

## Biometry of the sagittal otoliths for three demersal fish species from the Eastern Adriatic Sea (Montenegro)

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*The otolith morphology, biometry and otolith size and fish length relationship of three demersal fish species: red mullet *Mullus barbatus*, common pandora *Pagellus erythrinus* and hake *Merluccius merluccius* were examined. Based on otoliths relative sizes *P. erythrinus* and *M. merluccius* have large otoliths, while *M. barbatus* has small sagittal otoliths. The relationships between otolith variables and fish somatic growth were described by a linear function. All relationships were statistically highly significant ( $p < 0.001$ ). Otolith length (OL) was found to be the variable most strongly related to fish size, with 61.2 – 95.3 % of the variability, while otolith weight had the lowest coefficient of determination ( $r^2$ ). No differences were found neither between left and right otoliths, nor between male and female otoliths in these relationships. For all species studied the relationships of otolith length, height and weight against total fish length were all found to have positive allometry, indicating that the accretion of otoliths is relatively faster than increase in fish body size. The shape indices of form factor ( $F_F$ ), roundness ( $R_D$ ), aspect ratio ( $A_R$ ), circularity ( $C$ ), rectangularity ( $R$ ) and ellipticity ( $E$ ) were calculated and the relationships between otolith length (OL) and shape indices were determined.*

**Key words:** somatic growth; sagittal otolith; shape and size of otolith; hake; red mullet; common pandora

### INTRODUCTION

Marine demersal resources are represented by fish and other marine organisms that live or feed on or near the sea bottom. The European hake (*Merluccius merluccius*) and red mullet (*Mullus barbatus*), along with deep-water pink shrimp (*Parapenaeus longirostris*), represent main target species both in Montenegrin demersal fish-

ery (IKICA *et al.*, 2018; JOKSIMOVIĆ *et al.*, 2019) and in the rest of Adriatic (UNEP-MAP-RAC/SPA 2015). Common Pandora (*Pagellus erythrinus*) is not the main target species in Montenegrin fisheries, but is one of the “main commercial species” in Montenegro, meaning that it is counted in the group of species representing 90% in weight of total landing in the country (GFCM, 2018). All three species studied fall into this category, due

to their importance to the Montenegrin fisheries in terms of quantities and economic value, and are subject to sampling in the frame of the Annual Montenegro fishery data collection programme (DCF-DCRF) according to the GFCM DCRF methodology. The total landing of European hake in Montenegro increases slightly each year with 47 tons in 2018 (20 tons in 2016, 36 tons in 2017). The situation is similar with red mullet, with a total catch of 42 tons in 2018 (15 tons in 2016, 36 tons in 2017), while the landing of common pandora was estimated at 5 tons in 2018 (Monstat 2019). Despite the high commercial importance of these species in Montenegro, they were not a research subject in previous studies. Available data refer to the length-weight relationships (JOKSIMOVIĆ, 1999; JOKSIMOVIĆ *et al.*, 2007; DULČIĆ & KRALJEVIĆ, 1996; DULČIĆ & GLAMUZINA, 2006), growth parameters estimation (JOKSIMOVIĆ, 2001; JOKSIMOVIĆ *et al.*, 2007; 2008; CARBONARA *et al.*, 2018) and populations characteristics (JOKSIMOVIĆ, 2000; MANDIĆ *et al.*, 2008; JOKSIMOVIĆ *et al.*, 2004; PEŠIĆ *et al.*, 2011; PICCINETTI *et al.*, 2021; ZORICA *et al.*, 2020; VRGOČ *et al.*, 2004; VRGOČ *et al.*, 2005).

The otoliths are one of the main biomineral structures of the internal ear in fish, and play a role in balance and hearing. They serve as a permanent record of the life history of individual (BELCHIER *et al.*, 2004). The sagittas are the largest pair of otoliths in most bony fishes (PAXTON, 2000). The size, shape and otolith characteristics vary between species, and the otolith morphology can differ between populations of the same species in different locations (REICHENBACHER *et al.*, 2009; OZPICAČ *et al.*, 2018). The morphology of otolith is influenced by ontogenetic development (CAPPOCIONI *et al.*, 2011), size (HÜSSY, 2008, LOMBARTE & CRUZ 2007), sexual maturation (MÉRIGOT *et al.*, 2007), sex (BOLLES & BEGG, 2000) as well as diet (MILLE *et al.*, 2016). Environmental factors, such as water temperature, can also produce otolith growth variation, and therefore shape variability (CARDINALE *et al.*, 2004; LOMBARTE & CRUZ, 2007)

Otolith morphology is considered to be an efficient tool for fish species determination and differentiation between different fish stocks or

populations when comparative genetic data are not available (ZHUANG *et al.*, 2014; BOSTANCI *et al.*, 2015), in ecomorphological studies (AGUIRRE & LOMBARTE, 1999; CAPPOCIONI *et al.*, 2011, CARDINALE *et al.*, 2004), and they can serve as an index for environmental studies (DEGHANI *et al.*, 2015). With the development of image analysis system, the studies of otolith morphology have become increasingly more important in numerous ichthyological studies. Only two studies regarding the morphology and shape contour of fish species from Adriatic Sea have been conducted so far, and were related to pelagic (ZORICA *et al.*, 2010) and juvenile fish species (FERRI *et al.*, 2018). However, until now little information was available on demersal fish species otoliths from Montenegrin waters (South-Eastern Adriatic), and the aim of this study was to analyse the relationship of morphometric measurements of three demersal fish species and their otolith shape variations in order to determine the possible patterns between body size and otolith morphology. The other purpose of this study was to estimate the biometric relationship between fish body measurements and otolith measurements for the selected species and determine which measurements are intercorrelated.

