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The use of the preorbital bone as a suitable method to identify Italian species of Mulletts (Perciformes: Mugilidae)

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Key words: mullets, preorbital bone, Mediterranean Sea, Italy, taxonomy.

SUMMARY

In the Mediterranean sea the Mugilidae family is represented by 6 species: *Chelon labrosus*, *Liza aurata*, *L. ramada*, *L. saliens*, *Mugil cephalus* and *Oedalechilus labeo*. Taxonomic description of these species is based on several meristic characteristics.

Nevertheless, the selection of these characteristics is controversial since there is a significant intraspecific variability, mainly among youngsters. The preorbital bone (a bone located in the anterior-lower limit of the orbit) has never been used as a taxonomic characteristic. The aim of this work is to compare preorbital bones of 6 Italian Mugilidae species and discuss the reliability of this bone as a taxonomic characteristic. Results obtained indicate that the morphology of the pre-orbital bone is a suitable diagnostic characteristic as it is immutable within species but presents important differences between species. In addition, bone morphology is stable within a species throughout all developmental stages, as opposed to meristic characteristics, used in taxonomical keys, which are not fully developed in the larval stage.

Based on the morphometric study of the preorbital bone it has been possible to create a key descriptive-graphic which is an easy tool for swift taxonomical identification of individual Muller species.

INTRODUCTION

The Mugilidae family consists of 80 species from 17 genera. Six species are found in Italy: *Mugil cephalus* (Linnaeus, 1758), *Chelon labrosus* (Risso, 1827),

Oedalechilus labeo (Cuvier, 1829), *Liza aurata* (Risso, 1810), *L. ramada* (Risso, 1810) and *L. saliens* (Risso, 1810). Several problems occur for species identification when using meristic characteristics due to their huge variability at the intraspecific level. On the other hand, Mugilidae evolution has not brought about important differences between evolutionary lines or adaptations. Even at the morphological level species are quite similar to each other (Tortonese, 1972). This has led to much confusion in the classification within this family. This can be illustrated by the numerous synonyms and identification mistakes observed in scientific literature (Tab. I).

Tab. I - Synonyms of studied species

<i>Chelon labrosus</i>	(Risso, 1827)	Valid name
<i>Mugil provinsalis</i>	(Risso, 1810)	Identification mistake
<i>Mugil labrosus</i>	Risso, 1827	Original description
<i>Crenimugil labrosus</i>	(Risso, 1827)	Synonym
<i>Mugil chelon</i>	Cuvier, 1829	Synonym
<i>Mugil chelo</i>	Cuvier, 1829	Synonym
<i>Chelon chelo</i>	(Cuvier, 1829)	Synonym
<i>Liza chelo</i>	(Cuvier, 1829)	Synonym
<i>Mugil curtus</i>	Yarrell, 1836	Synonym
<i>Mugil Corrugatus</i>	Lowe, 1838	Synonym
<i>Mugil buegosa</i>	Nardo, 1847	Synonym
<i>Mugil septentrionalis</i>	Günther, 1861	Synonym
<i>Liza aurata</i>	(Risso, 1810)	Valid name
<i>Mugil auratus</i>	Risso, 1810	Original description
<i>Liza auratus</i>	(Risso, 1810)	Synonym
<i>Mugil chelo</i>	(Cuvier, 1829)	Identification mistake
<i>Mugil breviceps</i>	Valenciennes, 1836	Synonym
<i>Mugil cryptocheilis</i>	Valenciennes, 1836	Synonym
<i>Mugil maderensis</i>	Lowe, 1839	Synonym
<i>Mugil lotreganus</i>	Nardo, 1847	Synonym
<i>Mugil octoradiatus</i>	Günther, 1861	Synonym
<i>Liza ramada</i>	(Risso, 1810)	Valid name
<i>Mugil ramado</i>	Risso, 1810	Original description
<i>Mugil capito</i>	Cuvier, 1829	Synonym
<i>Liza capito</i>	Cuvier, 1829	Synonym
<i>Mugil britannicus</i>	Hancock, 1830	Synonym
<i>Mugil dubabra</i>	Valenciennes, 1836	Synonym
<i>Mugil caustelus</i>	Nardo, 1847	Synonym
<i>Mugil petherici</i>	Günther, 1861	Synonym
<i>Mugil octoradiatus</i>	(Günther, 1861)	Identification mistake
<i>Liza alosoides</i>	Fowler, 1903	Synonym
<i>Myxus maroccensis</i>	Mohr, 1927	Synonym
<i>Liza saliens</i>	(Risso, 1810)	Valid name
<i>Mugil saliens</i>	Risso, 1810	Original description
<i>Mugil verselata</i>	Nardo, 1847	Synonym
<i>Liza saliens furcata</i>	Popov, 1930	Synonym

