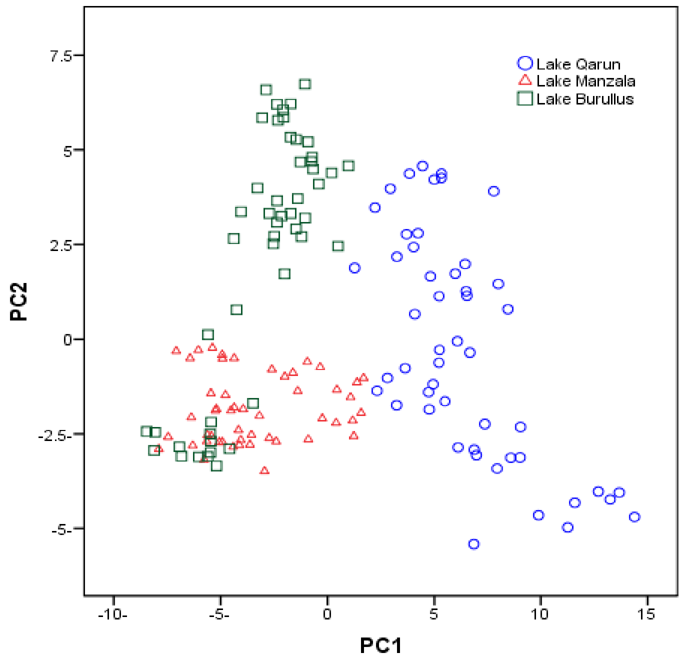

Fig. 3. Scatter plot of PC1 and PC2 from the analysis of morphometric characters for *Liza ramada* collected from Qarun, Manzala and Burullus lakes in Egypt

Table (4) shows the second principal component PC2. The results obtained from principal component analysis on the morphological data of all populations of *Liza ramada* indicated that the three major groups are discerned, and the majority of the specimens from three geographical regions can be distinguished from each other. *Liza ramada* lakes' populations had divergent morphometric traits. The most important result of this study is the fact that lakes populations are morphometrically divergent from each other.

Discriminant function analysis

Step-wise discriminant function analysis (DFA) using morphometric data from three *Liza ramada* populations yielded eleven characteristics. These characters indicated, significantly, three different morphotypes among the three populations. The characters selected on fish were BW, FL, CPD, DFL, PecFL, DV, D1, D2, HD, MBH, and CF. Morphometric variable analysis yielded two significant discriminant functions (Table 5), with the first separating groups.

Table 3. Standardized scores for the first component PC1 for *Liza ramada* collected from Qarun, Manzala and Burullus lakes in Egypt

Population	Lake Qarun		Lake Manzala		Lake Burullus	
	A	B	A	B	A	B
Standardized score	8.013	6.129	1.079	0.436	-0.410	-2.010
	5.344	3.234	1.227	-5.435	-1.721	-5.591
	6.461	4.815	-6.305	-4.931	-6.021	-0.913
	4.233	8.463	-0.345	-6.046	-5.608	-1.393
	2.940	4.084	-3.946	-4.915	-0.673	-5.456
	9.030	13.670	-4.411	-2.001	-3.274	-5.194
	1.269	5.248	-0.898	-5.456	-5.442	-2.532
	8.598	4.758	-5.384	-5.617	-3.049	-2.144
	6.098	4.996	-5.060	-7.458	-2.876	-2.726
	2.221	9.052	-7.890	-4.518	-4.381	-8.108
	6.990	3.244	-5.773	-1.391	-6.927	-2.362
	13.245	5.217	-4.371	-1.618	-2.320	0.489
	3.631	7.957	-0.245	-4.063	-2.072	0.978
	2.318	4.730	-5.241	-6.371	-0.720	-1.058
	5.230	14.384	-6.425	1.377	-5.470	0.191
	4.447	2.802	-5.201	-7.077	-3.482	-2.356
	5.342	6.683	-4.126	-3.188	-4.042	-1.048
	6.870	6.508	-4.775	-4.366	-6.828	-1.471
	7.801	6.545	-5.647	-2.603	-5.484	-4.583
	12.690	11.590	1.684	-2.727	-8.455	-4.250
	6.883	4.939	1.176	-3.627	-2.362	-1.215
	7.382	5.507	-2.401	-3.557	-1.274	-1.721
	5.999	3.831	-0.946	1.572	-8.062	-2.057
	4.027	3.698	-2.949	0.400	-2.491	-1.729
	9.895	11.261	-4.916	-4.162	-0.754	-1.466
Means	**6.406^{a}**		**-3.389^{b}**		**-3.078^{b}**	

A: Sample numbers from 1 to 25 and B: Sample numbers from 26 to 50. Means within the same row bearing different superscript differ significantly (*P*< 0.05).

