Turkish Journal of Fisheries and Aquatic Sciences 11: 315-321 (2011)

www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/trjfas.2011.0216

Systematic Status of Nine Mullet Species (Mugilidae) in the Mediterranean Sea

Cemal Turan[1,]*, Mevlüt Gürlek[1], Deniz Ergüden[1], Deniz Yağlıoğlu[1], Bayram Öztürk[2]

[1] Mustafa Kemal University, Faculty of Fisheries, TR-31200, Iskenderun-Hatay, Turkey.
[2] Istanbul University, Faculty of Fisheries, 34320, Avcilar, Istanbul, Turkey.

* Corresponding Author: Tel.: +90.326 6141877; Fax: +90.326 6141693;
E-mail: cturan@mku.edu.tr

Received 25 August 2009
Accepted 05 January 2011

Abstract

Systematic relationships among four genera and nine species (*Mugil cephalus* Linnaeus, 1758, *Mugil soiuy* Basilewsky, 1855, *Liza ramada* (Risso, 1827), *Liza aurata* (Risso, 1810), *Liza abu* (Heckel, 1843), *Liza saliens* (Risso, 1810), *Liza carinata* (Valenciennes, 1836), *Chelon labrosus* (Risso, 1827), *Oedalechilus labeo* (Cuvier, 1829)) of the Mugilidae family living in the Mediterranean Sea were investigated using morphological characters. Moreover the systematic relationship of *M. soiuy* and *L. abu* among other mullet species was investigated in the present study for the first time. Hierarchical cluster analyses of morphometric data were not concordant with the meristic data. Meristic characters in the present study were more discriminative than morphometric characters in terms of taxonomic classification of the mullets. According to meristic data in UPGMA tree, all nine species were grouped in two main branching. In the first branch, *C. labrosus* and *O. labeo* were clustered as closest taxa, and being the sister group to the *L. aurata*. The other four *Liza* species produced two sub-branching in this group; *L. carinata* was branched with *L. saliens*, which is neighbour to *L. ramada*. In the second branch two species, *M. soiuy* and *L. abu* were clustered together and highly isolated from others. *M cephalus* was clustered as a most differentiated species from all other *Mugil* species.

Keywords: Mugilidae, morphology, morphological characters, truss network system.

Akdenizde Bulunan Dokuz Barbun Türünün (Mugilidae) Sistematik Durumu

Özet

Akdeniz'de yaşayan Mugilidae familyasına ait dört cins ve dokuz kefal türü (*Mugil cephalus* Linnaeus, 1758, *Mugil soiuy* Basilewsky, 1855, *Liza ramada* (Risso, 1827), *Liza aurata* (Risso, 1810), *Liza abu* (Heckel, 1843), *Liza saliens* (Risso, 1810), *Liza carinata* (Valenciennes, 1836), *Chelon labrosus* (Risso, 1827), *Oedalechilus labeo* (Cuvier, 1829)) arasındaki sistematik ilişki morfolojik karakterler kullanarak incelenmiştir. Bu çalışmada ayrıca ilk olarak kefal türleri içerisinde *M. soiuy* ve *L. abu*'nun sistematik durumu birlikte incelenmiştir. Morfometrik verilere dayalı hiyerarşi küme analizi meristik verilerle aynı bulunmadı. Kefal türlerinin taksonomik sınıflandırılmasında meristik karakterler morfometrik karakterlere göre türleri daha ayırt edici özellikteydi. UPGM ağacına göre tüm türler iki ana branş altında toplandı. İlk branşta, *C. labrosus* ve *O. labeo* birlikte en yakın taksa olarak sınıflandırıldı ve *L. aurata*'da bu iki türe yakın en ilişki içerisinde sınıflandırıldı. Diğer dört *Liza* türü iki alt branş olarak bu grupta sınıflandırıldı; ilk branşta *L. carinat* ve *L. saliens* birbirine en yakın türler ve bunlara yakın olan *L. ramada* ile sınıflandırıldı, ikinci branşta iki tatlı su orijinli tür olan *L. abu* ve *M. soiuy* birlikte diğer türlerden çok farklı bir şekilde sınıflandırıldı. *M. cephalus* ise tüm türlerden çok farklı olarak sınıflandırıldı.

Anahtar Kelimeler: Mugilidae, morfoloji, morfolojik karakterler, hiyerarşi küme analizi.