<i>Mugil cephalus</i>	Linnaeus, 1758	Valid name, original description
<i>Mugil cephalus cephalus</i>	Linnaeus, 1758	Synonym
<i>Mugil albula</i>	Linnaeus, 1758	Synonym
<i>Mugil our</i>	Forsskål, 1775	Synonym
<i>Mugil crenilabris our</i>	Forsskål, 1775	Synonym
<i>Mugil tang</i>	Block, 1794	Synonym
<i>Mugil provinsalis</i>	Risso, 1810	Synonym
<i>Mugil lineatus</i>	Valenciennes, 1836	Synonym
<i>Mugil cephalotus</i>	Valenciennes, 1836	Synonym
<i>Mugil perusii</i>	Valenciennes, 1836	Identification mistake
<i>Mugil japonicus</i>	Temminck & Schlegel, 1845	Synonym
<i>Mugil vulpinus</i>	Nardo, 1847	Synonym
<i>Mugil chaptalii</i>	Eydoux & Souleyet, 1850	Identification mistake
<i>Mugil dobula</i>	Günther, 1861	Synonym
<i>Mugil ashanteensis</i>	Bleeker, 1863	Synonym
<i>Mugil cephalus ashanteensis</i>	Bleeker, 1863	Synonym
<i>Myxus superficialis</i>	Klunzinger, 1870	Synonym
<i>Mugil gelatinosus</i>	Klunzinger, 1870	Synonym
<i>Mugil occidentalis</i>	Castelnau, 1873	Synonym
<i>Mugil mexicanus</i>	Steindachner, 1876	Synonym
<i>Myxus caecutiens</i>	Günther, 1876	Synonym
<i>Mugil grandis</i>	Castelnau, 1879	Synonym
<i>Mugil muelleri</i>	Klunzinger, 1880	Synonym
<i>Mugil mulleri</i>	Klunzinger, 1880	Synonym
<i>Mugil hypseloma</i>	Ogilby, 1897	Synonym
<i>Myxus pacificus</i>	Steindachner, 1900	Synonym
<i>Myxus barnardi</i>	Gilchrist & Thompson, 1910	Synonym
<i>Mugil galapagensis</i>	(Ebeling, 1961)	Identification mistake
<hr/>		
<i>Oedalechilus labeo</i>	(Cuvier, 1829)	Valid name
<i>Mugil labeo</i>	Cuvier, 1829	Original description
<i>Mugil provensalis</i>	Risso, 1810	Identification mistake
<i>Liza labeo</i>	(Cuvier, 1829)	Synonym

In the Mediterranean area the Mugilidae family only consisted of the *Mugil* genus till the work of Tortonese (1975) or Forneris et al. (1990). These authors proposed to limit this genus to species with a well developed and transparent adipose eyelid. According to this criterion, the only Mediterranean species of this genus is *Mugil cephalus*, the others being associated with the *Liza* genus, which is characterized by the absence of a real adipose eyelid (Popov, 1930).