Table 4. Standardized scores for the second component PC2 for *Liza ramada* collected from Qarun, Manzala and Burullus lakes in Egypt

Population	**Lake Qarun**		**Lake Manzala**		**Lake Burullus**	
	A	B	A	B	A	B
Standardized score	1.457	-2.858	-1.534	-1.335	4.097	1.726
	4.374	-1.745	-2.563	-2.561	6.213	0.119
	1.985	1.656	-2.810	-0.412	-3.108	5.211
	2.799	0.791	-0.744	-0.287	-3.094	3.712
	3.974	0.661	-1.847	-0.513	4.496	-2.694
	-3.126	-4.049	-2.841	-0.987	3.990	-3.344
	1.881	-0.284	-2.648	-1.431	-2.190	2.521
	-3.131	-1.857	-0.229	-2.534	5.846	3.250
	-0.055	4.214	-2.721	-2.583	6.585	3.321
	3.473	-2.320	-2.902	-1.886	2.653	-2.940
	-3.062	2.177	-3.184	-1.372	-2.839	6.204
	-4.232	-0.623	-0.505	-0.889	5.780	2.455
	-0.768	-3.416	-2.097	-2.662	6.055	4.576
	-1.364	-1.400	-1.890	-2.065	4.803	6.733
	1.132	-4.695	-0.502	-1.144	-2.992	4.389
	4.572	-1.025	-1.842	-0.316	-1.694	3.655
	4.256	-0.354	-2.797	-2.024	3.364	3.197
	-5.413	1.265	-1.478	-1.808	-3.092	2.909
	3.906	1.144	-2.698	-0.799	-2.507	-2.895
	-4.023	-4.319	-1.024	-2.610	-2.439	0.776
	-2.919	-1.191	-2.151	-2.785	3.081	2.705
	-2.242	-1.643	-2.705	-2.530	4.679	3.321
	1.730	4.369	-0.598	-1.949	-2.461	5.864
	2.429	2.771	-3.489	-2.214	2.712	5.333
	-4.649	-4.971	-2.721	-2.399	4.690	5.272
Means	**-0.294^{b}**		**-1.852^{c}**		**2.16^{a}**	

A: Sample numbers from 1 to 25 and B: Sample numbers from 26 to 50. Means within the same row bearing different superscript differ significantly ($P < 0.05$).

Two canonical functions in the DFA accounted for 100% of the variance in the data (First function 80.11% and second function 19.89%). The first axis had high positive loadings for BW, CPD and PecFL ratios and high negative loadings for MBH and CF ratios. While, the second axis had high positive loadings for BW and PecFL ratios and high negative loadings for D2, which were important in discriminating groups. Standardized coefficients of the first function and standardized coefficients of the second function are shown in Table (5). The percentage of successfully recognized individuals indicates the morphological distinctness of the samples. Canonical variants can be interpreted using pooled within-group correlations between variables and discriminant scores, much as PCA loadings are **(Cadrin, 2005)**.

Scatter plot

Fig. (4) exhibits the bivariate plot of two canonical functions. The first function separated *Liza ramada* Qarun wild population from *Liza ramada* Manzala wild and *Liza ramada* Burullus wild. The plot of the first discriminant function scores showed that all the scatter points of *Liza ramada* Qarun wild specimens were located on the positive sector of the first function, while most of the scores for *Liza ramada* Manzala wild and most of the scores for *Liza ramada* Burullus wild specimens are situated on the negative sector of the first function. Scatter plots of two discriminant function scores demonstrated the separation of three morphotypes, the Qarun, Manzala and Burullus lakes (Fig. 4).

Examination of the bivariate scatter plot and Duncan statistics between locations for the first and second functions (Tables 6, 7) indicated that specimens from Qarun Lake were significantly different from those in Manzalla and Burullus lakes in function scores 1 (Table 6).

