ISSN: 0001-5113
AADRAY

ACTA ADRIAT.,
42 (2): 3-13, 2001

UDC: 597.5 (262.4)
Original scientific paper

Comparative body and otolith morphometrics of Mugilidae in Homa Lagoon (Izmir Bay, Aegean Sea)

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Every species otoliths and body forms have characteristic shape and features. Because of that otoliths and body morphometrics are widely used in the systematic researches of the Teleost fishes. In the Homa Lagoon (Izmir Bay), of 5 members of the family Mugilidae, otolith characteristics are valued by using the Discriminant Analysis and it is found that the greatest similarity is observed among Liza aurata, Liza ramada *and* Chelon labrosus. *The different groups are* Mugil cephalus and Liza saliens. *Body characteristics showed that* L. saliens, L. aurata *are similar while* C. labrosus *and* M. cephalus *are different. Although the otoliths and body morphometrics of the family* Mugilidae *are in general similar ones, it is possible to distinguish the species according to the special body and otolith morphologies.*

Key words: Mugilidae, otolith and body morphologies, Homa Lagoon, Izmir Bay, Aegean Sea

INTRODUCTION

Mugilidae, a catadromous family, live in large groups mostly on the coasts of tropical and subtropical seas. They are represented with approximately 13 genus and about 70 species in the world seas (McDOWAL,1988).

OREN (1975) and KIRK (1987) pointed out that there had been serious problems on the taxonomy of this family including a lot of species.

Although 7 species of grey mullet have been registered in the Aegean Sea, there is not enough amount of studies on their morphology and systematics.

AKKIRAN (1984) indicated that otolith of each species had a different form and characteristics, thus otoliths could commonly be used in systematical researches of Teleost fishes. HOPKINS (1986), CASTONGUAY *et al.* (1991), LOMBARTE and FORTUNO (1992) and RIEMAN *et al.* (1994) also used otolith characteristics of various Teleost fishes in order to obtaine correct classification. Since body morphology is an important character in the discrimination of species, it can be possible to reach certain results in discrimination of species by using these characteristics.

Considering this study, the aim was to describe comparatively with body and otolith morphologies the 5 members of Mugilidae, which is the most commercially important fish family of Homa Lagoon in the Bay of Izmir (Aegean Sea).

MATERIAL AND METHODS

The area of study is Homa Lagoon, which is 1824 hectare and lies 25 km northeast of Izmir (Fig. 1). The latitude: 38°31'10"N; the longitude: 26°49'50"E.