Meristic characteristics used to identify Mediterranean species of Mugilidae are numerous: the form of the jugular space; the size of the upper lip; the number of spinal rays on the anal fin; the development of the adipose membrane covering the eye; the presence or absence of a fleshy vermiform appendix on the dorsal lip; the form of the otholiths; the presence of fossa on the dorsal scales, etc. (De Angelis, 1967; Tortonese, 1975). On the basis of these characteristics, Tortonese (1975) proposed a taxonomic key to separate 4 Mediterranean genera: *Mugil*, *Liza*, *Chelon* and *Oedalechilus*. This key is still used to identify species. Nevertheless, there is a controversy regarding the meristic characteristics used.

They are not applicable to youngsters where they are not well developed yet (Athanasopoulos, 1919, based on Brunelli, 1914) and present a significant intraspecific variability (Serventi et al., 1996).

The pre-orbital bone was never used as a taxonomic characteristic. Only some general *in situ* descriptions of lower and posterior margins were done for one species by Tortonese (1975). The aim of this work is to compare the pre-orbital bone of 6 Italian Mugilidae species and discuss its validity as a taxonomic characteristic.

MATERIALS AND METHODS

More than 4,000 individuals were sampled with a net, between 1998 and 2001 in 6 different stations: (A) Porto Vecchio lagoon in Oliveri-Tindari (38°08'N 15°03'E); (B) Lago Faro lagoon in Torre Faro (38°17'N 15°39'E); (C) Lungolago lagoon in Ganzirri (38°16'N 15°38'E); (D) in the Strait of Messina near Ganzirri (38°16'N 15°38'E); (E) in the Trieste Gulf (45°46'N 13°36'E); (F) in the Grado lagoon (45°46'N 15°11'E). Between 3 to 6 of the following Mugilidae species were collected in each station: *C. labrosus*, *L. aurata*, *L. ramada*, *L. saliens*, *M. cephalus* and *O. labeo*. Characteristics of samples are summarised in the Tab. II.

Tab. II - Characteristics of sampled fish at different stations : frequence (N), size of the smaller and bigger individuals, mean \pm standard error of mean. All sizes are expressed in centimetres.

	Strait of Messina	Lungo Lago (Ganzirri)	Lago Faro (Torre Faro)	Porto Vecchio (Tindari)	Grado lagoon	Trieste Gulf	TOTAL
<i>C. labrosus</i>	N=12 [6,8–45,6] 20,4 \pm 3,4	N=21 [11,3–27,4] 17,8 \pm 1,2	N=16 [15,9–43,9] 30,1 \pm 2,1	/	N=12 [24,6–38,1] 33,4 \pm 1,2	N=4 [20,7–24,5] 23,28 \pm 0,89	N=65 [6,8–45,6] 24,5 \pm 1,2
<i>L. aurata</i>	N=5 [18,3–34,9] 26,9 \pm 2,9	N=8 [21,9–38,9] 29,6 \pm 2,2	N=9 [22,6–37,3] 28,4 \pm 1,7	N=8 [10,4–15,6] 12,5 \pm 0,6	N=10 [22,8–35,9] 30,5 \pm 1,6	N=18 [20,4–32,3] 24,8 \pm 0,8	N=57 [10,4–38,9] 25,5 \pm 0,9
<i>L. ramada</i>	N=11 [15,7–40,4] 27,8 \pm 2,4	n=6 [24,7–36,3] 30 \pm 1,9	N=6 [27,9–37,3] 34,1 \pm 1,4	N=4 [16,9–24,7] 21,9 \pm 1,8	N=6 [24,9–34,8] 30,3 \pm 1,6	N=23 [23,7–36,9] 30,2 \pm 0,93	N=55 [15,7–40,4] 29,5 \pm 0,8
<i>L. saliens</i>	N=14 [10,4–30,1] 18,4 \pm 1,4	N=8 [13,8–26,9] 20,1 \pm 1,6	N=7 [16,7–23,8] 21 \pm 1,0	N=2 [14,5–14,8] 14,7 \pm 0,2	N=11 [15,5–21,1] 18,7 \pm 0,5	N=16 [12,4–24,5] 17,4 \pm 0,9	N=58 [10,4–30,1] 18,6 \pm 0,5
<i>M. cephalus</i>	N=5 [15,5–50,3] 34,2 \pm 6,5	/	/	/	N=5 [37,9–55,8] 47,3 \pm 2,9	N=1 [15,5–56,7] 56,7	N=11 [3,5–23] 42,2 \pm 3,9
<i>O. labeo</i>	N=124 [3,5–23] 15,4 \pm 0,4	N=14 [10,4–15,9] 13,3 \pm 0,4	N=10 [10,4–15,3] 12,6 \pm 0,4	/	N=14 [10,6–19,7] 13,4 \pm 0,6	/	N=161 [3,5–23] 14,9 \pm 0,3