Introduction

Mullets have worldwide distribution and inhabit tropical and temperate seas; a few spend their lives in freshwater (Nelsonv, 2006). The Mugilidae family includes 17 genera and 72 species in the world (Harrison and Senou, 1999; Nelson, 2006). Eight species of Mugilidae inhabit the Mediterranean Sea, and originally classified as part of the single genus *Mugil*, under different names (*M. cephalus, M. ramada, M. labrosus, M. labeo, M. aurata, M. abu, M. saliens, M. carinata*). Lately, the systematic relationships of these species were revised and subdivided into four genera, *Mugil*, *Liza*, *Chelon, Oedalechilus.* After revision, the species names have been changed as *Mugil cephalus*, *Liza ramada*,

© Published by Central Fisheries Research Institute (CFRI) Trabzon, Turkey
in cooperation with Japan International Cooperation Agency (JICA), Japan

Chelon labrosus, Oedalechilus labeo, Liza aurata, Liza abu, Liza saliens, Liza carinata, occurring along the Mediterranean Sea (Nelson, 2006) and one species, *Mugil capurii,* found at the Atlantic coast of Morocco and southward to Senegal (Nelson, 2006). *Mugil soiuy* has also recently been found in the Black Sea (Unsal, 1992). This is native to the Amur River estuary and brackish waters of the Sea of Japan (Zaitsev, 1991). *Mugil soiuy* was introduced into the Azov Sea during the early 1980s by Soviet scientists (Zaitsev, 1991). This species started to reproduce in the Sea of Azov and was reported to be very numerous along the South Crimean coast and was caught for the first time along the eastern Turkish Black Sea coast (Unsal, 1992). At the present *Mugil soiuy* are commonly fished in the Black Sea and rarely found in the Aegean Sea (Kaya *et al.,* 1998; Golani *et al.,* 2002). *L. abu* inhabit Asia: Irak and Pakistan and is reported from the Tigris, Europhrates and recently Orontes (connected to Mediterranean Sea) (Turan *et al.,* 2004) river systems in Turkey. The geographic distribution of *O. labeo* is restricted to the Mediterranean Sea. *C. Labrosus* and *L. carinata* inhabit the Mediterranean, the Eastern Atlantic coast and Indo-Pacific areas (Tortonese, 1975). *L. ramada* is found Mediterranean and the Black Sea (Ben-Tuvia, 1986) and *L. saliens* inhabit Eastern Atlantic, Mediterranean Sea, Black Sea, Sea of Azov and Atlantic coasts from Morocco to France, Caspian Sea (Baltz, 1991). *M. cephalus* is the only worldwide species occurring on several continental waters (Crosetti *et al*., 1994).

To date limited number of studies on morphologic between species and genera in the Mugilidae family in the Mediterranean Sea has been found (Schultz, 1946; Corti and Crosetti, 1996; Trewavas and Ingham, 1972; Harrison and Howes, 1991; Stiassny, 1993; Turan *et al*., 2000). Turan *et al.* (2000) investigated four species (*Mugil cephalus, Chelon labrosus, Liza aurata, Liza ramada*) of the Mugilidae family with morphologic data. On the other hand, it appears that there is lack of systematic studies comprising all the species using morphometric and meristic data together in the Mediterranean Sea. Also the systematic position of *M. soiu*y and *L. abu* among other mullet species was investigated in the present study for the first time.

The aim of this study is to contribute to the understanding of the systematic relationship of the Mediterranean grey mullet species using morphometric and meristic characters.

Material and Methods

Laboratory Procedures

Individual samples from each species were collected from Iskenderun Bay in North-eastern Mediterranean Sea and Trabzon Seaport in the Black Sea. Certain biological aspects of the samples are given in Table 1**.**

Morphometric

The truss network system described for fish body morphometrics (Strauss and Bookstein, 1982) was used to construct a network on mullet's body. Thirteen landmarks determining 24 distances were chosen and measured on the body, as illustrated in Figure 1. Fish were thawed, placed on their right side on acetate sheets, and body posture and fins were teased into a natural position. Each landmark was obtained by piercing the acetate sheet with a dissecting needle, and additional data such as eye diameter (ED), head width (HW), pectoral fin length (PFL) were also recorded with digital calliper. Only undamaged fish were included in the analyses. There were no significant correlation ($P>0.05$) between the standardized truss measurements and standard length, indicating that the size effect was successfully removed with the allometric transformation (Somers, 1986).

Meristic

Five meristic characters commonly used to describe mullets were examined using the number of: first dorsal fin rays (DFR1), second dorsal fin rays (DFR2), ventral fin rays (VFR), anal fin rays (AFR), pectoral fin rays (PFR), pyloric caeca (PC) under a binocular microscope.