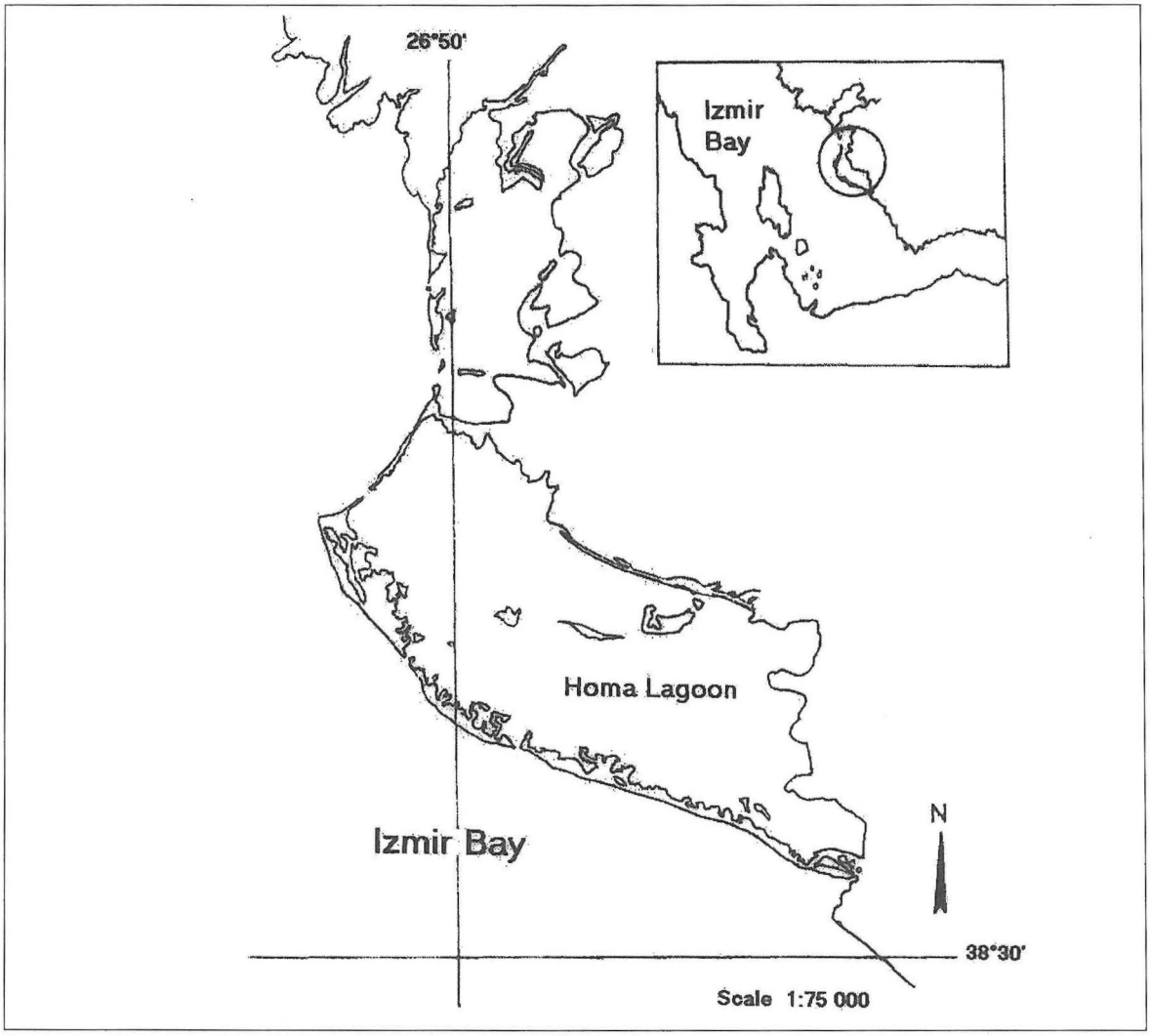

Fig. 1. The sampling area

During the sampling which was carried out monthly in 1998, reed-fence nets (barrier seines), trammel nets and traps were used.

The grey mullets used as material in this study, are *Mugil cephalus* (LINNAEUS,1758); *Liza saliens* (RISSO,1810); *Liza aurata* (RISSO, 1810); *Liza ramada* (RISSO,1826) and *Chelon labrosus* (RISSO,1826). Discrimination of the species was achieved with grey mullets' pyloric caecas and various keys (SLASTANENKO,1956; ERMAN,1961; FAO,1981; ZISMANN,1981; BEN-TUVIA,1986). Moreover, some of the mullets can be distinguished through their external morphological characteristics. For example, *M. cephalus* is easily distinguished from the others with its distinct adipose eyelids; *C. labrosus* with its thick upperlip; on the contrary *L. ramada* has a thin upperlip; and *L. saliens* differs from *L. aurata* by having 2 to 3 groovs (instead of 1) on the scales of the top of the head (THOMSON,1981; ZISMANN,1981).

While identifying the metric characteristics we used 1 mm length measurement tool, calipers and digital analytical balance nearest to 0.1 g. As a meristic character, we took first dorsal fin, second dorsal fin, ventral, anal and pectoral fin rays' numbers. As a metric character, on the other hand, fork length (*FL*), predorsal (*PD*), head length (*HL*), body height (*BH*), interorbital (*IO*), preorbital (*PO*) and eye diameter (*ED*) were measured (Fig. 2).

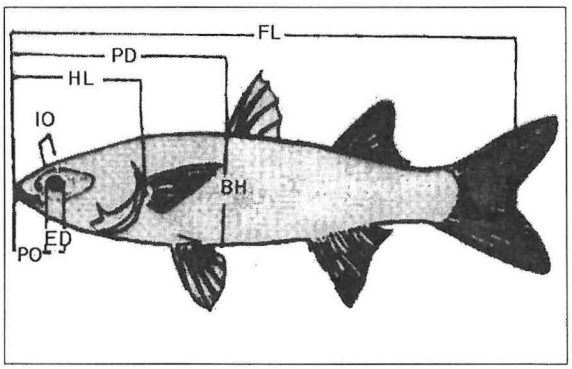

Fig. 2. Morphological measures of a grey mullet

We examined if there was any difference, in terms of shape, between the species by applying discriminant analysis of morphometric characteristics of grey mullets. From the 7-morphometric characteristics of these species, we found 4 discriminant functions. Besides, the reliability of the distinguishing force was tested with χ^2 test (TATLIDIL,1996). The functions of this analysis were obtained by using SPSS (Statistical Package for the Social Sciences) package program.