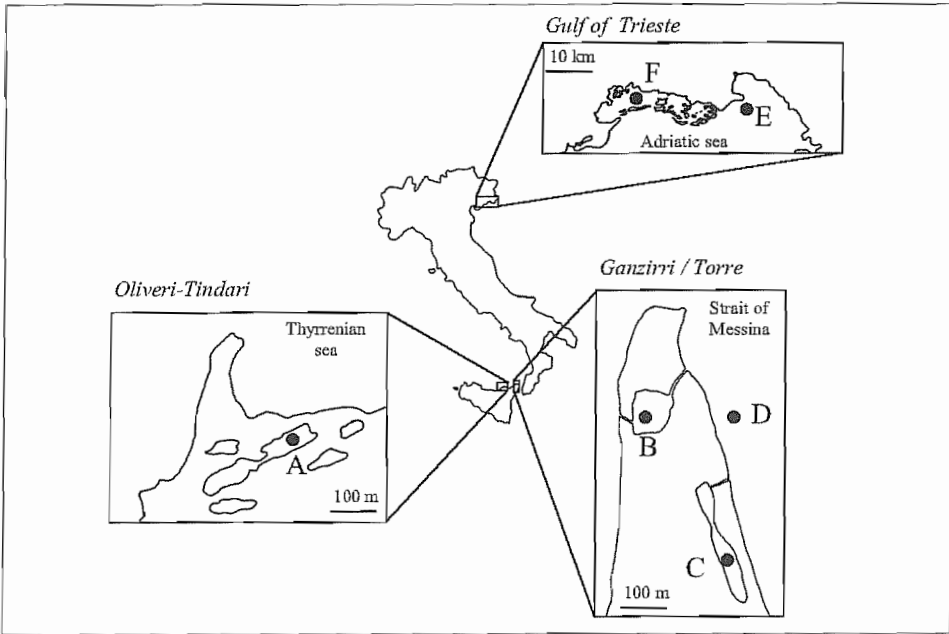


Fig. 1 - Sampling stations. A: Porto Vecchio lagoon in Oliveri-Tindari; B: Lago Faro lagoon in Torre Faro; C: Lungolago lagoon in Ganzirri; D: Strait of Messina; E: Grado lagoon; F: Trieste Gulf