Table 1. Location and biological features of mullet species. Standard deviations of mean stanfad length (STL) of samples are given brackets

Species	Locations	Collection Time	Gear	Sample size	Mean STL (cm) (± SD) (Min-Max)
Chelon labrosus	36°02' N 35°57' E	07.06.2007	Gill Net	25	13.75±3.03 (9.6-19.2)
Oedalechilus labeo	36°05' N 35°55' E	21.05.2007	Gill Net	25	21.50±2.24 (17.7-27.7)
Mugil cephalus	36°22' N 35°50' E	15.05.2007	Gill Net	25	15.70±0.90 (14.1-17.2)
Mugil soiuy	41°01' N 39°35' E	14.07.2007	Gill Net	10	39.33±1.51 (37.0-41.2)
Liza aurata	36°25' N 35°53' E	04.06.2007	Gill Net	25	14.03±3.05 (9.8-18.0)
Liza abu	36°04' N 36°01' E	16.07.2007	Gill Net	25	13.67±1.99 (11.5-17.0)
Liza carinata	36°36' N 35°30' E	24.11.2007	Gill Net	25	11.59±0.82 (10.1-13.2)
Liza ramada	36°49' N 36°09' E	09.07.2007	Gill Net	25	13.20±0.82 (12.0-14.7)
Liza saliens	36°45' N 36°10' E	14.07.2007	Gill Net	25	22.28±5.39 (15.4-29.7)

Multivariate Analyses

Morphometric and meristic characters were used separately in the multivariate analyses, though these variables are different both statistically and biologically (Allendorf *et al.,* 1987; Ihssen *et al.,* 1981). Body measurements strongly correlate with body size, while in most fish meristic characters do not change during growth beyond some threshold body size (Strauss, 1985). Therefore allometric growth can result in heterogeneity of shape without providing information on differences in body proportion among populations (Reist, 1985). In the present study, there were significant correlations in size only for morphometric characters between the samples. Therefore transformation of absolute measurements to size–independent shape variables was accomplished by using the formula by Elliott *et al.* (1995);

$$M_{adj} = M\,(L_s / L_o)^b$$

where M: original measurement, M_{adj}: size adjusted measurement, L_o: standard length of fish, L_s: overall mean of standard length for all fish from all samples in each analysis. Parameter b was estimated for each character from the observed data as the slope of the regression of logM on $\log L_o$, using all fish in all groups. Correlation coefficients between transformed variables and standard length were calculated to check if the data transformation was effective in removing the effect of size in the data. The effectiveness of size transformations was evaluated by testing the significance of correlation between transformed variables and standard length. A significant correlation indicated an incomplete removal of size effects from the data. Size adjusted data were standardized and submitted to a canonical discriminant function analysis (DFA), and discriminant function (DF) scores were used in hierarchical cluster analyses using SPSS*v*13.0 statistical package program. The DFA combines a selection of body measures in a linear fashion to produce a mathematical function, which can be used to classify individuals into groups. In hierarchical cluster analyses, UPGMA dendogram based on Squared Euclidean distance was constructed to monitor taxonomic relationships among the species that does not plot actual distances but rescales the distance to numbers between 0 and 25.

Results

Morphometric

Univariate statistics (ANOVA) revealed highly significant ($P<0.001$) differences between species from all truss measurements. The canonical discriminant function analysis produced 8 functions (DFs). The first DF explained 49% and second and third DFs explained 20% and 12% of between-group variability respectively. The overall random assignment of individuals into their original group by the DFA was 100%. In order to illustrate which morphometric characters are playing role to differentiate species contribution of each variable to the canonical functions were examined, and high contribution from measurements 2_3, 3_12, 1_2, PFL, HW, ED were observed (Table 2).

The UPGMA cluster analysis of morphometric data did not cluster species on the bases of current meristic status of Mugilidae (Figure 2). Three main branching were produced: in the first branch, *C. labrosus* was clustered as a closest taxa to *L. ramada*, being the sister group to *O. labeo*, and *L. aurata* and *M. cephalus* were branched more divergently from these three species. In the second group, *L. carinata* was clustered together with *L. abu*, being sister to *M. soiuy*. *L. saliens* seen to be morphometrically most divergent from the other species and was branched as a third group.