Since otolith of each species has different form and characteristics, Discriminant Analysis was applied in order to put forward the difference in otoliths. So, otolith length (*OL*), otolith breadth (*OB*) and otolith depth (*OD*) were measured by using 0.01 mm digital calipers. Moreover, fish length was used as a variable as well. The morphologic characteristics of sagittal otoliths were examined under a binocular microscope and drawn on a milimetric paper by being enlarged. Morphometric characters were given in 95% confidence interval. Four functions were obtained with discriminant analyses of each species. In addition, confidence of discrimination power was put forward with χ^2 test (TATLIDIL,1996). The functions of these analyses were also gathered with SPSS program.

RESULTS

The meristic characteristics of five species of grey mullets are seen in Table 1. According to this, the numbers of first and second dorsal fin-rays and ventral fin-rays were found the same for all species. However, the number of anal fin-rays were found III-8,9 for *L. saliens* and *L. aurata*; III-9 for *L. ramada* and *C. labrosus*; and III-7,8 for *M. cephalus*. Numbers of pectoral fin-rays varied between 15-17 (Table 1).

Some meristic characteristics of grey mullets and 95% confidence intervals were given in Table 2.

Table 1. Meristic characteristics of grey mullets

Meristic Characteristics	*M. cephalus* n=30	*L. saliens* n=79	*L. aurata* n=22	*L. ramada* n=17	*C. labrosus* n=37
1st Dorsal Fin	IV	IV	IV	IV	IV
2nd Dorsal Fin	I-7,8	I-7,8	I-7,8	I-7,8	I-7,8
Ventral Fin	I-5	I-5	I-5	I-5	I-5
Anal Fin	III-7,8	III-8,9	III-8,9	III-9	III-9
Pectoral Fin	16,17	15,16,17	15,16	15,16	15,16

Table 2. Some metric characteristics of grey mullets and confidence intervals

	M. cephalus						
N=30	*BH*	*HL*	*PD*	*PO*	*ED*	*IO*	*FL*
Minimum (mm)	53	57	121	10.5	10	18	285
Maximum (mm)	86	94	197	20	19	45	473
Mean (mm)	71.42	79.42	164.72	17.15	14.8	33.65	387.5
Standard Deviation	9.44	10.5	21.56	2.47	2.14	6.33	49.04
95% C.I. (±)	3.52	3.93	8.04	0.92	0.8	2.37	18.3

Table 2. cont'd

L. saliens

N=79	*BH*	*HL*	*PD*	*PO*	*ED*	*IO*	*FL*
Minimum (mm)	32	36	81	8	7	12	179
Maximum (mm)	59.5	67	143	15.5	13	25	326
Mean (mm)	47.61	48.37	109.02	11.65	9.66	17.85	251.05
Standard Deviation	4.99	5.1	11.46	1.81	1.16	2.2	24.53
95% C.I. (±)	1.11	1.13	22.81	3.6	2.31	4.38	48.81

L. aurata

N=22	*BH*	*HL*	*PD*	*PO*	*ED*	*IO*	*FL*
Minimum (mm)	36	41	86	8.5	7	15	207
Maximum (mm)	55	58	121	13	10	22	293
Mean (mm)	42.77	44.82	96.55	9.98	8.41	16.82	228.59
Standard Deviation	3.83	3.39	6.88	1.11	0.68	1.47	17.16
95% C.I. (±)	1.71	1.5	3.06	0.5	0.29	0.64	7.61

L. ramada

N=17	*BH*	*HL*	*PD*	*PO*	*ED*	*IO*	*FL*
Minimum (mm)	32	30	66	7.5	7	12	157
Maximum (mm)	40	47	95	11	9	17	218
Mean (mm)	37.24	43.35	89.18	9.68	8.15	15.76	203.12
Standard Deviation	2.05	3.71	6.89	0.92	0.49	1.25	14.07
95% C.I. (±)	1.06	1.91	3.54	0.47	0.25	0.64	7.25

C. labrosus

N=37	*BH*	*HL*	*PD*	*PO*	*ED*	*IO*	*FL*
Minimum (mm)	29	27	59	6	6	10	137
Maximum (mm)	68	62	138	16.5	11	26	324
Mean (mm)	48.92	44.58	98.68	10.28	8.59	18.27	227.7
Standard Deviation	12.63	10.64	24.07	2.85	1.58	4.9	56.19
95% C.I. (±)	4.22	3.55	8.04	0.95	0.53	1.64	18.76