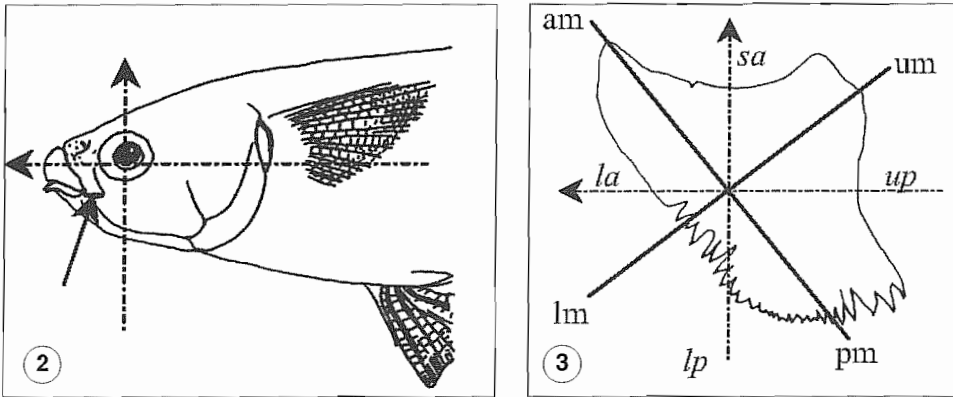


Fig. 2 - Preorbital bone location and anterior-posterior and lower-upper axis

Fig. 3 - Terminology related to preorbital bone: am: anterior margin; pm: posterior margin; um: upper margin; lm: lower margin; ua: upper-anterior margin; up: upper-posterior margin; la: lower-anterior margin; lp: lower-posterior margin

For each fish collected, the total body (LT, cm) length was measured and the pre-orbital bone was isolated. The head of the fish was immersed in boiling water for 1 to 2 minutes to facilitate the collection of this bone. It is located in the anterior-lower limit of the orbit. Its main axis makes a 20 to 25° angle with the dorsal-ventral axis of the fish from the tail to the mouth (Fig. 2). Two axes were

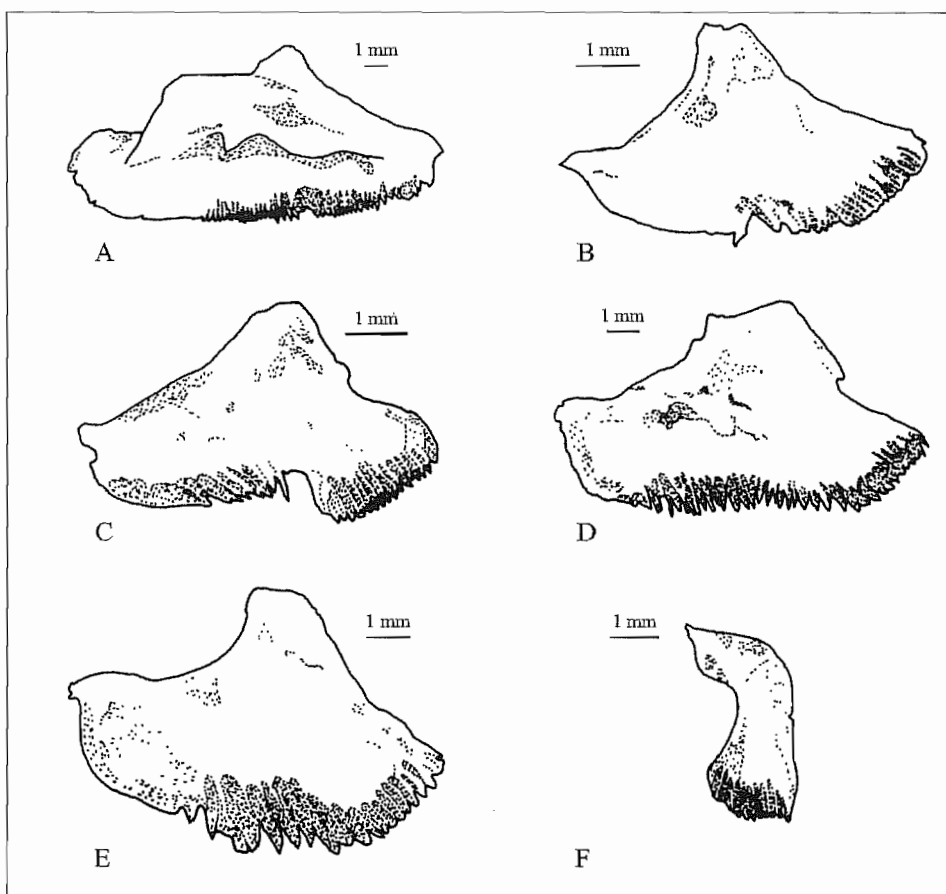


Fig. 4 - Preorbital bones of six Mugilidae species. A: *M. cephalus*; B: *L. aurata*; C: *L. saliens*; D: *L. ramada*; E: *C. labrosus*; F: *O. laeo*