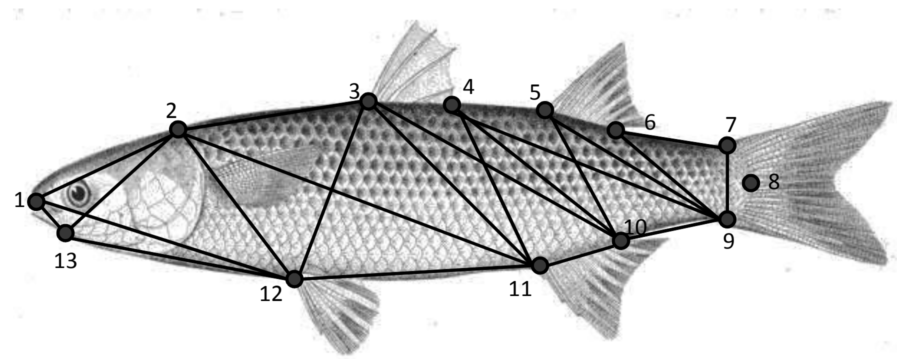

Figure 1. Locations of the 13 landmarks for constructing the truss network on fish (●) and morphometric lengths between dots. Landmarks refer to (1) anterior tip of snout at upper jaw, (2) most posterior aspect of neurocranium (beginning of scaled nape), (3) origin of dorsal fin, (4) insertion of dorsal fin, (5) origin of 2nd dorsal fin, (6) insertion of 2nd dorsal fin, (7) anterior attachment of dorsal membrane from caudal fin, (8) posterior end of vertebrae column, (9) anterior attachment of ventral membrane from caudal fin, (10) insertion of anal fin, (11) origin of anal fin, (12) insertion of pelvic fin, (13) posteriomost point of maxillary. Picture modified from Bauchot (1987).

Meristic

Observed meristic characters of nine mullet species (Table 3) were in the range of their description given by Nelson (2006). Highly significant (P<0.001) differences between species were observed from all meristic characters. Dorsal (DFR1) and ventral fin rays (VFR) were constant in each group and could not be computed in the Univariate analysis.

Table 2. Contribution of morphometric and meristic variables to the canonical functions. Variables ordered by size of correlation within the functions *, indicate largest correlation between each variable and any discriminant function

	Function							
Morphometric	1	2	3	4	5	6	7	8
2_3	-0.065	0.416*	-0.126	0.076	-0.029	-0.051	0.097	0.022
3_12	-0.232	-0.345*	0.137	0.258	0.129	-0.225	-0.068	0.128
1_2	-0.125	-0.213*	0.129	0.095	-0.076	0.056	0.163	0.196
PFL	0.008	0.177	0.438*	0.233	-0.026	-0.028	0.056	-0.070
ED	-0.202	0.076	0.422*	0.302	-0.369	0.142	0.006	-0.030
HW	-0.015	-0.234	0.268*	-0.134	-0.149	-0.019	0.121	0.031
6_9	-0.163	0.008	-0.079	0.476*	-0.023	0.323	0.080	-0.058
7_9	-0.028	-0.213	-0.297	0.372*	0.060	0.186	0.133	-0.247
5_9	-0.146	-0.005	-0.107	0.313*	-0.134	0.280	-0.144	-0.084
1_12	0.026	0.062	-0.064	0.251*	0.014	-0.002	0.212	0.227
12_13	0.042	0.019	-0.178	0.225*	0.068	-0.107	0.137	0.005
10_11	-0.163	0.118	0.055	-0.221*	-0.035	0.197	0.051	-0.179
6_7	-0.026	0.025	-0.041	0.211*	0.183	0.105	0.046	-0.111
2_12	0.047	0.083	-0.018	0.196*	0.176	0.011	0.152	0.014
2_11	0.078	0.131	-0.071	0.189*	-0.131	-0.110	-0.044	0.104
3_4	0.055	-0.311	-0.097	0.152	0.492*	0.058	-0.188	0.040
4_10	0.073	-0.034	0.003	0.068	-0.402*	0.251	0.068	0.203
4_11	0.026	-0.181	0.071	0.168	-0.308*	0.241	-0.149	0.129
3_10	0.105	-0.159	0.032	0.169	-0.285*	0.020	-0.053	0.024
4_9	0.064	0.018	-0.022	0.151	-0.285*	0.181	-0.050	0.216
1_13	-0.064	0.018	0.198	0.011	-0.128	0.462*	0.299	-0.048
5_10	-0.195	-0.146	-0.075	0.139	-0.332	0.343*	-0.051	-0.072
3_11	0.126	-0.230	0.035	0.262	-0.103	0.160	-0.352*	0.273
2_13	-0.072	-0.116	0.122	-0.064	0.017	-0.100	0.240*	0.035
4_5	0.172	-0.017	0.088	-0.036	-0.298	0.197	0.097	0.309*
11_12	-0.061	-0.029	-0.093	0.174	-0.104	0.002	-0.174	0.277*
9_10	-0.051	0.046	-0.052	0.174	0.170	0.173	-0.203	0.238*
Meristic								
PFR	0.950*	-0.177	0.100	-0.239				
PC	0.228	0.833*	0.381	-0.330				
DFR2	0.021	-0.273	0.896*	-0.349				
AFR	0.087	-0.042	0.570	0.816*				