## MATERIAL AND METHODS

### Study area

Eastern Adriatic is characterized by a relatively narrow continental shelf and a steep slope, reaching maximum depth of 1,233 m (TEŠIĆ, 1962). The total length of Montenegrin coast is 294 km, 112 km of which represents the coast of Boka Kotorska Bay and 182 km face the open sea. A large part of Montenegrin coastline consists of precipitous rocky cliffs intersected with beaches that become more prevalent towards the south, culminating in a long stretch of sandy beach (Velika plaža in Ulcinj, 13 km in length, the longest Montenegrin beach) extending to the Albanian border at the mouth of the Bojana River. The total surface area of internal waters is 362 km<sup>2</sup>, while the surface of territorial waters is 2,098.9 km<sup>2</sup> (Fig. 1).

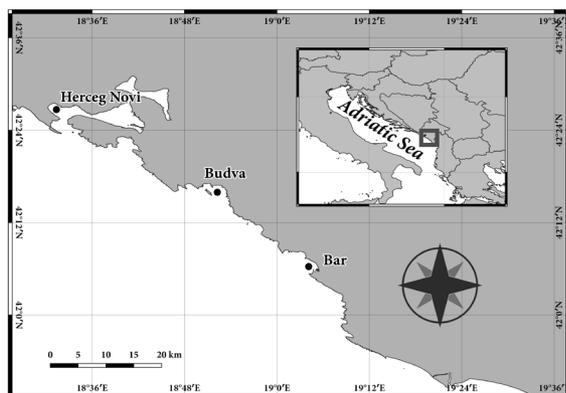


Fig. 1. Map of the study area

### Sample collection

Otoliths of three demersal fish species, *M. barbatus*, *P. erythrinus* and *M. merluccius*, originating from the Montenegrin waters, were examined. The data was collected within the frame of Data Collection Reference Framework (DCRF) programme (GFCM, 2018) performed in Montenegro since 2017 through support by Ministry of Agriculture and Rural Development (DCF-DCRF, 2020). Within the DCRF, several fishing fleet segments are sampled on a quarterly basis, among them segments using demersal trawl nets, fixed nets, i.e. gillnets and trammel-nets (DCF-DCRF, 2020). Samples were collected during direct on-board observation. Total catch of each species was weighted, and subsamples collected for further laboratory analysis. Length of individuals was measured to the nearest 0.1 cm, and weight of individuals measured to the nearest 0.01 g. Specimens were dissected to determine their sex and remove the otoliths. Sagittal otoliths were extracted under a NIKON stereomicroscope, under 50× magnification, and washed in distilled water. After drying the otoliths with filter paper, each otolith was placed on a microscopic plate, with the convex side facing up and measured to the nearest 0.001 mm under Carl Zeiss Axio Scope A1 microscope and computer-connected camera system. Four morphometric characteristics were measured: the otolith length (OL, mm), otolith width (OW, mm), otolith area (A, mm<sup>2</sup>) and otolith perimeter (P, mm). These measurements allowed the six shape indices to be calculated:

form factor ( $F_F$ ), roundness ( $R_D$ ), aspect ratio ( $A_R$ ), circularity (C), rectangularity (R), and ellipticity (E) (TUSET *et al.*, 2003; LORD *et al.*, 2012). The  $F_F$  is the inverse ratio of the squared perimeter of a circle of the same surface;  $R_D$  is the ratio between the actual area and the area of the circle of the same length while  $A_R$  is the ratio between the otolith length and otolith width (ZORICA *et al.*, 2010). The otolith weight (OW) was recorded by Mettler Toledo XPE206 analytic balance to the nearest 0.01 mg. For all measurements, descriptive statistics (mean, standard error and minimal and maximal values) were calculated. The relationships between otolith measurements (length, height and weight) and fish body lengths were estimated using the linear regression model applied the method of least squares (SOKAL & ROHLF, 1981). All otolith shape indices were first analysed for normality with Kolmogorov-Smirnov and Shapiro-Wilk tests. Analysis of variance (ANOVA) was used to compare indices between analysed species. Tukey HSD post-hoc test was used to explore differences between multiple group means in cases when ANOVA showed statistically significant differences. Moreover, relationships between shape indices and sagittal otolith length were evaluated. The strength of each relationship was evaluated from the determination coefficient ( $r^2$ ). The otolith relative size value of each species was calculated using the index  $O_R = 1000 \times OL \times TL^{-2}$ . According to  $O_R$ , otoliths were grouped into four categories: very small ( $O_R < 0.10$ ), small (0.10–0.32), medium (0.33–0.65) and large ( $> 0.65$ ) (LOMBARTE & CRUZ, 2007). The statistical procedure was completed using SPSS Statistics 20 and STATISTICA 7.0.