While, in function scores 2 (Table 7), specimens from Manzalla Lake were significantly different from those of Burullus Lake. Morphometric variation among the three *Liza ramada* wild populations was used to test the presence of stock structuring. Significant heterogeneity in morphology among the three *Liza ramada* wild populations was revealed by univariate statistics and discriminant function analysis (Tables 1, 6, 7). Between- morphotype discrimination for three *Liza ramada* wild populations forms were based on measures of BW, CPD, PecFL, MBH and CF ratios.

Table 5. Eigen values and standardized canonical discriminant function coefficients for *Liza ramada* collected from Qarun, Manzala and Burullus lakes in Egypt

Trait	Discriminant function (all characters)		Discriminant stepwise function (selected characters)	
	1	2	1	2
BW	0.244	0.638	1.099	1.710
TL	0.126	-0.186	-	-
FL	-0.717	-0.298	-0.534	-0.089
CPD	1.526	-0.537	1.475	-0.604
DFL	0.411	-0.088	0.290	-0.326
PecFL	1.083	1.178	1.161	1.280
HL	-0.557	-0.445	-	-
DV	0.588	0.440	0.565	0.367
DCA	-0.759	-0.462	-	-
DA	0.731	0.079	-	-
NL	0.131	-0.487	-	-
ED	-0.306	-0.027	-	-
D1	-0.115	0.876	-0.189	0.764
D2	0.102	-1.175	0.074	-1.257
HD	-0.463	0.142	-0.421	0.329
MBH	-1.110	-0.178	-1.176	-0.115
W	-0.280	0.128	-	-
TailL	0.478	0.869	-	-
CF	-0.505	-0.206	-0.983	-0.620
Eigen values	**32.374**	**8.606**	**30.217**	**7.504**
% of variance	**79**	**21**	**80.106**	**19.894**
Cumulative %	**79**	**100**	**80.106**	**100**

Morphometric data indicated that *Liza ramada* wild populations are highly structured morphologically. Morphology though, is a record of not only the genetic difference, but also of the environmental conditions experienced during an individual lifetime.

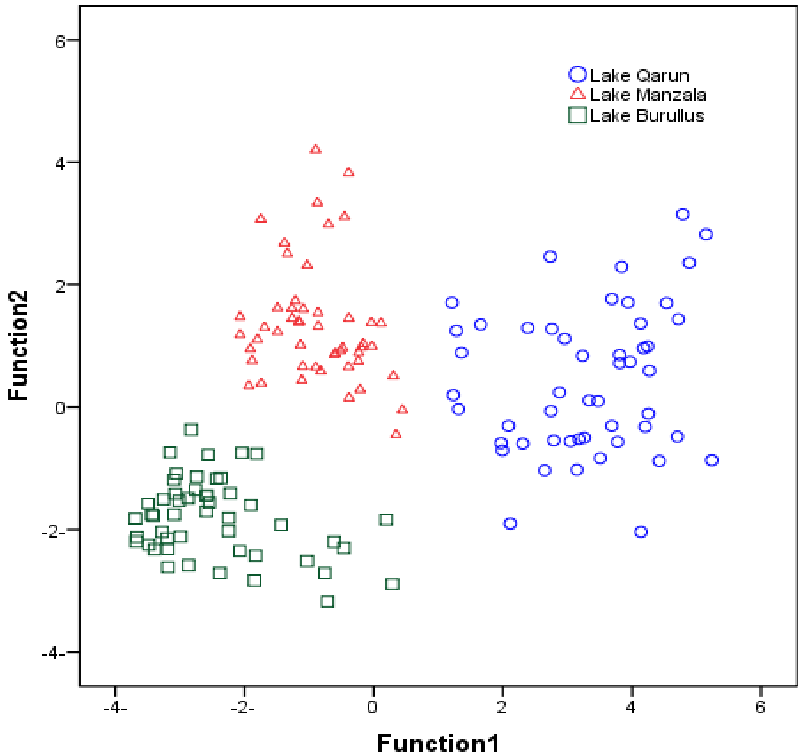

Fig. 4. Scatter plot of two discriminant functions of morphometric characters for *Liza ramada* collected from Qarun, Manzala and Burullus lakes in Egypt

The step-wise canonical discriminant analysis generated standardized canonical coefficients for the five morphometric variables that differentiate *Liza ramada* populations. The standardized canonical coefficients for the first function, which explained 80.11% of the total variance, were as follows: BW ratio (1.099), CPD ratio (1.475), PecFL ratio (1.161), MBH ratio (-1.176), and CF ratio (-0.983). These coefficients were then used as an index to classify specimens from the three *Liza ramada* populations **(Hotos, 2019)**.