Three discriminant functions were obtained as a result of discriminant analysis which was done in order to put forward the morphologic differences between the four species (except *L. ramada*) of grey mullets ($y1$, $y2$ and $y3$ are dependent variables);

Function 1

$y1$= -0.682(*BH*) +2.345(*HL*) -0.955(*PD*) -0.668(*PO*) +0.576(*ED*) +0.612(*IO*) -0.504(*FL*)

Function 2

$y2$= +1.876(*BH*) +1.365(*HL*) -1.439(*PD*) -0.401(*PO*) -0.210(*ED*)+1.273(*IO*) -2.435(*FL*)

Function 3

$y3$= +1.079(*BH*) -2.222(*HL*) +2.110(*PD*) +0.417(*PO*) +0.707(*ED*) +0.009(*IO*) -1.389(*FL*)

The results of this were:

Function	WILK's Lambda Values	χ^2
1	0.076	416.08
2	0.413	142.87
3	0.833	29.47

Since the lowest two values among WILK's Lambda values represented the best function, graphic of discriminant function due to the first and second value was drawn (Fig. 3).

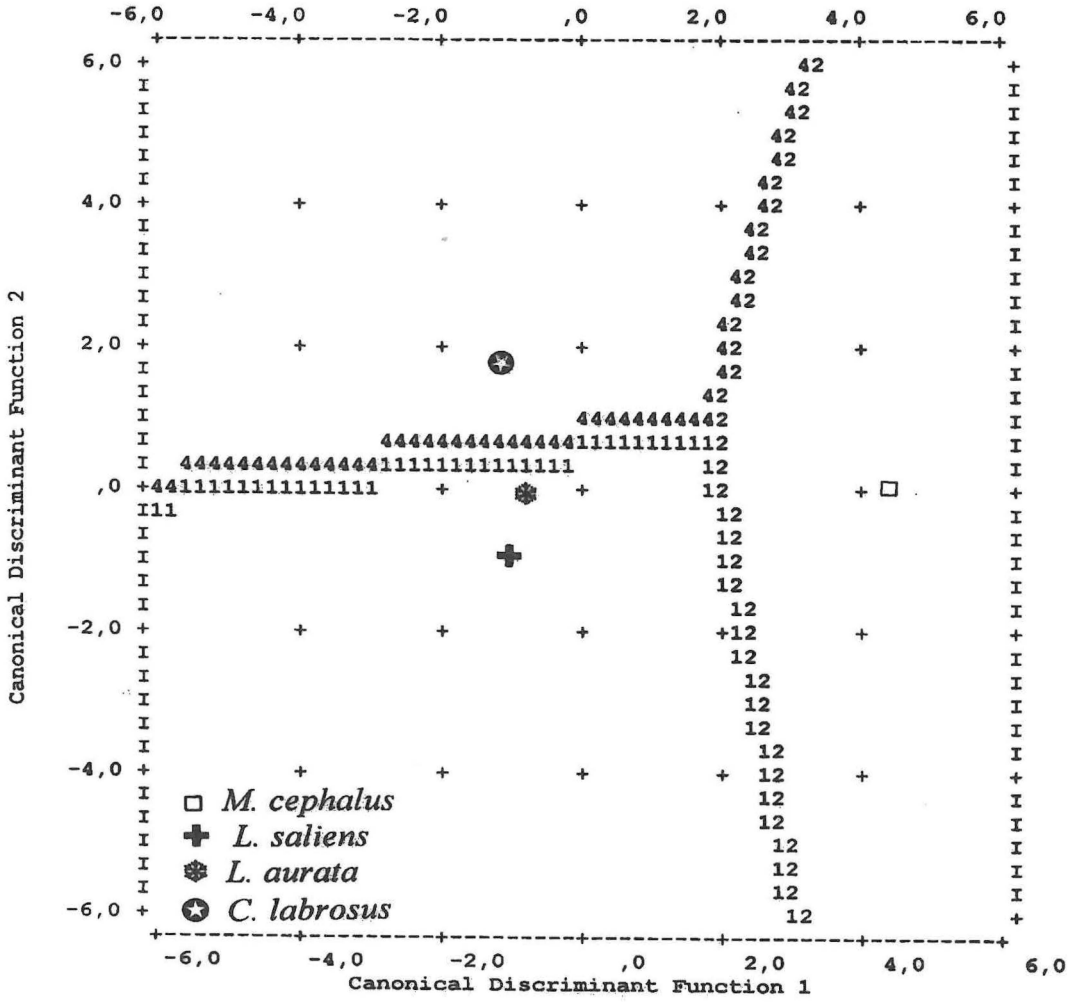

Fig. 3.The species body discrimination depending on the canonical discrimination function