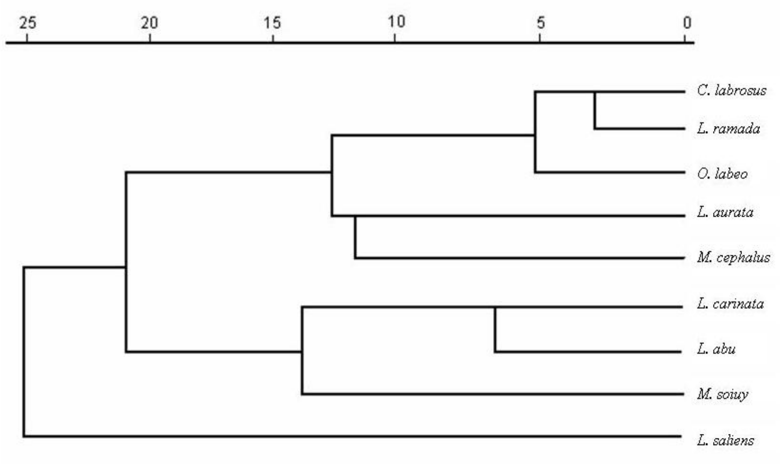

Figure 2. UPGMA tree of Squared Euclidiean distances based on morphometric data.

Table 3. Observed meristic counts of the nine mullet species.

Species	DFR 1	DFR 2	VFR	AFR	PFR	PC
Chelon labrosus	IV	I 8	I 5	III 8-9	17	6-7
Oedalechilus labeo	IV	I 8	I 5	III 8-10	16-17	6
Mugil cephalus	IV	I 8	I 5	III 8-9	17	2
Mugil soiuy	IV	I 8-9	I 5	III 8-9	16	4-5
Liza aurata	IV	I 8	I 5	III 8-9	16	7-8
Liza abu	IV	I 7-8	I 5	III 8	11-12	3-5
Liza carinata	IV	I 7	I 5	III 7	15	5
Liza ramada	IV	I 7-8	I 5	III 8-9	16-17	6-8
Liza saliens	IV	I 7	I 5	III 7-8	16	7-9

The first discriminant function explained 63% of between group variability and the second, third and fourth explained 29%, 6%, 2% respectively. Component loadings showed that PFR, PC, DFR2, AFR characters are playing key role to differentiate species respectively (Table 2).

Hierarchical cluster analyses of meristic data clustered *O. labeo* and *C. labrosus* as a closest taxa being the sister group to *L. aurata.* The neighbouring branch is made up of *L. carinata, L. saliens* and *L. ramada*. *M. cephalus* was most divergently clustered in the dendogram and close to its sister species *M. soiuy* and *L. abu* (Figure 3).

Discussion

Taxonomic description of fishes has commonly relied on the description of unique sets of morphological characters. Meristic characters in the present study were rather more discriminative than morphometric characters in terms of taxonomic classification of the mullets. Segmented rays in the dorsal (DFR2) and anal fins and pectoral fins, and also pyloric caeca were most discriminative characters in the present classification of mullets. Such characters are phylogenetically informative to distinguish between species of the Mugilidae.

The present meristic analysis within the family Mugilidae did not reveal similar pattern of morphologic results among the species. On the other hand, morphometric data were not congruent with meristic data. Based on meristic data UPGMA tree splited *Liza* and *Mugil* genera species into two main clusters. In the first group, *M. cephalus* was clustered with its sister species *M. soiuy*, supporting monophyletic status of *Mugil* genera. The results revealed that *M. cephalus* was morphologically more divergent than *M. soiuy* from the other Mediterranean taxa. On the other hand, *L. abu* is grouped within the *Liza* genera and sister group into three *Liza* species (*L. ramada*, *L. saliens*, *L. carinata*). However *O. labeo* and *C. labrosus* species was clustered together and included within the *Liza* genera. Similar controversy was also reported in connection with chromosome analysis by Cataudella *et al*. (1974) who did not find significant differences in the karyotype of *C. labrosus* compared to the three Mediterranean species of the *Liza* genus. Several studies have also questioned the present systematic status of the Mugilidae. Turan *et al.* (2000) analyzed by using Truss network system and 10 meristic characters of four grey mullets and all mullet species (*M. cephalus, C. labrosus, L. aurata, L. ramada*) were clearly different from each other. Antovic and Simonovic (2006) investigated interspecific variability and phenetic relationships in six southern Adriatic mullet species (*M. cephalus*, *C. labrosus*, *L. aurata, L. ramada*, *L. saliens* and *O. labeo*), and as a result *M. cephalus* was clearly separated from the other species and the species of the genus *Liza* were phenetically most similar.

Caldara *et al.* (1996) compared DNA sequences of mitochondrial cytochrome b and 12S rRNA genes for six mullets species and observed lowest genetic distance between *C. labrosus* and *L. saliens*. Papasotiropoulos *et al.* (2002) investigated phylogenetic relationship of five mullet species (*M. cephalus*, *C. labrosus*, *L. aurata*, *L. ramada* and *L. saliens*) with PCR-RFLP of mtDNA gene segments and found that *L. saliens* and *C. labrosus* were the closely related species while *M. cephalus* was the most distinct one. A similar result reported by Rossi *et al.* (2004) using allozyme data and 16s mt-rRNA, reffered to *M. cephalus* as being the most divergent species and the existence of a main cluster including all the Mediterranean species of *Liza* and *C. labrosus.* Also, Rossi *et al.* (2004) indicated that the Mediterranean species of *Liza* did not form a monophyletic group exclusive of *Chelon* and thus, the monophyly of the whole genus should be reconsidered.