### RESULTS

The sagittal otoliths of *M. merluccius* (35.71% female, 64.28% male), *M. barbatus* (70% female and 30% male) and *P. erythrinus* (68.08% female and 46.87% male) were evaluated. Table 1 shows a number of individuals studied and their length and weight distribution. There were no statistically significant differences found between left and right otoliths

Table 1. Sample size (N), total length (TL) and weight (W) range of three demersal fish species used in this study

| Species                      | Common name    | N  | TL range (cm) | W range (gr) |
|------------------------------|----------------|----|---------------|--------------|
| <i>Merluccius merluccius</i> | Hake           | 56 | 14.5-32.3     | 17.35-216.32 |
| <i>Mullus barbatus</i>       | Red mullet     | 50 | 11.5-20.5     | 16.25-99.24  |
| <i>Pagellus erythrinus</i>   | Common pandora | 47 | 14.0-25.7     | 30.37-196.52 |

Table 2. Descriptive statistics of morphometric characteristics of sagittal otoliths of three demersal fish species from Montenegro. Shown are mean value and standard error for maximum otolith length – OL, otolith width – OH, otolith weight – OW, area – A and perimeter – P

| Species                      | OL (mm)    | OH (mm)     | OW (gr)       | A (mm <sup>2</sup> ) | P (mm)      |
|------------------------------|------------|-------------|---------------|----------------------|-------------|
| <i>Merluccius merluccius</i> | 12.05±1.89 | 5.13 ± 0.76 | 0.071 ± 0.028 | 42.36 ± 12.51        | 30.48± 4.53 |
| <i>Mullus barbatus</i>       | 3.07±0.36  | 2.27 ± 0.27 | 0.033 ± 0.001 | 4.78 ± 0.98          | 9.34± 1.21  |
| <i>Pagellus erythrinus</i>   | 7.88±1.27  | 5.76 ± 0.88 | 0.089 ± 0.042 | 29.46 ± 1.93         | 22.50± 3.59 |

Table 3. Regression parameters of the relationship between otolith dimensions and the total body length of three demersal fish species from Montenegro. TL-total body length, OL-otolith length, OH-otolith height, OW-otolith weight, r<sup>2</sup>-correlation coefficient, p-level of significance

| Species                      | Relationship | Regression equation | r <sup>2</sup> | p          |
|------------------------------|--------------|---------------------|----------------|------------|
| <i>Merluccius merluccius</i> | OL/TL        | OL=1.1406+0.0457TL  | 0.9531         | P<0.001*** |
|                              | OH/TL        | OH=0.8022+0.0181TL  | 0.9298         | P<0.001*** |
|                              | OW/TL        | OW=-0.0902+0.0007TL | 0.9084         | P<0.001*** |
| <i>Mullus barbatus</i>       | OL/TL        | OL=1.133+0.0126TL   | 0.7099         | P<0.001*** |
|                              | OH/TL        | OH=0.827+0.0094TL   | 0.6823         | P<0.001*** |
|                              | OW/TL        | OW=-0.0284+0.0003TL | 0.6121         | P<0.001*** |
| <i>Pagellus erythrinus</i>   | OL/TL        | OL=0.604+0.039TL    | 0.8846         | P<0.001*** |
|                              | OH/TL        | OH=0.851+0.026TL    | 0.8393         | P<0.001*** |
|                              | OW/TL        | OW=-0.146+0.001TL   | 0.8429         | P<0.001*** |

( $p > 0.05$ ), or between otoliths of males and females ( $p > 0.05$ ). All otoliths morphometric measurements for the species studied are given in Table 2. Otoliths of *M. barbatus* had the smallest values of all observed parameters, while the otoliths of *M. merluccius* were the largest and with the highest otolith extent area (Table 2). The otolith relative size ( $O_R$ ) ranged between 0.21-0.84. According to  $O_R$  size categories defined in the methodology, *M. barbatus* are considered to have Small otoliths, while *M. merluccius* and *P. erythrinus* have Large otoliths (Table 4). The otolith length, weight and height were linearly related to total fish length for the studied species. Their regression parameters were highly significant ( $p < 0.001$ ). The best fit for all three fish species were for the TL-OL

relationships, but some differences were also noticed. Namely, all otolith–fish body biometric relationships (i.e. TL-OL, TL-OH, TL-OW) had high values for *M. merluccius* and *P. erythrinus*. The lowest values of coefficient of determination for all examined biometric relationships were found for *M. barbatus* (Table 3).

According to the mean values of six examined shape indices the otoliths of *M. merluccius* had the smallest values of  $F_F$  and  $R_D$  while the values of  $A_R$ , C and E were the highest. *P. erythrinus* has the highest value of  $F_F$  indicating flattest edges compared to other species, while *M. merluccius* has the most uneven edges. The otoliths of *M. merluccius* were the most elongated while the otolith of *M. barbatus* was the most rounded among the examined demersal fish spe-

