Biogeographia vol. XXV - 2004
(Printed December, 30 th 2004)
Marine Biogeography of the Mediterranean Sea: patterns and dynamics of biodiversity

The use of the preorbital bone as a suitable method to identify Italian species of Mullets (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 Mullet 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 mersistic 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

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

Mugil cephalus	Linnaeus, 1758	Valid name, original description
Mugil cephalus cephalus	Linnaeus, 1758	Synonym
Mugil albula	Linnaeus, 1758	Synonym
Mugil our	Forsskål, 1775	Synonym
Mugil crenilabris our	Forsskål, 1775	Synonym
Mugil tang	Block, 1794	Synonym
Mugil provinsalis	Risso, 1810	Synonym
Mugil lineatus	Valenciennes, 1836	Synonym
Mugil cephalotus	Valenciennes, 1836	Synonym
Mugil perusii	Valenciennes, 1836	Identification mistake
Mugil japonicus	Temminck & Schlegel, 1845	Synonym
Mugil vulpinus	Nardo, 1847	Synonym
Mugil chaptalii	Eydoux & Souleyet, 1850	Ide,tification mistake
Mugil dobula	Günther, 1861	Synonym
Mugil ashanteensis	Bleeker, 1863	Synonym
Mugil cephalus ashanteensis	Bleeker, 1863	Synonym
Myxus superficialis	Klunzinger, 1870	Synonym
Mugil gelatinosus	Klunzinger, 1870	Synonym
Mugil occidentalis	Castelnau, 1873	Synonym
Mugil mexicanus	Steindachner, 1876	Synonym
Myxus caecutiens	Günther, 1876	Synonym
Mugil grandis	Castelnau, 1879	Synonym
Mugil muelleri	Klunzinger, 1880	Synonym
Mugil mulleri	Klunzinger, 1880	Synonym
Mugil hypseloma	Ogilby, 1897	Synonym
Myxus pacificus	Steindachner, 1900	Synonym
Myxus barnardi	Gilchrist & Thompson, 1910	Synonym
Mugil galapagensis	(Ebeling, 1961)	Identification mistake
Oedalechilus labeo	(Cuvier, 1829)	Valid name
Mugil labeo	Cuvier, 1829	Original description
Mugil provensalis	Risso, 1810	Identification mistake
Liza labeo	(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 Meditereanean 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 (Athanassopoulos, 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 ± 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
C. labrosus	N=12 [6,8–45,6] 20,4±3,4	N=21 [11,3–27,4] 17,8±1,2	N=16 [15,9–43,9] 30,1±2,1	/	N=12 [24,6–38,1] 33,4±1,2	N=4 [20,7–24,5] 23,28±0,89	N=65 [6,8–45,6] 24,5±1,2
L. aurata	N=5 [18,3–34,9] 26,9±2,9	N=8 [21,9–38,9] 29,6±2,2	N=9 [22,6–37,3] 28,4±1,7	N=8 [10,4–15,6] 12,5±0,6	N=10 [22,8–35,9] 30,5±1,6	N=18 [20,4–32,3] 24,8±0,8	N=57 [10,4–38 ,9] 25,5±0,9
L. ramada	N=11 [15,7–40,4] 27,8±2,4	n=6 [24,7–36,3] 30±1,9	N=6 [27,9–37,3] 34,1±1,4	N=4 [16,9–24,7] 21,9±1,8	N=6 [24,9–34,8] 30,3±1,6	N=23 [23,7–36,9] 30,2±0,93	N=55 [15,7–40,4] 29,5±0,8
L. saliens	N=14 [10,4–30,1] 18,4±1,4	N=8 [13,8–26,9] 20,1±1,6	N=7 [16,7–23,8] 21±1,0	N=2 [14,5–14,8] 14,7±0,2	N=11 [15,5–21,1] 18,7±0,5	N=16 [12,4–24,5] 17,4±0,9	N=58 [10,4–30,1] 18,6±0,5
M. cephalus	N=5 [15,5–50,3] 34,2±6,5/	/	/	/	N=5 [37,9–55 ,8] 47,3±2,9	N=1 [15,5–56,7] 56,7	N=11 [3,5–23] 42,2±3,9
O. labeo	N=124 [3,5–23] 15,4±0,4	N=14 [10,4–15,9] 13,3±0,4	N=10 [10,4–15,3] 12,6±0,4	/	N=14 [10,6–19,7] 13,4±0,6	/	N=161 [3,5–23] 14,9±0,3