***Score1* = 1.099 (*BW*) +1.475 (CPD) + 1.161 (PecFL) -1.176 (MBH) -0.983 (CF)**.

Table 6. Standardized scores for the first standardized canonical discriminant function for *Liza ramada* collected from Qarun, Manzala and Burullus lakes in Egypt

Population	Lake Qarun		Lake Manzala		Lake Burullus	
	A	B	A	B	A	B
Standardized score	2.790	3.235	-1.114	-0.391	-2.824	-2.221
	1.213	3.475	-0.452	-0.381	-3.185	-3.183
	3.508	2.878	0.446	-2.070	0.194	-3.071
	1.234	5.236	-1.742	-1.908	-1.032	-2.041
	1.992	3.147	-1.029	-2.071	-3.090	-0.756
	4.242	5.145	0.303	-1.099	-2.561	-1.434
	2.649	4.133	-1.748	-1.157	-1.828	-2.543
	3.810	4.253	-1.799	-0.590	-3.688	-2.760
	3.686	1.359	-0.027	0.344	-3.663	-3.091
	1.972	3.686	-0.513	-1.335	-1.845	-0.714
	4.177	2.088	-0.210	-0.478	-0.612	-3.673
	2.955	3.263	-1.134	-0.818	-3.393	-2.367
	3.336	4.534	-0.872	-0.606	-3.275	-3.149
	3.048	3.179	-1.154	-0.861	-3.410	-3.479
	4.421	4.784	-1.881	-1.265	-1.903	-2.589
	1.656	2.744	-1.489	-1.932	-2.866	-3.009
	1.280	4.202	-0.898	-1.382	-3.255	-2.874
	3.808	3.970	-1.089	-1.214	-0.463	-2.432
	2.385	3.776	-0.391	-1.490	-2.381	-1.809
	3.839	2.734	-0.035	-0.239	-2.073	-2.246
	4.718	4.702	-0.901	-0.161	-2.245	-2.591
	2.759	4.269	-0.864	-0.233	-3.492	-3.054
	4.139	1.312	-1.260	-0.697	0.289	-3.194
	2.310	2.114	-0.190	-1.688	-2.576	-2.991
	3.937	4.886	-0.386	0.116	-2.738	-3.435
Means	**3.299**^{a}		**-0.881**^{b}		**-2.452**^{c}	

A: Sample numbers from 1 to 25 and B: Sample numbers from 26 to 50. Means within the same row bearing different superscript differ significantly ($P < 0.05$).

According to *score1* of *Liza ramada*, specimens were distributed in a histogram according to population (Fig. 5) based on the discriminant index, using only morphometric characters. Generally, Qarun Lake population scored positively (> zero) while most other populations scored negatively (< zero), suggesting the separation of two groups (Table 8). The model was successful in discriminating *Liza ramada* population of Qarun Lake from other populations (Fig. 5). *Liza ramada* specimens were correctly classified to location of origin (Table 8).

Using the developed formula, the classification rate was at its highest for Qarun Lake's population (100%). Jacknife classification of *Liza ramada* populations was based on the first discriminant function scores: positive scores (more than zero) for Qarun Lake's population and negative scores (less than zero) for Manzala and Burullus lakes' populations (**Yulianto *et al*., 2020)**.

Score2 = 1.710 (BW) +1.280 (*PecFL*) -1.257 (D2).

Table 7. Standardized scores for the second standardized canonical discriminant function for *Liza ramada* collected from Qarun, Manzala and Burullus lakes in Egypt