then defined according to the orientation of the bone (Fig. 3). We used the following terminology to describe the bone: upper (**um**) and lower (**lm**) margins, sub-divided into anterior (upper-anterior, *ua* and lower-anterior, *la*) and posterior (upper-posterior, *up* and lower-posterior, *lp*) margin.

Once collected, the pre-orbital bone was photographed by using parameters which have been previously standardised (same enlargement, the same distance, *etc.* after having placed the bone on a graph paper). The acquired images were scanned and analysed by computer in order to extrapolate the coordinates of the various profiles for the morphometric exam. The morphometric software *FORME 1.1* used for the analysis of the curves (kindly provided by Pr. Puccio, Department of. Mathematic, University of Messina) is available on the web site: <http://www.forme.too.it>.

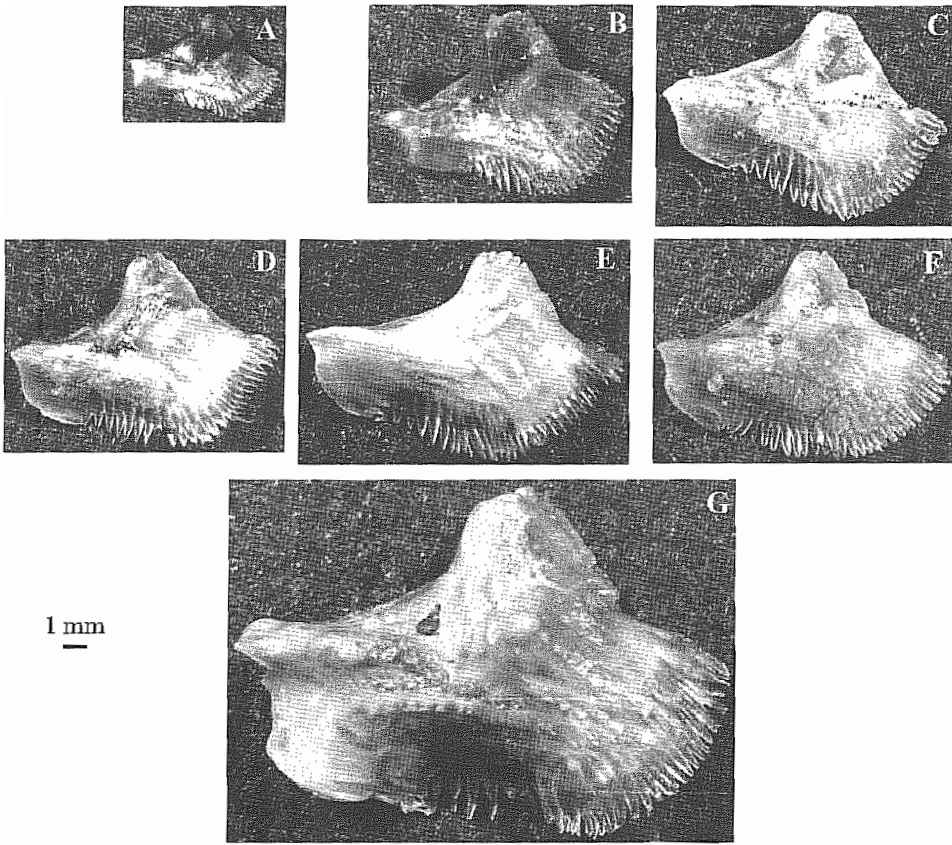


Fig. 5 - Pictures of preorbital bones of *Chelone labrosus*. A: juveniles (Strait of Messina); B: adult (Trieste Gulf); C: adult (Lungolago); D, E: adult (Grado lagoon); F: adult (Strait of Messina); G: adult (Lago Faro)