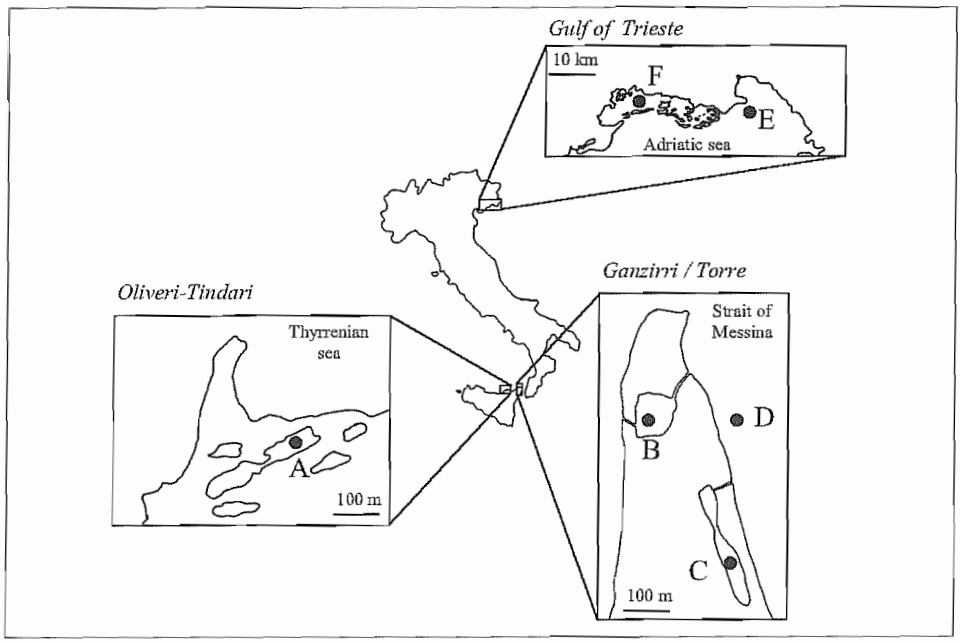
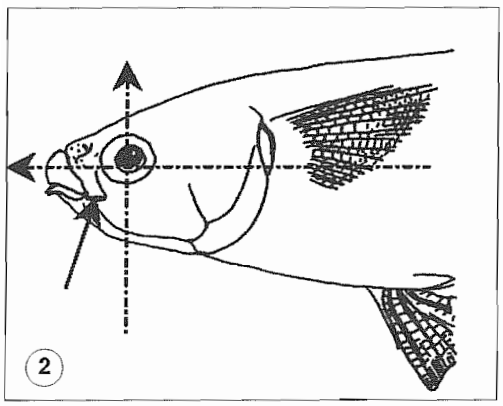


Fig. 1 - Sampling stations. A: Porto Vecchio lagoon in Oliveri-Tindari; B: Lago Faro lagoon in Torre Faro; C: Lungolago lagoon in Ganzirri; D: Strait of Messina; E: Grado lagoon; F: Trieste Gulf



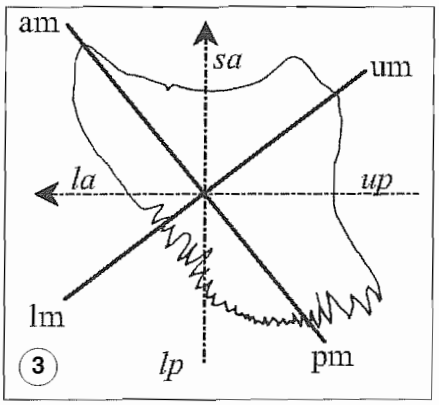


Fig. 2 - Preorbital bone location and anterior-posterior and lower-upper axis
Fig. 3 - Terminology related to preorbital bone: am: anterior margin; pm: posterior margin; um: upper margin; lm: lower margin; ua: upper-anterior margin; up upper-posterior margin; la: lower-anterior margin; lp: lower-posterior 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 immerged 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