Population	Lake Qarun		Lake Manzala		Lake Burullus	
	A	B	A	B	A	B
Standardized score	-0.544	0.839	0.439	3.828	-0.366	-1.405
	1.709	0.099	3.112	0.152	-2.318	-2.615
	-0.834	0.241	-0.049	1.474	-1.837	-1.413
	0.198	-0.867	0.388	0.950	-2.511	-0.747
	-0.706	-1.021	2.319	1.182	-1.754	-2.708
	0.991	2.825	0.510	0.664	-0.775	-1.924
	-1.031	1.367	3.074	1.400	-2.423	-1.556
	0.719	-0.106	1.106	0.877	-1.819	-1.352
	-0.306	0.889	0.989	-0.448	-2.121	-1.184
	-0.585	1.767	0.921	2.511	-2.831	-3.175
	0.963	-0.306	0.287	0.967	-2.198	-2.191
	1.118	-0.498	1.017	0.588	-2.320	-1.156
	0.111	1.701	3.341	0.857	-2.038	-0.739
	-0.557	-0.521	1.387	1.321	-1.775	-2.245
	-0.878	3.151	0.762	1.615	-1.599	-1.704
	1.349	-0.063	1.233	0.346	-2.580	-1.531
	1.248	-0.319	0.655	2.686	-1.505	-1.486
	0.855	0.738	1.601	1.735	-2.299	-1.168
	1.294	-0.567	0.656	1.622	-2.708	-0.759
	2.295	2.462	1.377	0.752	-2.347	-2.023
	1.437	-0.481	4.206	1.037	-1.808	-1.451
	1.278	0.596	1.543	0.891	-1.576	-1.085
	-2.037	-0.032	1.451	2.990	-2.888	-2.144
	-0.593	-1.900	0.977	1.303	-1.438	-2.112
	1.712	2.360	1.451	1.371	-1.136	-1.752
Means	**0.431^{b}**		**1.348^{a}**		**-1.811^{c}**	

A: Sample numbers from 1 to 25 and B: Sample numbers from 26 to 50. Means within the same row bearing different superscript differ significantly ($P < 0.05$).

Table 8. Jacknife classification matrix (numbers of specimens within population) based on the first discriminant function scores calculated from measurements of *Liza ramada* in Qarun, Manzala and Burullus lakes' specimens

Number of specimens within populations			
Score	**Lake Qarun**	**Lake Manzala**	**Lake Burullus**
(>3)	**31**	0	0
(2.5 3)	**7**	0	0
(2 2.5)	**4**	0	0
(1.5 2)	**3**	0	0
(1 1.5)	**5**	0	0
(0.5 1)	0	0	0
(0 0.5)	0	4	2
(-0.5 0)	0	13	1
(-1 -0.5)	0	10	3
(-1.5 -1)	0	14	2
(-2 -1.5)	0	7	4
(-2.5 -2)	0	2	8
(-3 -2.5)	0	0	11
(-3 >)	0	0	19

Jacknife edge = Zero score.

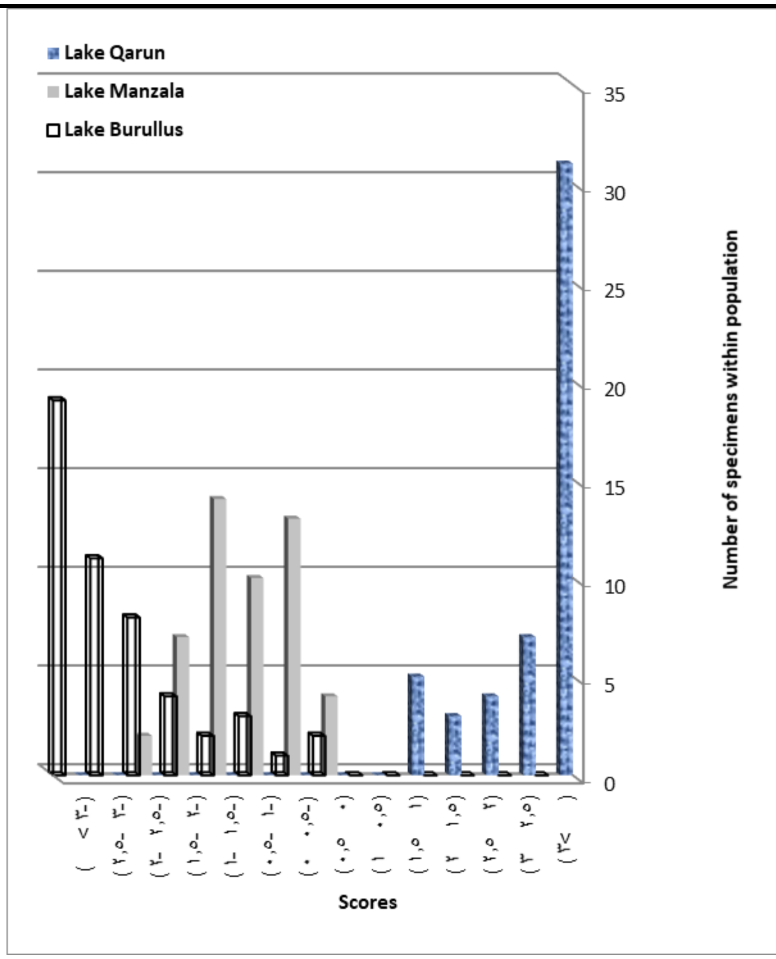

Fig. 5. Classification histogram for *Liza ramada* in Qarun, Manzala and Burullus lakes' populations according to the first discriminant scores