Confidence of selectivity of discriminant analysis was checked with χ^2 test and according to this, the characteristic of selectivity of *Ho*: the discrimination feature of the discriminant analysis is unimportant. Departing from the hypothesis that characteristics of selectivity of *H1*: the discrimination feature of the discriminant analysis is important, the Q= 688.4 was calculated, and hypothesis of *Ho* was rejected. Because $\chi^2_{1;0.05)}$ was 3.841, selectivity characteristics of discriminant function are important. According to the metric characters, it can be tested with 95% of reliability that correct discriminating force is 85.1%.

In order to put forward the morphologic differences of otoliths used in systematics as well as in age determination, a detailed study was done for each species.

Mugil cephalus

Otolith is in form of cubiceps, slightly elongated and pentagonal. Rostrum is slightly elongated and pointed; antirostrum is pointed. Postrostrum and posterior sides are lobbed. Sulcus is evident, and cauda reaches toward posterio-ventral, with a slight slope. Dorsal area is long and wide, medial surface is convex, while lateral surface is quite concave (Table 3; Fig. 4a).

Table 3. Morphologic characters of the species

	M. cephalus			
N=17	*FL*	*OL*	*OB*	*OD*
Minimum (mm)	263	6.33	3.21	1.48
Maximum (mm)	337	8.97	4.11	2.03
Mean (mm)	302.76	7.54	3.64	1.75
Standard Deviation	22.68	0.62	0.23	0.16
95% C.I. (±)	11.72	0.32	0.13	0.08

	L. saliens			
N=47	*FL*	*OL*	*OB*	*OD*
Minimum (mm)	165	5.28	2.35	0.89
Maximum (mm)	331	8.66	4	1.86
Mean (mm)	225.19	6.62	3.02	1.25
Standard Deviation	40.42	0.94	0.37	0.28
95% C.I. (±)	11.8	0.28	0.1	0.08

	L. aurata			
N=34	*FL*	*OL*	*OB*	*OD*
Minimum (mm)	174	5.36	3.05	1.05
Maximum (mm)	293	7.83	3.95	1.69
Mean (mm)	226.68	6.61	3.35	1.27
Standard Deviation	17.33	0.4	0.2	0.14
95% C.I. (±)	6.1	0.14	0.06	0.04

	L. ramada			
N=26	*FL*	*OL*	*OB*	*OD*
Minimum (mm)	144	4.85	2.68	0.96
Maximum (mm)	268	7.02	3.65	1.47
Mean (mm)	201.15	6.38	3.26	1.18
Standard Deviation	22.96	0.66	0.25	0.11
95% C.I. (±)	9.27	0.27	0.10	0.04

	C. labrosus			
N=50	*FL*	*OL*	*OB*	*OD*
Minimum (mm)	137	4.26	2.52	0.79
Maximum (mm)	324	8.06	4.02	1.75
Mean (mm)	194.48	5.66	3.11	1.1
Standard Deviation	48.82	1.04	0.4	0.26
95% C.I. (±)	13.86	0.3	0.12	0.08