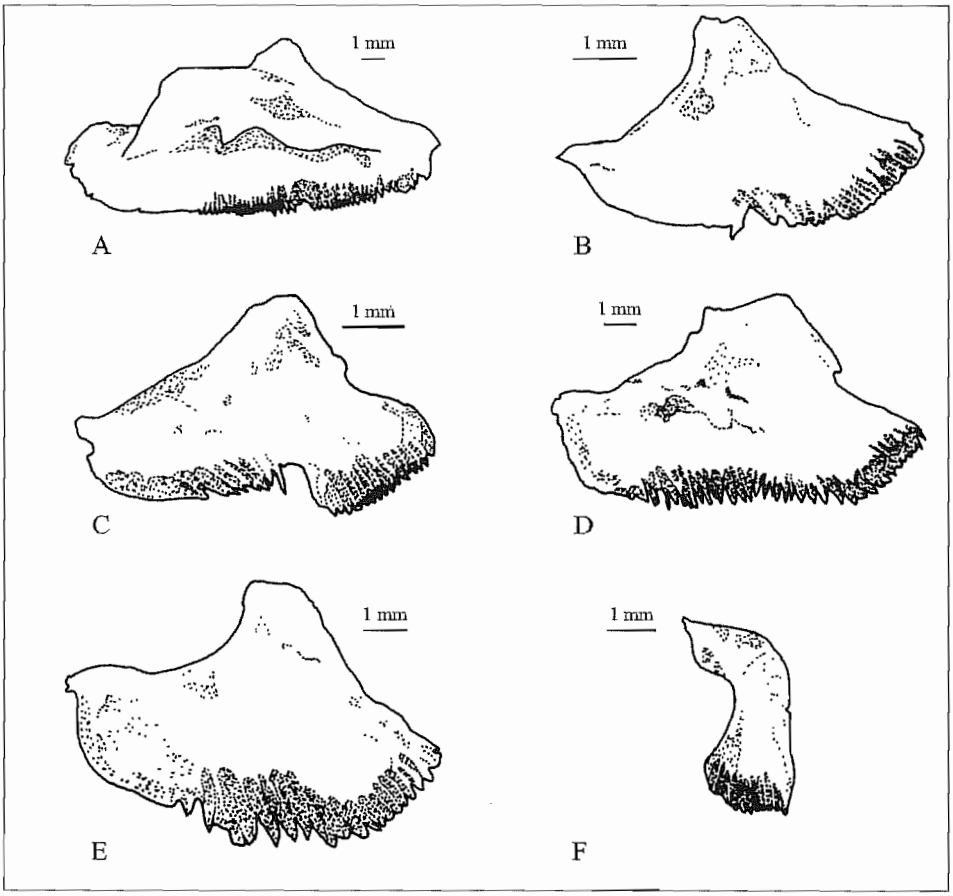


Fig. 4 - Preorbital bones of six Mugilidae species. A: *M. cephalus*; B: *L. aurata*; C: *L. saliens*; D: *L. ramada*; E: *C. labrosus*; F: *O. labeo*