In addition to several previous studies (Harrison and Howes, 1991; Caldara *et al*., 1996; Murgia *et al*., 2002; Gornung *et al*., 2001, 2004), and this study is consistent in not identifying the Mediterranean Liza species as a monophyletic group. This is in agreement with our previous studies based on allozyme data (Turan *et al*., 2005). Morever, Turan *et al.* (2005) reported that *C. labrosus* and *O. labeo* clustered as closest taxa and were sister group to *L. ramada. M. cephalus* and *M. soiuy*, clustered together and were clearly isolated from the other three genera. It is

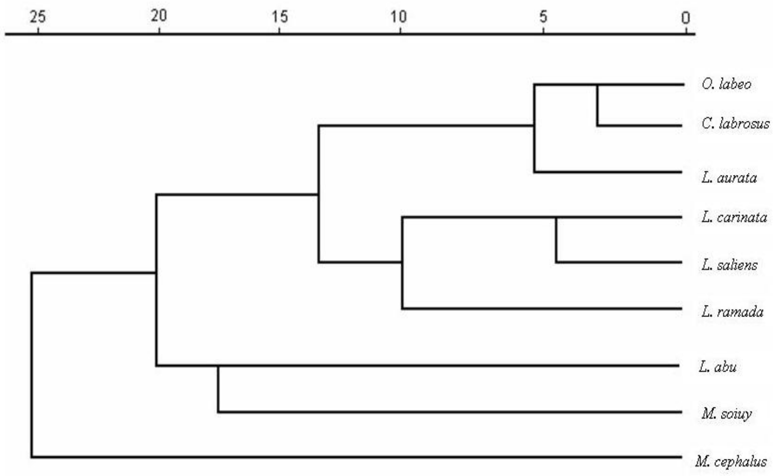

Figure 3. UPGMA tree of Squared Euclidiean distances based on meristic data.

reported in a recent phylogenetic study by Papasotiropoulos *et al.* (2007) using three (12s rRNA, 16s rRNA, and COI) mtDNA segments that the greatest genetic differentiation was observed between *M. cephalus* and all the other species studied, while *C. labrosus* and *L. aurata* were the closest taxa.

Our present study, indicated that *Liza* monophyly were not supported, allowing room for the plea to get more data to resolve the systematics of mullets. *M. cephalus* and *M. soiuy* supported monophyletic status of *Mugil* genera, which had higher morphologic compared to other Mediterranean taxa. However, *Chelon* and *Oedalechilus* genera species were clustered within the *Liza* genera. The separation of *Liza*, *Chelon* and *Oedalechilus* might be unnatural, and that the monophyletic origin of the genus *Liza* is questionable. However the existence of such differences in morphologic and phylogenetic studies of Mugilidae in the literatures is not uncommon (Cataudella *et al.*, 1974; Menezes *et al.*, 1992; Caldara *et al.*, 1996; Rossi *et al.*, 1998; Fraga *et al.*, 2007). Therefore, more studies are needed to integrate not only more species but also different genetic data (mtDNA, nDNA vs.).

In conclusion, we did not detect any appreciable degree of morphologic differentiation between *Liza, Chelon* and *Oedalechilus* species. This was strongly supported by our previous genetic study (Turan *et al.*, 2005) based on allozymic data. At the same time, other similar studies based on mtDNA and allozyme data (e.g., Caldara *et al.*, 1996; Rossi *et al.*, 2004; Papasotiropoulos *et al.*, 2007) seem to be in agreement with our current findings, leaving room for reconsidering the modern systematic classification of those species. The lack of congruence in the morphologic results of mullet species suggests us scrutinizing the present status of *Mugil* species with more comprehensive investigations using molecular genetic and morphologic markers together.

References

Allendorf, F.W., Ryman, N. and Utter, F. 1987. Genetics and Fishery Management. In: N. Ryman and F. Uttter (Eds.), Past, Present and Future in Population Genetic Fisheries Management, University of Washington Press, Seattle and London: 1-20.

Antovic, I. and Simonovic, P. 2006. Phenetic relationships of six species of mullets (Mugilidae) from the south Adriatic, as inferred from the study of the visceral and dermal skeleton. Russian Journal of Marine Biology, 32: 250-254. doi:10.1134/S1063074006040080.

Baltz, D.M. 1991. Introduced fishes in marine systems and inland seas. Biological Conservation, 56: 151-177. doi:10.1016/0006-3207(91)90015-2.