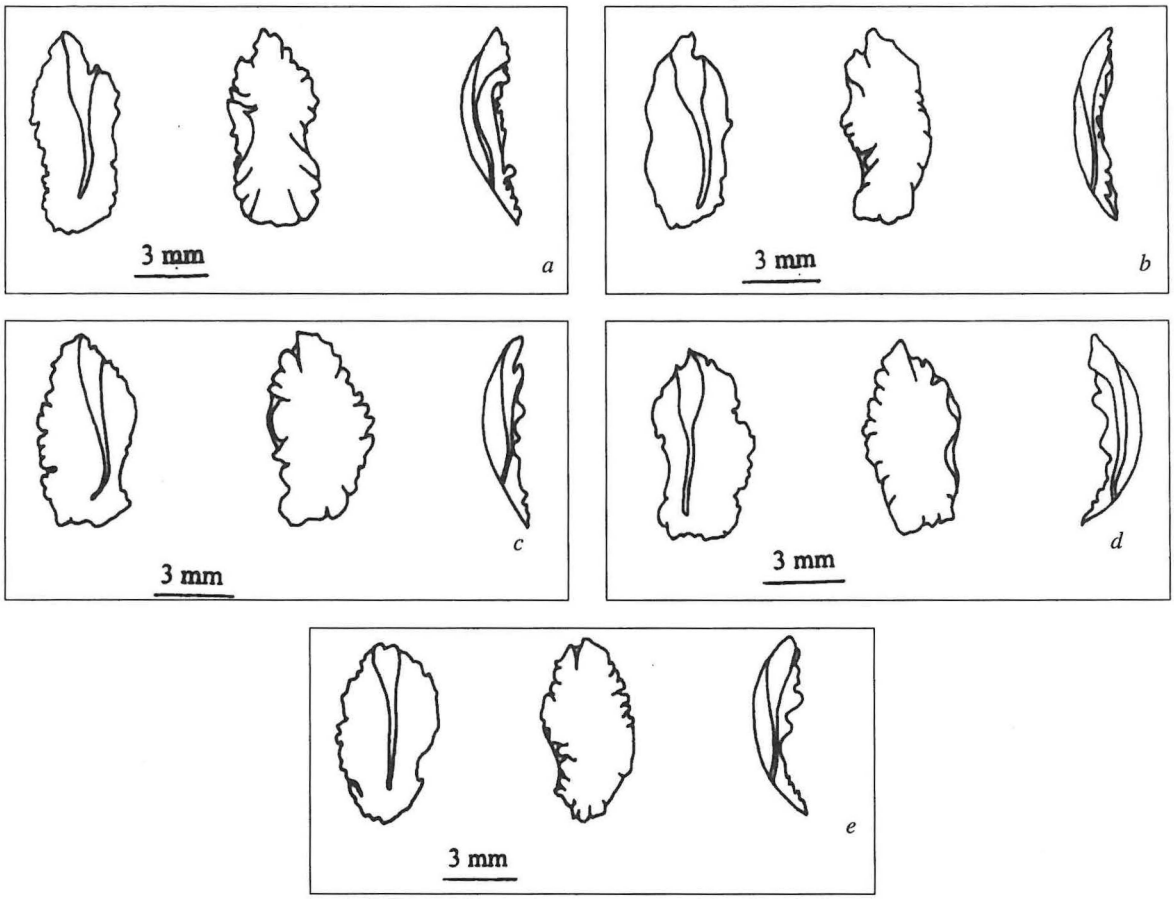

Fig.4. Sagittae of M. cephalus (a), Sagittae of L. saliens (b), Sagittae of L. aurata (c), Sagittae of L. ramada (d), Sagittae of C. labrosus (e)

Liza saliens

Otolith is oval and elongated. Rostrum is slightly elongated and round; antirostrum small and pointed. Postrostrum is lobbed, sides are almost flat and slightly wavy. Sulcus is deep and evident, cauda reaches toward posterio-ventral with a slight slope. Dorsal area is wide and long. Medial surface is convex, while lateral surface is concave (Table 3; Fig. 4b).

L. aurata

Otolith is slightly elongated and pentagonal. Rostrum is slightly elongated and blunt. Antirostrum appears to be small and rounded. Postrostrum is wide, round and lobbed. Sides are also lobbed. Sulcus is deep, cauda thin and flat, but has a strong slope at posterio-ventral. Dorsal area is wide. Medial surface is convex and lateral surface is concave (Table 3; Fig. 4c).

Liza ramada

Otolith is oval-like pentagonal. Rostrum is slightly long, pointed; antirostrum small and pointed. Postrostrum is lobbed, almost flat, its sides are also lobbed. Sulcus is not too deep, cauda reaches toward posterio-ventral like a narrow channel with a slight slope. Dorsal area is wide. Medial surface is slightly convex, lateral surface is concave (Table 3; Fig. 4d).

Chelon labrosus

Otolith is oval-like pentagonal. Rostrum is slightly long and blunt. Postrostrum is wide and round, sides are slightly lobbed. Sulcus is not too deep, cauda straightly comes down with a narrow channel. Dorsal area is wide, medial surface is convex, while lateral surface is concave (Table 3; Fig. 4e).