RESULTS

Preorbital bone morphology is different for each species (Fig. 4). On the other hand, the bone morphology is stable within a species for all developmental stages and for the different stations. For instance, Fig. 5 presents the comparison of preorbital bones of juvenile and adult *Chelone labrosus*. More important bone characteristics for taxonomy appear in earlier stages of development and do not change with growth. We can then present a table that shows the main characteristics of the bones for each species (Tab. III).

The inferior margin is the main taxonomical characteristic: straight in *M. cephalus* and *O. labeo*; convex in *L. aurata* and *C. labrosus*; concave in *L. saliens* and *L. ramada*. Presence, number and structure of teeth of inferior margin allow separation of different species without ambiguity.

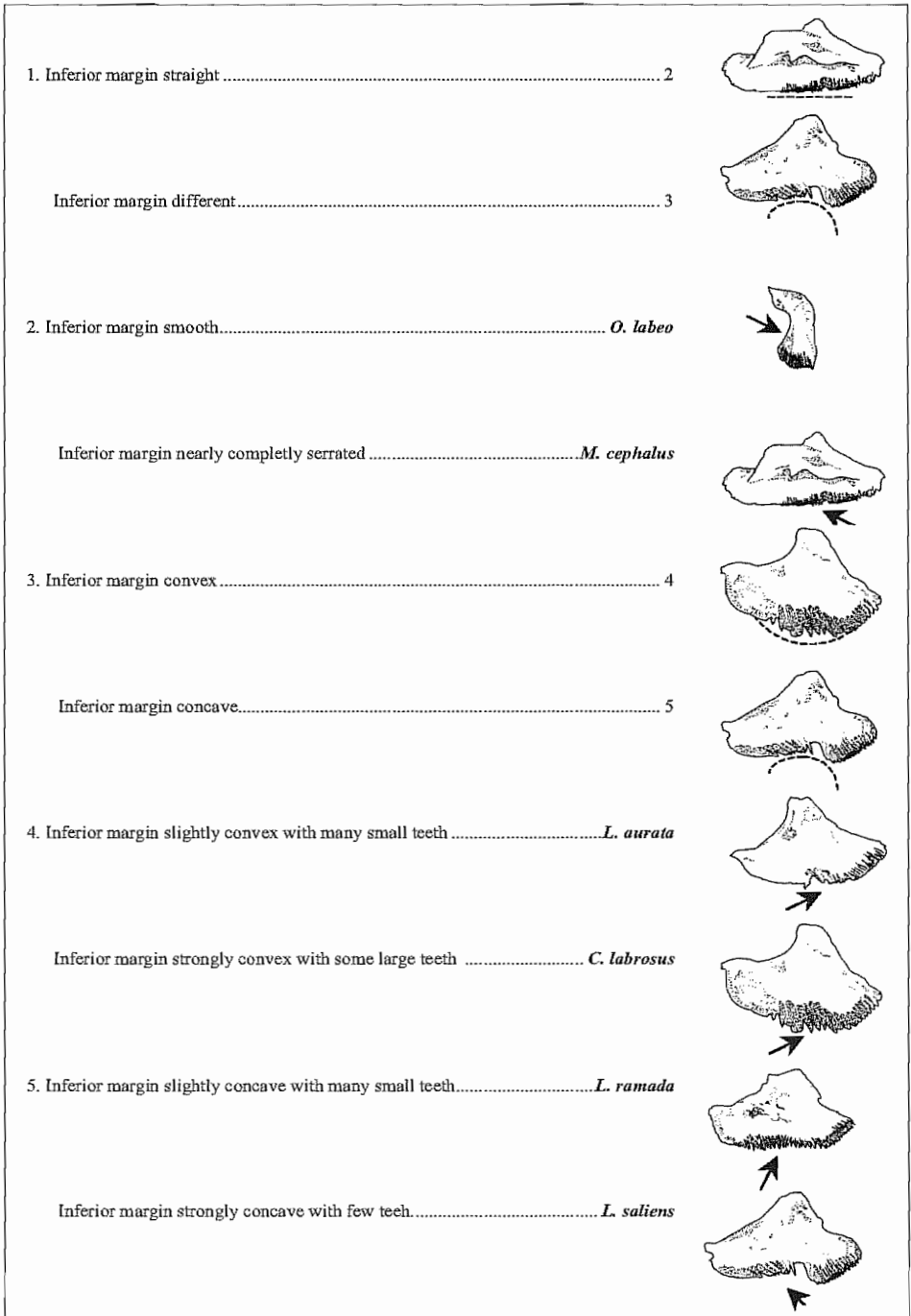


Fig. 6 - Dichotomic key for the six italian species

Tab. III - Characteristics of preorbital bones for several Mugilidae species. Ratio between maximal width and height (l/L), characteristics of the different margins (am, pm, um, lm, la, lp, ua, up) and external (ext) and internal (int) faces.

	<i>M. cephalus</i>	<i>L. aurata</i>	<i>L. saliens</i>	<i>L. ramada</i>	<i>C. labrosus</i>	<i>O. labeo</i>
l/L	2	1	2,5	2	1,5	1,5
am	Convex	Pointed	Strongly pointed or slightly convex	Small protuberances rounded	Pointed or slightly rounded	Pointed
pm	Convex	Slightly convex + serrated	Straight + slightly serrated	Straight + serrated	Slightly convex + serrated	Straight + slightly serrated
um	Straight + small protuberance	Slightly convex + central depression	Prominent + convex	Prominent + convex	Prominent + convex	Straight
lm	Straight + strongly serrated	Slightly convex + serrated	Concave + serrated	Concave + serrated	Convex + strongly serrated	Straight
la	Slightly convex	Convex	Convex + notched	Convex	Convex	/