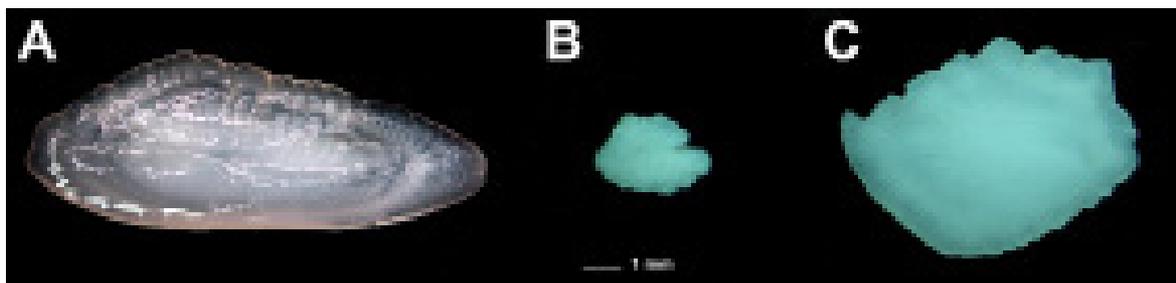


Fig. 2. Images of the sagitta of three demersal fish species: A- *M. merluccius*; B - *P. erythrinus* C - *M. barbatus*

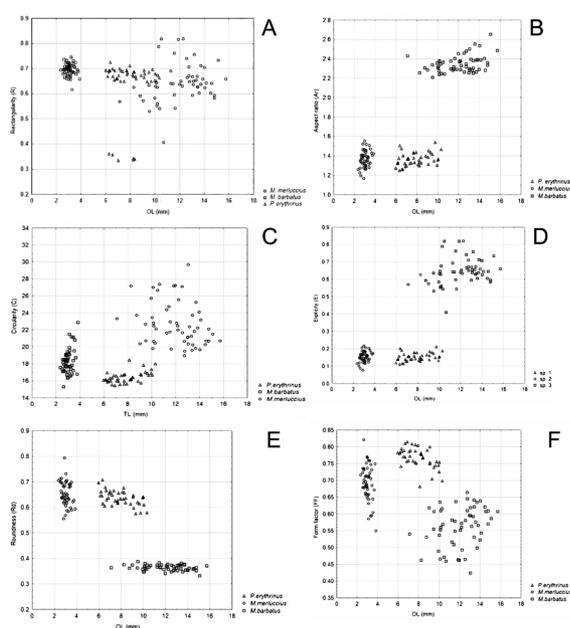


Fig. 3. Form factor (A), Roundness (B), Aspect ratio (C), Circularity (D), Rectangularity (E) and Ellipticity (F) vs. maximal otolith length of tree demersal fish species

cies (Fig. 2). ANOVA showed that there were significant differences among shape indices of all analysed demersal fishes ( $p < 0.05$ ).

The values of shape indices showed correlation with otolith lengths for studied species, but the correlation values differed for different shape indices. Namely, when otoliths length increased, values of  $R_D$  and  $C$  decreased, while  $F_F$ ,  $A_R$ ,  $R$  and  $E$  increased for the *M. merluccius* and *P. erythrinus*. For *M. barbatus*, when otolith length increased,  $F_F$ ,  $R_d$  and  $R$  decreased, while  $A_R$ ,  $C$  and  $E$  increased (Table 4, Fig. 3).

## DISCUSSION

This study contributes to the understanding the morphological features of sagittal otoliths of demersal fish species from Eastern Adriatic Sea. The present study analysed relationships between otolith length, height and weight and fish length using a linear function. The results obtained suggest there are no statistically significant differences between left and right otoliths for the studied fish species. When considering application of these results we have to emphasize that all future analyses would be standardized by using measurements from one selected otolith, left or right. The lack of statistically significant differences between left and right sagitta indicates that otoliths on either body side are equally usable for fish-size estimations (BATTAGLIA *et al.*, 2010; MEHANNA *et al.*, 2016; PARK *et al.*, 2018; YILMAZ *et al.*, 2015). Moreover, results of this study indicate there are no differences in relationships between otolith biometry and fish size between sexes. Contrary to these results, differences in otolith variables were observed between sexes for some species (VAL-LISNERI *et al.*, 2008; BOSTANCI *et al.*, 2012; KONTAS & BOSTANCI, 2015).

There are many studies that determine the relationships between otolith biometry and fish sizes (PAXTON, 2000; ZORICA *et al.*, 2010; JAWAD *et al.*, 2012, DEGHANI *et al.*, 2015). For most species, the relationship between otolith length and fish length can be described by a simple linear regression (HARVEY, 2000). In present study, otolith length showed the strongest and otolith weight the weakest relationship to fish length in all three species. These results are consistent with literature data for demersal fish species

from genera *Symphodus* and *Coris* (ŠKELJO & FERRI, 2012). Contrary to this, results of the study of pelagic fish species indicate that the otolith weight could be a more accurate indicator of somatic growth (ZORICA *et al.*, 2010).