Discriminant analysis was done in order to put forward the morphologic differences between five species of grey mullets, and at the end of the analysis, 4 discriminant functions were obtained. These are the following:

Function 1

$y1 = 1.819(FL) - 0.732(OL) - 1.292(OB) + 0.653(OD)$

Function 2

$y2 = 0.071(FL) - 1.678(OL) + 1.247(OB) + 0.660(OD)$

Function 3

$y3 = -1.214(FL) + 1.301(OL) + 0.675(OB) + 0.153(OD)$

Function 4

$y4 = 1.792(FL) + 0.084(OL) + 0.310(OB) - 2.040(OD)$

As a result of this, the following was found:

Function	WILK's Lambda Values	χ^2
1	1.525	108.4
2	2.803	36.8
3	3.979	3.5

Two small values among WILK's Lambda values show discriminant functions. The graphic was drawn through these two small values (Fig. 5).

As a result of discriminant analysis of grey mullets, otoliths of the species *Chelon labrosus, Liza aurata* and *Liza ramada* were found to be similar to each other. Those of *Mugil cephalus* and *Liza saliens* were found to be different.

When we use χ^2 test to test the confidence of discriminant analysis, the discrimination

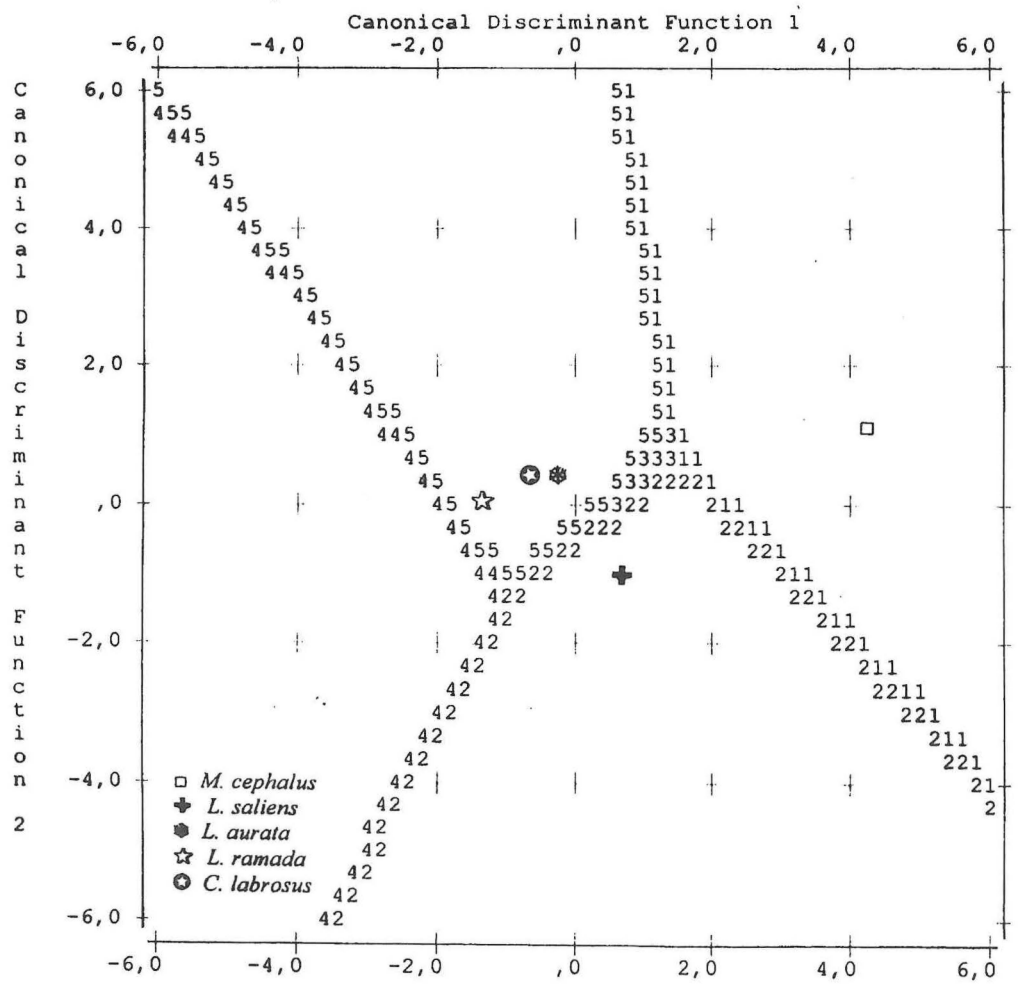

Fig. 5. Otolith discrimination of grey mullets, depending on discriminant functions

characteristic of *Ho*: the discrimination feature of the discriminant function is unimportant; the hypothesis claiming that the discrimination characteristic of *Hı*: the discrimination feature of the discriminant function is important was set. *Q* value was calculated as 219.656 and *Ho* was rejected, since χ^2 (1;0.05) was 3.841, the discriminational characteristics of discriminant function was found to be important. According to the otolith characteristics, it can be tested with 95% of reliability that correct discriminating force is 64.94%.