Bauchot, M.L. 1987. Poissons osseux. In: W. Fischer, M.L. Bauchot and M. Schneider (Eds.), Fiches FAO d'identification pour les besoins de la pêche. (rev.1). Méditerranée et mer Noire. Zone de pêche 37. Commission des Communautés Européennes and FAO, Rome: 891-1421.

Ben-Tuvia, A. 1986. Mugilidae. In: P.J.P. Whitehead, M.L. Bauchot, J.C. Hureau, J. Nielsen and E. Tortonese (Eds.), Fishes of the North-eastern Atlantic and Mediterranean, UNESCO, Paris: 1197-1204.

Caldara, F., Bargelloni, L., Ostellari, L., Penzo, E., Colombo, L. and Patarnello, T. 1996. Molecular phylogeny of grey mullets based on Mitochondrial DNA sequence analysis: Evidence of differential rate of evolution at the intra family level. Molecular Phylogenetics and Evolution, 6: 416-424. doi: 10.1006/mpev.1996.0090.

Cataudella, S., Civitelli, M.V. and Capanna, E. 1974. Chromosome complement of the Mediterranean mullets (Pisces, perciformes). Caryologia, 27: 93.

Corti, M. and Crosetti, D. 1996. Geographic variation in the grey mullet geometric morphometric analysis using partial warp scores. Journal of Fish Biology, 48: 255-269. doi: 10.1111/j.1095-8649.1996.tb01117.x.

Crosetti, D., Nelson, W.S. and Avice, J.C. 1994. Prononunced genetic structure of mitochondrial DNA among populations of the circum-globally distributed grey mullet (*Mugil cephalus* Linnaeus). Journal of Fish Biology, 44: 47-58. doi: 10.1111/j.1095-8649.

1994.tb01584.x.

Elliott, N.G., Haskard, K. and Koslow, J.A. 1995. Morphometric analysis of orange roughy (*Hoplostethus atlanticus*) off the continental slope of southern Australia. Journal of Fish Biology, 46: 202-220. doi: 10.1111/j.1095-8649.1995.tb05962.x.

Fraga, E., Schneider, H., Nirchio, M., Santa-Brigida, E., Rodrigues-Filho, L.F. and Sampaio, I. 2007. Molecular phylogenetic analyses of mullets (Mugilidae, Mugiliformes) based on two mitochondrial genes. Journal of Applied Ichthyology, 23: 598-604. doi: 10.1111/j.1439-0426.2007.00911.x.

Golani, D., Orsi-Relini, L., Massuti, E. and Quingnard, J.P. 2002. CIESM Atlas of Exotic Species in the Mediterranean. In: F. Briand (Ed.), Fishes, Volume 1, CIESM Publisher, Monaco: 256.

Gornung, E., Cordisco, C.A., Rossi, A.R., De Innocentiis, S., Crosetti, D. and Sola, L. 2001. Chromosomal evolution in mugilids: karyotype characterization of *Liza saliens* and comparative localization of major and minor ribosomal genes in the six Mediterranean grey mullets. Marine Biology, 139: 55-60. doi: 10.1007/s002270100576.

Gornung, E., Mannarelli, M.E., Rossi, A.R. and Sola, L. 2004. Chromosomal evolution in Mugilidae (Pisces, Mugiliformes): FISH mapping of the (TTAGGG)n telomeric repeat in the six Mediterranean mullets. Hereditas, 140: 158-159. doi: 10.1111/j.1601-5223.2004.01784.x.

Harrision, I.J. and Howes, G.J. 1991. The pharyngobranchial organ of mugilid fishes. Its structure, variability, ontogeny, possible function and taxonomic utility. Bulletin of the British Museum of Natural History, 57: 111-132. ISSN 0007-1498.

Harrison, I.J. and Senou, H. 1999. Order Mugiliformes. In: K.E. Carpenter and V.H. Niem (Eds.), The Living Marine Resources of the Western Central Pacific, FAO Species Identification Guide for Fisheries Purposes. FAO, Rome: 2069-2790. ISSN 1020-6868.

Ihssen, P.E., Booke, H.E., Casselman, J.M., Mcglade, J.M., Payne, N.R. and Utter, F.M. 1981. Stock Identification: Materials and Methods. Canadian Journal of Fisheries and Aquatic Sciences, 38: 1838-1855. doi: 10.1139/f81-230.

Kaya, M., Mater, S. and Korkut, A.Y. 1998. A new grey mullet species "*Mugil so-iuy* Basilewsky" (Teleostei. Mugilidae) from the Aegean Coast of Turkey. Turkish Journal Zoology, 22: 303-306.

Menezes, M.R., Martins, M. and Naik, S. 1992. Interspecific genetic divergence in grey mullets from the Goa region. Aquaculture, 105 (2): 117-129. doi:10.1016/0044-8486(92)90124-4.