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.**

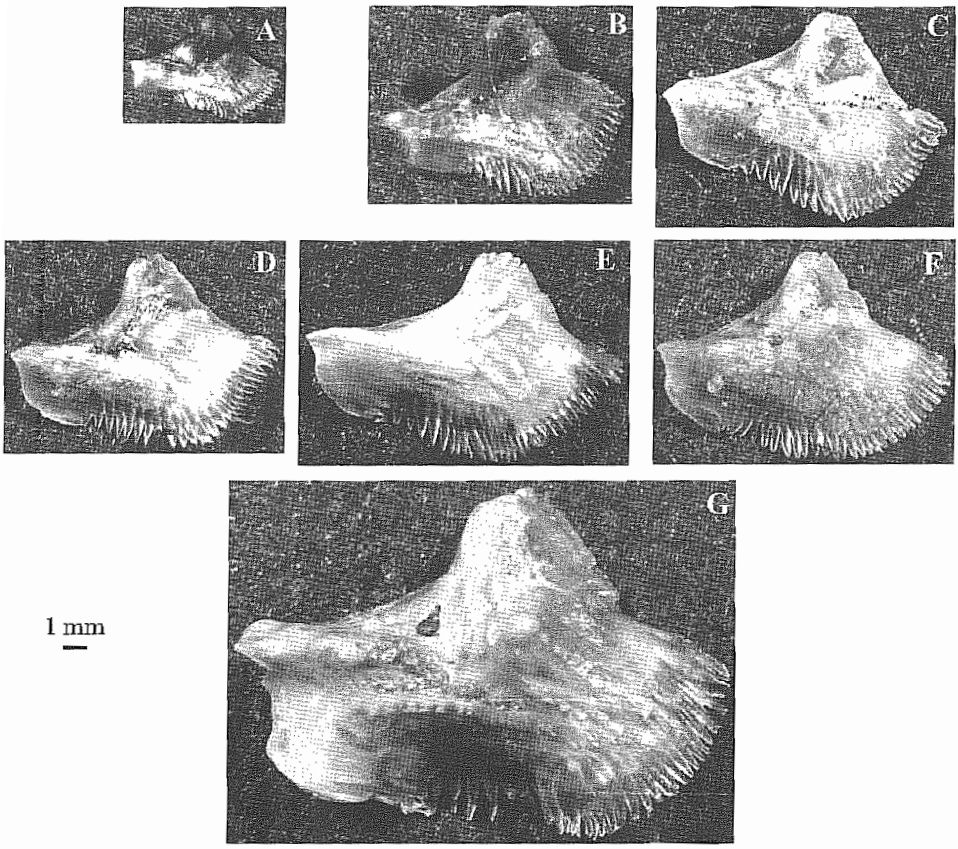


Fig. 5 - Pictures of preorbital bones of *Chelon labrosus*. A: juveniles (Strait of Messina); B: adult (Trieste Gulf); C: adult (Lungolago); D, E: adult (Grado lagoon); F: adult (Strait of Messina); G: adult (Lago Faro)

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 *Chelon 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.

1. Inferior margin straight 2

Inferior margin different 3

2. Inferior margin smooth ..... *O. labeo*

Inferior margin nearly completly serrated ..... *M. cephalus*

3. Inferior margin convex 4

Inferior margin concave 5

4. Inferior margin slightly convex with many small teeth ..... *L. aurata*

Inferior margin strongly convex with some large teeth ..... *C. labrosus*

5. Inferior margin slightly concave with many small teeth ..... *L. ramada*

Inferior margin strongly concave with few teeh ..... *L. saliens*

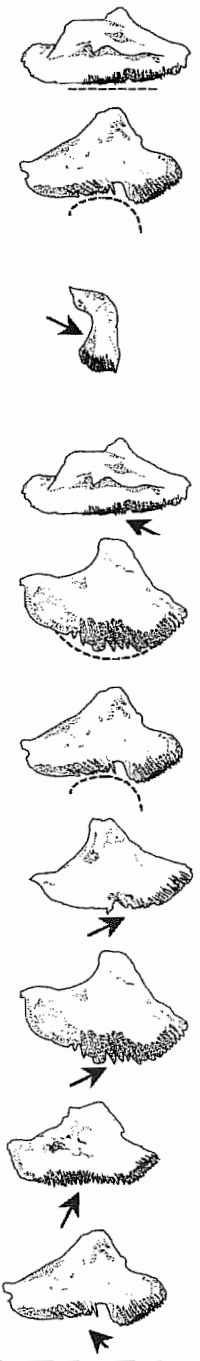


Fig. 6 - Dichotomic key for the six italian species

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.

	M. cephalus	*L. aurata*	*L. saliens*	*L. ramada*	*C. labrosus*	*O. labeo*
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).

ACKNOWLEDGEMENTS

This work was supported by a FRIA grant (Belgium) to S. Dupont. Authors would like to thank Nino Donato for his help during sampling and Pr. Puccio of the Department of Mathematic (University of Messina) for her assistance in providing the necessary software.

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