DISCUSSION

When we look at the general morphologic structures of the five species of grey mullets which were obtained from Homa Lagoon, we see that we have found out meristic characters, the numbers of ventral and the first and second dorsal fin-rays were the same for all species: I-5, IV and I-7,8, respectively. While the number of anal fin-rays was found III-8,9 for *L. saliens* and *L. aurata*; III-9 for *L. ramada* and *C. labrosus*; III-7,8 for *M. cephalus*; pectoral fin-rays, on the other hand, was 16,17 for *M. cephalus*; 15,16,17 for *L. saliens*; 15,16 for *L. aurata, L. ramada* and *C. labrosus*. With external morphologic characteristics, at the end of the discriminant analysis, *L. aurata* and *L. saliens* were found to be quite similar in terms of form, while *C. labrosus* and *M. cephalus* were rather different.

DENİZCİ (1956) indicated, IV spine-rays on first dorsal fin, I-5 on ventral, III-7, 8,9,10 on anal fin, varying according to the species. GELDIAY (1969, 1977) gave the meristic characters of the grey mullets living in Turkish seas as IV on the first dorsal, I-7,8,9 on the second dorsal, 14,15,16,17,18 rays on pectoral fin; I-5 on ventral fin and III-7,8,9,10 on anal fin. GELDIAY and BALIK (1988) stated the first dorsal and ventral the same for all the species as IV and I-5, respectively; the second dorsal as I-7, 8,9; the number of anal fin-rays as III-7, 8,9,10 and pectoral fin as 16,17. All these results are similar to our findings.

MINOS *et al.*(1994) compared *L. ramada* with *L. saliens* in Messolongi-Etoliko Lagoon (Greece), for their morphometric characters and emphasised the formal differences between these two species (*L. saliens's* body is more cylindrical), and length-weight relationship. AGUIRRE and LLEONART (1996), put the morphometrics of *M. cephalus* and *M. curema* from the Gulf of Mexico comparatively into discriminant analysis and found that they have differences in form and they also put forward sexual dimorphism.

In Homa Lagoon (Izmir Bay), otolith characteristics of five species of family Mugilidae were evaluated with discriminant analysis, and the highest similarity was observed between *L. ramada, L. aurata* and *C. labrosus*, while otoliths of *M. cephalus* and *L. saliens* were found to be different.

ANGELIS (1967) found that otoliths of *L. ramada* and *M. cephalus* were similar, at the end of the observations on otolith morphology. He also emphasised that *L. aurata*'s otolith characteristic was wider than *L. ramada* and *M. cephalus* and its denticulations on the sides were smaller and more frequent. Moreover, he indicated that *L. saliens*'s otolith was quite similar to that of *L. ramada* and that otolith of *C. labrosus* was wide, stout and concave. He defined the otolith of *M. cephalus* as long, jutting and pointed.

There can come out a difference with this study, since the researcher defined otolith characteristics with direct observation method. In addition, there can be differences between the otolith morphologies of fish in different stocks, depending on the region (HOPKINS, 1986; CAMPANA and CASSELMAN, 1993). In conclusion, in the Bay of Izmir (Aegean Sea), despite external morphologies and otoliths of the species of family Mugilidae are generally similar to each other, it is also possible to make a definite differentiation of species through body and otolith morphologies that are peculiar to the species.

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Accepted: 22 December 2000

Usporedba morfometrike tijela i otolita obitelji *Mugilidae* u Laguni Homa (Izmirski zaljev, Egejsko more)

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SAŽETAK

Otoliti i oblik tijela svake vrste imaju specifičan oblik i svojstva. Stoga su otoliti i morfometrika tijela u širokoj primjeni kod sistematskih istraživanja riba koštunjača. U Laguni Homa (Izmirski zaljev) kod 5 primjeraka iz obitelji Mugilidae obilježlja otolita su vrednovana diskriminantnom analizom, te je ustanovljena najveća sličnost vrsta *L. aurata*, *L. ramada* i *C. labrosus*. Slične karakteristike tijela imaju *L. saliensi*, *L. aurata*, dok *C. labrosus* i *M. cephalus* imaju različite tjelesne karakteristike. Iako otoliti i morfometrijska obilježja tijela obitelji Mugilidae imaju opće sličnosti, moguće je razlikovati vrste prema posebnoj morfologiji tijela i otolita.