According to *score2* from the second function, the scores of *Liza ramada* specimens were distributed in a histogram according to population (Fig. 6) based on the discriminant index, using only morphometric characters. Generally, Burullus population scored negatively (< zero) while, most other populations scored positively (> zero), suggesting the separation of two groups (Table 9). The model was successful in discriminating *Liza ramada* from Burullus Lake's population and *Liza ramada* from Qarun and Manzala lakes' populations (Fig. 6). *Liza ramada* specimens were correctly classified to location of origin. Using the developed formula, the classification rate was the highest for Burullus Lake's population (100%) (Table 9). Jacknife classification of *Liza ramada* populations was based on the second discriminant function scores: positive scores (more than zero) for Qarun and Manzala lakes populations and negative scores (less than zero) for Burullus Lake's population (**Yulianto *et al.*, 2020)**.

Table 9. Jacknife classification matrix (numbers of specimens within population) based on the second discriminant function scores calculated from measurements of *Liza ramada* in Qarun, Manzala and Burullus lakes' specimens

Number of specimens within populations			
Score	**Lake Qarun**	**Lake Manzala**	**Lake Burullus**
(>3)	1	5	0
(2.5 - 3)	1	3	0
(2 - 2.5)	3	1	0
(1.5 - 2)	4	5	0
(1 - 1.5)	7	14	0
(0.5 - 1)	8	15	0
(0 - 0.5)	4	5	0
(-0.5 - 0)	8	2	**1**
(-1 - -0.5)	10	0	**4**
(-1.5 - -1)	2	0	**11**
(-2 - -1.5)	1	0	**13**
(-2.5 - -2)	1	0	**13**
(-3 - -2.5)	0	0	**7**
(-3 >)	0	0	**1**

Jacknife edge = Zero score.

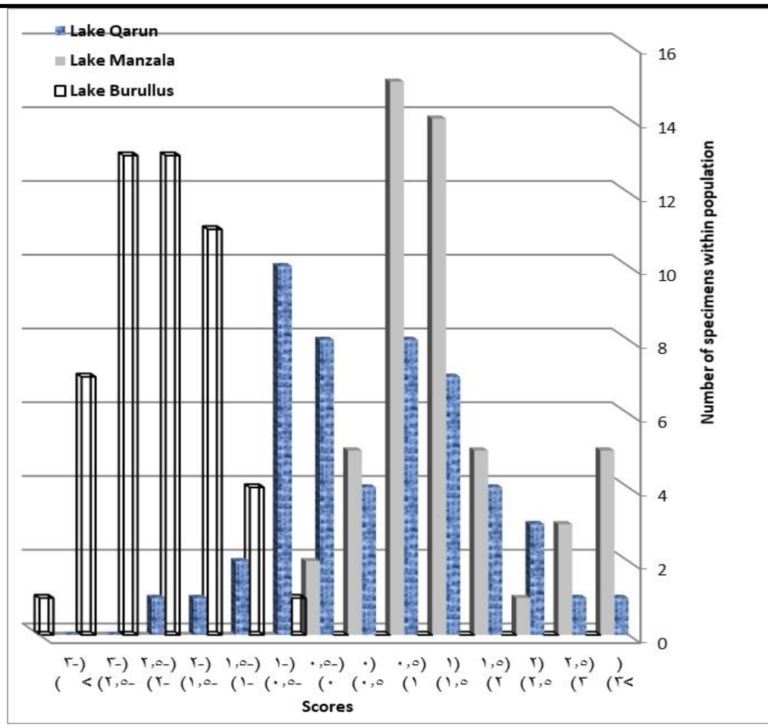

Fig. 6. Classification histogram for *Liza ramada* in Qarun, Manzala and Burullus lakes' populations according to the second discriminant scores

CONCULSION

It may be concluded that morphometric data acquired using PCA and DFA techniques revealed considerable difference between the morphotypes of the thinlip mullet population. The morphometric trait variation will help understand the genetic diversity of the *L. ramada* genotypes and can help initiate the program for the preservation of the thinlip mullet genetic resources.

ACKNOWLEDGEMENT

This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia (KFU241754).

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