Murgia, R., Tola, G., Archer, S.N., Vallerga, S. and Hirano, J. 2002. Genetic identification of grey mullet species (Mugilidae) by analysis of mitochondrial DNA sequence: Application to identify the origin of processed ovary products (Bottarga). Marine Biology, 4: 119-126. doi: 10.1007/s10126-001-0074-6.

Nelson, J.S. 2006. Fishes of the World, 4th Edition. John Wiley and Sons, Inc. Hoboken, New Jersey, USA, 601 pp.

Papasotiropoulos, V., Klossa-Kilia, E., Kilias, G. and Alahiotis, S. 2002. Genetic divergence and phylogenetic relationships in grey mullets (Teleostei: Mugilidae) based on PCR-RFLP analysis of mtDNA segments. Biochemical Genetics, 40 (3-4): 71-86. doi: 10.1023/A:1015162304934

Papasotiropoulos, V., Klossa-Kilia, E., Alahiotis, S.N. and Kilias, G. 2007. Molecular phylogeny of grey mullets (Teleostei: Mugilidae) in Greece: Evidence from sequence analysis of mtDNA segments. Biochemical Genetics, 45: 623-636. doi: 10.1007/s10528-007-9101-2.

Reist, J.D. 1985. An empirical evaluation of several univariate methods that adjust for size variation in morphometric variation. Canadian Journal of Zoology, 63: 1429-1439. doi: 10.1139/z86-203.

Rossi, A.R., Capula, M., Crosetti, D., Campton, D.E. and Sola, L. 1998. Genetic divergence and phylogenetic inferences in five species of Mugilidae (Pisces: Perciformes). Marine Biology, 131: 213. doi: 10.1007/s002270050313.

Rossi, A.R., Ungaro, A., De Innocentiis, S., Crosetti, D. and Sola, L. 2004. Phylogenetic analysis of Mediterranean mugilids by allozymes and 16S mt-rRNA genes investigation: are the Mediterranean species of Liza monophyletic? Biochemical Genetics, 42: 301-315. doi: 10.1023/B:BIGI.0000039806.12756.81.

Schultz, L.P. 1946. A revision of the genera of mullets, fishes of the family Mugilidae, with descriptions of three new genera. Proceedings of the United States National Museum, 96: 377-395.

Somers, K.M. 1986. Multivariate allometry and removal of size with Principal component analysis. Systematic Zoology, 35: 359-368. doi:10.2307/2413387.

Stiassny, M.L.J. 1993. What are grey mullets? Bulletin of Marine Science, 52: 197-219.

Strauss, R.E. and Bookstein, F.L. 1982. The truss. Body form reconstruction in morphometrics. Systematic Zoology, 31: 113-135. doi:10.2307/2413032.

Strauss, R.E. 1985. Evolutionary allometry and variation in body form in the South American catfish genus *Corydoras* (Callichthyidae). Systematic Zoology, 34: 381-396. doi:10.2307/2413203.

Tortonese, E. 1975. Fauna d' Italia: Osteichtyes (Pessi Ossei). Parte Seconda, Edizioni Calderini, Bologna: 11-26.

Trewavas, E. and Ingham, S.E. 1972. A key to the species of Mugilidae (Pisces) in the northeastern Atlantic and Mediterranean, with explanatory notes. Journal Zoology, 167: 15-29. doi: 10.1111/j.1469-7998.1972.tb01720.x.

Turan, C., Başusta, N. and Çekiç, M. 2000. Kuzeydoğu Akdeniz'de Bulunan Kefal Türlerinin (Mugilidae) Truss Sistemine Göre Sistematik Olarak İncelenmesi. I.Ulusal Deniz Bilimleri Konferansı, 30 Mayıs-2 Haziran 2000, ODTÜ., Ankara: 272-273.

Turan, C., Erguden, D., Gürlek, M. and Turan, F. 2004. Genetic and morphologic variations in *Liza abu* (Heckel, 1843) populations from the Orontes, Euphrates and Tigris Rivers. Turkish Journal of Veterinary and Animal Sciences, 28: 729-734.

Turan, C., Caliskan, M. and Kucuktas, H. 2005. Phylogenetic relationships of nine mullet species (Mugilidae) in the Mediterranean Sea. Hydrobiologia, 532: 45-51. doi: 10.1007/s10750-004-8772-5.

Unsal, S. 1992. A new mullet species in Turkish Seas, *Mugil so-iuy* Basilewsky. Turkish Journal of Veterinary and Animal Sciences, 16: 427-432.

Zaitsev, Y.P. 1991. Eutrophication in the Black Sea. Paper Presented at International Workshop on the Black Sea. Focus on the Western Black Sea Shelf. 30 September- 04 October 1995. Varna, Bulgaria.