Otolith development occurs under dual regulation: genetic conditions regulate the form of the otolith, while environmental conditions, mainly temperature, regulate the quantity of material deposited during the formation of the otolith (LOMBARTE & LLEONART, 1993). In order to describe in detail the shape of the otoliths, six shape descriptors from scientific literature were used (TUSET *et al.*, 2003; LORD *et al.*, 2012). In addition to the shape analysis, otolith relative sizes were also estimated. Variation in size and shape of sagittal otoliths has long been used as taxonomic features (NAFPAKTITIS & PAXTON, 1969). The variation in size of sagittal otoliths is significant and apparently correlated with taxonomic group, habitat, depth and luminescence (PAXTON, 2000; LOMBARTE & CRUZ, 2007). Also, environmental abiotic factors, such as temperature and salinity, are also known to influence otolith shape (LOMBARTE & LLEONART, 1993), and spatial variations in otolith shape are often interpreted as resulting from habitat differentiation (MORAT *et al.*, 2012). However, such variation in abiotic factors is generally related to differences in prey categories available to an individual predator, such that geographical variations in diet composition could also generate geographical variations in otolith shape (VIGNON, 2012). The current study results show that shape indices have a different relationship pattern with maximum otolith length. More specifically,  $R_D$ ,  $A_R$  and  $E$  show similar patterns in relations to maximum otolith length for all species, while  $F_F$ ,  $C$  and  $R$  show a different morphological pattern. Namely, when otolith lengths increased, the values of  $F_F$  and  $R$  of *M. barbatus* decreased, while for *M. merluccius* and *P. erythrinus* these values increased. On the other hand, when  $C$  for *M. barbatus* increased, the values for *M. merluccius* and *P. erythrinus* decreased (Table 5, Fig. 3). Contrary to these results, the shape indices of the pelagic fish species show a similar pattern in relationship with maximum otolith

length (ZORICA *et al.*, 2010). The similarity in otolith shape descriptors may come from the fact that all studied pelagic fish species have similar ecological traits and occupy the same ecological niche (ZORICA *et al.*, 2010). Obviously, difference in otolith shape reflects the characteristics of the individual habitat. GAULIDE & CRAMPTON (2002) suggest that there is evident separation between most pelagic fish species and most deep-living species. LOMBARTE & CRUZ (2007) found a relationship between otolith size composition, habitat and depth. The epipelagic community was characterized by species with very small otolith sizes, while in the demersal communities, the proportion of species with large sagittas increased with depth (LOMBARTE & CRUZ, 2007). CAPPOCCIONI *et al.* (2011) reported the occurrence of changes in the morphology of the European eel (*Anguilla anguilla*) otoliths as a function of growth and the different habitat ecology (a river and two brackish water lagoons). Also, the shape outline of otoliths changes during ontogenesis, along with the increase in animal size (CAPPOCCIONI *et al.*, 2011).

There is a clear relationship between taxonomic groups and otolith relative size (NOLF, 1985). Also, numerous endogenous factors can influence the otolith relative size, such as phylogeny (GAEMERS 1984; NOLF 1985), adaptive aspects related with the inner ear functions (PAXTON 2000; PARMENTIER *et al.*, 2001), or specialization in acoustic communication (LOMBARTE & CRUZ, 2007). In this study two species from order Perciformes (*M. barbatus* and *P. erythrinus*) and *M. merluccius* from Order Gadiformes were studied. The results of otolith relative size analysis show that sagittas of *M. merluccius* and *P. erythrinus* can be classified as Large ( $O_R = 0.73$  and  $O_R = 0.82$  respectively) while sagittal otoliths of *M. barbatus* could be considered Small ( $O_R = 0.21$ ). Some taxonomic group like Gadiformes tend to have medium or large sagittae, while Perciformes, with their great ecological and morphological variability, exhibit a wide range of otolith sizes (LOMBARTE & CRUZ, 2007). These results also agreed with previously reported large-sized otoliths for *P. erythrinus* and small for *M. barbatus* (LOMBARTE & CRUZ,

Table 4. Descriptive statistics of six shape indices ( $F_F$ -form factor,  $R_D$ -roundness,  $A_R$ -aspect ratio,  $C$ -circularity,  $R$  – rectangularity,  $E$ -ellipticity) of three demersal fish species from Montenegro. Shown is otolith relative size-  $O_R$ , size category in relation to  $O_R$  (S-small, L-large) also ( $C_0$ )

| Species                      | $F_F$     | $R_D$     | $A_R$     | $C$         | $R$        | $E$       | $O_R$ | $C_0$ |
|------------------------------|-----------|-----------|-----------|-------------|------------|-----------|-------|-------|
| <i>Merluccius merluccius</i> | 0.56±0.06 | 0.36±0.01 | 2.35±0.09 | 22.63±2.54  | 0.64±0.08  | 0.40±0.02 | 0.73  | L     |
| <i>Mullus barbatus</i>       | 0.69±0.06 | 0.65±0.05 | 1.35±0.10 | 18.43±1.89  | 0.68±0.02  | 0.15±0.04 | 0.21  | S     |
| <i>Pagellus erythrinus</i>   | 0.71±0.13 | 0.59±0.11 | 1.36±0.06 | 18.63± 1.12 | 0.63± 0.11 | 0.15±0.02 | 0.84  | L     |

Table 5. Coefficient of correlation ( $r$ ) between the maximum length of fish otolith and shape indices ( $F_F$ -form factor,  $R_D$ -roundness,  $A_R$ -aspect ratio,  $C$ -circularity,  $R$  – rectangularity,  $E$ -ellipticity) of three demersal fish species from Montenegro

| Species                      | $F_F$     | $R_D$      | $A_R$    | $C$      | $R$       | $E$     |
|------------------------------|-----------|------------|----------|----------|-----------|---------|
| <i>Merluccius merluccius</i> | 0.2804*   | -0.2275    | 0.3590** | -0.2692* | 0.236     | 0.356*  |
| <i>Mullus barbatus</i>       | -0.4577** | -0.5020*** | 0.3527*  | 0.4694** | -0.3945** | 0.3403* |
| <i>Pagellus erythrinus</i>   | 0.0372    | -0.0244    | 0.3012*  | -0.0744  | 0.0556    | 0.3098* |