lp	Straight + slightly serrated	Slightly convex + serrated	Convex serrated +	Slightly rounded + serrated	Strongly convex + serrated	Straight
ua	Convex	Concave	Concave + notched	Concave + ondulations	Strongly concave	/
up	Slightly concave	Concave	Concave	Concave + encoche	Strongly concave	Straight
ext	Smooth	Smooth + anteriorly slightly convex	Smooth	Smooth + convex	Convex	Smooth
int	Convex + 1 protuberance	Convex + 1 protuberance	Concave + 2 protuberances	Concave + 2 protuberances	Concave + 2 protuberances	Convex + 1 protuberance

DISCUSSION

Members of the Mugilidae family are widely distributed in tropical, subtropical and temperate regions. These fish have a huge economical importance all over the world (fishery). Eight species were observed in the Mediterranean area (Ben-Tuvia, 1975, 1986; Bauchot, 1987; Koutrakis AND Economidis, 2000) and 6 were observed in Italy (Tortonese, 1975); all these species are important

for fishery and aquaculture (Thomson, 1990). It is therefore essential to identify species without ambiguity, also in juvenile stages. This is not possible using classical meristic characteristics since they present significant intraspecific variability and they are not clearly present in the youngest developmental stages (Serventi et al., 1996).

Our results demonstrate that preorbital bone is a perfect taxonomic characteristic for Italian Mugilidae species. It reveals significant differences between species and remains stable within species.

From the morphometric study of the preorbital bone it has been possible to create a key descriptive-graphic which is easy to consult for swift taxonomical identification of individual Mullet species. Classification is based on a dichotomic key which depends on the shape of the lower margin of the preorbital bone, and on the presence, abundance and structure of lower margin teeth (Fig. 6).

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