2007). However, it should be emphasized that the values of the relative size of otoliths of *P. erythrinus* and *M. barbatus* from Adriatic Sea were higher than in the research of LOMBARTE & CRUZ (2007) ( $O_R = 0.69$  and  $O_R = 0.16$ , respectively). On the other hand, large otoliths of *M. merluccius* are in contrast with reported medium otoliths ( $O_R=0.53$ ) for hake from north-western Mediterranean Sea (Balearic Sea) (LOMBARTE & CRUZ, 2007). The same authors suggested that the importance of acoustic communications is correlated with a moderate to large otolith size in a benthic environment in order to compensate for the reduction of light with depth. Closely related species or populations from temperate or shallower waters have relatively larger otoliths than

those from colder or deeper water (GAULDIE 1993; TORRES *et al.*, 2000).

In summary, this study demonstrated the variation in the size and shape of sagittal otoliths of demersal fish and confirmed its potential as a powerful tool for fish identifications and fish size estimation, important factors in fish stock monitoring and management. In addition, different patterns of otolith shape descriptors imply that morphology variations were correlated with ecological and environmental variations in depth and substrate type more than phylogenetics relationships. It is suggested that future studies should concentrate on the relationship between otolith shape and size with environmental factors.

## REFERENCES

- AGUIRRE, H. & A. LOMBARTE. 1999. Ecomorphological comparisons of sagittae in *Mullus barbatus* and *M. surmuletus*. J. Fish Biol. 55: 105-114. DOI: <https://doi.org/10.1111/j.1095-8649.1999.tb00660.x>
- BELCHIER, M., C. CLEMMESSEN, D. CORTES, T. DOAN & A. FOLKVORD. 2004. Recruitment studies: Manual on precision and accuracy of tools. ICES Techniques in Marine Environmental Sciences 35: 35pp. DOI: <http://dx.doi.org/10.25607/OBP-23>
- BATTAGLIA, P., D. MALARA, T. ROMEO & F. ANDOLARO. 2010. Relationship between otolith size and fish size in some mesopelagic and bathypelagic species from the Mediterranean Sea (Strait of Messina, Italy). Sci-

- entia Marina 74: 605-612. DOI: 10.3989/scimar.2010.74n3605
- BOLLES, K.L. & A.G. BEGG. 2000. Distinctions between silver hake (*Merluccius bilinearis*) stocks in U.S. waters of the northwest Atlantic based on whole otolith morphometric. Fish Bulletin 98: 451-462.
- BOSTANCI, D., S., YILMAZ, N. POLAT & S. KONTAS. 2012. The otolith biometry characteristics of black scorpion fish, *Scorpaena porcus* L., 1758. The Black Sea J. Sci 2: 59-68.
- BOSTANCI, D., N. POLAT N, G. KURUCU, S. YEDIER, S. KONTAS & M. DARCIN. 2015. Using otolith shape and morphometry to identify four *Alburnus* species (*A. chalcoides*, *A. escherichii*, *A. mossulensis* and *A. tarichi*) in Turkish inland waters. J. Appl. Ichthyol. 31(6): 1013-1022. DOI: 10.1111/jai.12860.
- CARBONARA, P., S., INTINI, J., KOLITARI, A. JOKSIMOVIĆ, N. MILONE, G. LEMBO, L. CASCIARO, I. BITETTO, W. ZUPA, M.T. SPEDICATO & L. SION. 2018. A holistic approach to the age validation of *Mullus barbatus* L., 1758 in the Southern Adriatic Sea (Central Mediterranean). Sci. Rep. 8: 13219. DOI: <https://doi.org/10.1038/s41598-018-30872-1>
- CARDINALE, M., P. DOERING-ARJES, M. KASTOWSKY & H. MOSEGAARD. 2004. Effects of sex, stock, and environment on the shape of known-age Atlantic cod (*Gadus morhua*) otoliths. Can. J. Fish. Aquat. Sci. 61: 158-167. DOI: 10.1139/f03-151
- CAPOCCIONI, F., C. COSTA, J. AGUZZI, P. MENESATTI, A. LOMBARTE & E. CICCOTI. 2011. Ontogenetic and environmental effects on otolith shape variability in three Mediterranean European eel (*Anguilla anguilla*, L.) local stocks. J. Exp. Mar. Biol. Ecol. 397(1): 1-7. DOI: 10.1016/j.jembe.2010.11.011.
- DEGHANI, M., E. KAMRANI, A. SALARPOUR & E. KAMALI. 2015. Relationship Between Fish Length and Otolith Dimensions (Length, Width) and Otolith Weight of *Sardinella sindensis*, as Index for Environmental Studies, Persian Gulf, Iran. Journal of Fisheries and Livestock Production 3:2. DOI: 10.4172/2332-2608.1000134
- DULČIĆ, J. & M. KRALJEVIĆ. 1996. Weight-length relationships for 40 fish species in the eastern Adriatic (Croatian waters). Fisheries Research, Volume 28, Issue 3: 243-251. DOI: [https://doi.org/10.1016/0165-7836\(96\)00513-9](https://doi.org/10.1016/0165-7836(96)00513-9).
- DULČIĆ, J. & B., GLAMUZINA. 2006. Length-weight relationships for selected fish species from three eastern Adriatic estuarine systems (Croatia). Journal of Applied Ichthyology, 22: 254-256. DOI: <https://doi.org/10.1111/j.1439-0426.2006.00633.x>
- FERRI, J., K. BARTULIN & F. ŠKELJO. 2018. Variability of Otolith Morphology and Morphometry in Eight Juvenile Fish Species in the Coastal Eastern Adriatic. Croatian Journal of Fisheries 76(3):91-98. DOI: 10.2478/cjf-2018-0012.
- GAULDIE, R. W. 1993. Continuous and discontinuous growth in the otolith of *Macruronus novaezelandiae* (Merlucciidae: Teleostei). J. Morphol. 216: 271-294.
- GAULDIE, R. W. & J. S. CRAMPTON. 2002. An eco-morphological explanation of individual variability in the shape of the fish otolith: comparison of the otolith of *Hoplostethus atlanticus* with other species by depth. J. Fish. Biol. 60: 1204-1221. <https://doi.org/10.1111/j.1095-8649.2002.tb01715.x>
- GFCM 2018. GFCM Data Collection Reference Framework (DCRF). Version: 20.1.
- HARVEY, J. T., R.T. LOUGHLIN, A. M. PEREZ & S.D. OXMAN. 2000. Relationship between fish size and otolith length for 63 species of fishes from the eastern North Pacific Ocean. NOAA/National Marine Fisheries Service, (NOAA Technical Report NMFS, 150).
- HUESSY, K. 2008. Otolith shape in juvenile cod (*Gadus morhua*): Ontogenetic and environmental effects. J. Exp. Mar. Biol. Ecol. 364(1):35-41. DOI: 10.1016/j.jembe.2008.06.026.
- IKICA, Z., M. DJUROVIĆ, A. JOKSIMOVIĆ, M. MANDIĆ, O. MARKOVIĆ, A. PEŠIĆ, E. ARNERI, L. CERIOLA & N. MILONE. 2018. Monitoring of the Montenegrin Fisheries Sector: Biological Sampling (September 2007 - August 2011). Stud. Mar. Monograph Series 1. ISBN: 978-9940-9613-1-2.
- JAWAD, L. Z., SADIGHZADEH & H. AL-BUSAIDI. 2012. The relationship between fish length

- and otolith dimension of mugilid fish, *Liza kluzingeri* (Day, 1988) collected from the Persian gulf near Bandar Abbas. *Ann. Ser. Hist. Nat.* 22: 77-82.
- JOKSIMOVIĆ, A. 1999. Length-weight relationship of pandora, *Pagellus erythrinus* (Linnaeus, 1758), from the Montenegrin shelf. *Acta Biologica Iugoslavica- Ichthyologia*, 31(1): 9-21.
- JOKSIMOVIĆ, A. 2000. Biomass estimate and maximum sustainable yield of Pandora *Pagellus erythrinus* (Linnaeus, 1758) in trawling fisheries at Montenegrin shelf. *Acta Biologica Iugoslavica-Ichthyologia* 32 (1): 17-29.
- JOKSIMOVIĆ, A. 2001. Growth of pandora, *Pagellus erythrinus* in Montenegrin shelf (South Adriatic). *In*: 36<sup>th</sup> Congress Commission Internationale pour l'Exploration Scientifique de la mer Mediterranee, CIESM, 24-28 September 2001, Monte-Carlo. Conference proceedings: 278.
- JOKSIMOVIĆ, A. 2004. Mortality of pandora, *Pagellus erythrinus* in Montenegrin shelf (South Adriatic). *In*: 37<sup>th</sup> Congress Commission Internationale pour l'Exploration Scientifique de la mer Mediterranee, CIESM, 7-11 June 2004, Barcelona. Conference proceedings: 374.
- JOKSIMOVIĆ, A., S. REGNER & O. KASALICA. 2007. Length-wight relationship of Red mullet, *Mullus barbatus* (L. 1758) in trawl fisheries on the Montenegrin coast. *In*: III International Conference »Fishery«, 1-3 February 2007, Zemun-Belgrade. Conference proceedings: pp. 353-358.
- JOKSIMOVIĆ, A., S. REGNER, O. KASALICA, M. ĐUROVIĆ, A. PEŠIĆ & M. MANDIĆ. 2008. Growth of the Red Mullet, *Mullus barbatus*, Linnaeus, 1758 on the Montenegrin shelf (South Adriatic). *Electron J. Ichthyol (EJI)* 4(1): 1-7. ISSN: 1565-7396.
- JOKSIMOVIĆ, A., A. PEŠIĆ, M. ĐUROVIĆ, Z. IKICA, O. MARKOVIĆ & M. MANDIĆ. 2019. The state of marine fisheries in Montenegro in the last 15 years. *Stud. Mar.* 33(2): 12-22. ISSN: 0585-5349.
- KONTAS, S. & D. BOSTANCI. 2015. Morphological and biometrical characteristics on otolith of *Barbus tauricus* Kessler, 1877 on light and scanning electron microscope. *Int. J. Morphol.* 33 (4): 1380-1385. <http://dx.doi.org/10.4067/S0717-95022015000400032>
- LOMBARTE, A. & A. CRUZ. 2007. Otolith size trends in marine communities from different depth strata. *J. Fish Biol.* 71 (1): 53-76. DOI: 10.1111/j.1095-8649.2007.01465.x.
- LOMBARTE, A. & J. LLEONART. 1993. Otolith size changes related with body growth, habitat depth and temperature. *Environ. Biol. Fishes* 37 (3): 297-306.
- LORD, C., L. MORAT, R. LECOMTE-FINIGER & P. KEITH. 2012. Otolith shape analysis for three Scleropterus (Teleostei: Gobioidae: Sciaenidae) species from New Caledonia and Vanuatu. *Environ. Biol. Fishes.* 93 (2): 209-222.
- MANDIĆ, M., A. PEŠIĆ, A. JOKSIMOVIĆ & M. ĐUROVIĆ. 2008. Main characteristic of Population Dynamic of Hake (*Merluccius merluccius*, Linnaeus 1758) in the Open Sea of the Montenegrin coastal waters. *Natura Montenegrina* 7(3): 529-536.
- MEHANNA, S. F., A. L. JAWAD, Y. A. AHMED, M. A. ABU EL-REGAL & D. DAWOOD. 2016. Relationships between fish size and otolith measurements for *Chlorurus sordidus* (Forsskal, 1775) and *Hipposcarus harid* (Forsskal, 1775) from the Red Sea coast of Egypt. *J. Appl. Ichthyol.* 32: 356-358. doi: 10.1111/jai.12995
- MERIGOT, B., Y. LETOURNEUR Y. & R. LECOMTE-FINIGER. 2007. Characterization of local populations of the common sole *Solea solea* (Pisces Soleidae) in the NW Mediterranean through otolith morphometrics and shape analysis. *Mar. Biol.* 151 (3): 997-1008. DOI: 10.1007/s00227-006-0549-0.
- MORAT, F., D. BANARU, B. MERIGOT, E.I. BATJAKAS, S. BETOULLE, M. VIGNON, R. LECOMTE-FINIGER & Y. LETOURNEUR. 2007. Relationships between fish length and otolith length for nine teleost fish species from the Mediterranean basin, Kerguelen Islands and Pacific Ocean. *Cybiurn* 32 (3): 265-269.
- MILLE, T., K. MAHE K, M. CACHERA, C. M. VILLANUEVA, H DE PONTUAL & B. ERNARDE. 2016. Diet is correlated with otolith shape

- in marine fish. Mar. Ecol. Prog. Ser. 555: 167-184. DOI: <https://doi.org/10.3354/meps11784>
- MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT. 2020. Annual Montenegro fishery data collection programme (DCF-DCRF), Podgorica.
- NAFPAKTITIS, B. G. & R. J. PAXTON. 1969. Review of the lanternfish genus *Lampadena* with a description of a new species. LA Co.Mus. Nat. His. Contrib. Sci., 138: 1-29.
- NOLF, D. 1985. Otolith piscium. In: Schultze H. P. (Edsitors) Handbook of Paleoichthyology, Vol. 10 Gustav Fisher Verlag, Stuttgart., Pp. 1-145.
- OZPICAK, M., S. SAYGIN, A. AYKUT AYDIN, E. HANCER, S. SAVAŞYILMAZ & N. POLAT. 2018. Otolith shape analyses of *Squalius cephalus* (Linnaeus, 1758) (Actinopterygii: Cyprinidae) inhabiting four inland water bodies of the middle Black Sea region, Turkey. Iran. J. Ichthyol. 5 (4): 293-302. DOI: 10.22034/iji.v5i4.311
- PAXTON, R. J. 2000. Fish otolith: do sizes correlate with taxonomic group, habitat and/or luminiscence? The Royal society 355: 1299-1303. doi: 10.1098/rstb.2000.0688
- PARK, J.M., F. T. GASTON, R. RIEDEL & E.J. WILLIAMSON. 2018. Biometric relationships between body and otolith measurements in nine demersal fishes from north-eastern Tasmanian waters, Australia. J. Appl. Ichthyol. 34: 801-805. <https://doi.org/10.1111/jai.13612>
- PARMENTIER, E., P. VANDEWALLE & F. LAGARDE. 2001. Morpho-anatomy of the otic region in carapid fishes: eco-morphological study of their otoliths. J. Fish Biol. 58: 1046-1061. <https://doi.org/10.1111/j.1095-8649.2001.tb00554.x>
- PEŠIĆ, A., A. JOKSIMOVIĆ, S. REGNER. & B. MIĆKOVIĆ. 2011. Some biological parameters of red mullet, *Mullus barbatus* (Linnaeus, 1758), in Montenegrin waters. Stud. Mar. 25 (1): 121-136.
- PICCINETTI, C., N. VRGOČ, B. MARČETA & C. MANFREDI. 2012. Recent state of demersal resources in the Adriatic Sea. Acta Adriat., Monograph Ser. No. 5, 220 p.
- REICHENBACHER, B., E. KAMRANI, R.H. ESMAEILI & A. TEIMORI. 2009. The endangered cyprinodont *Aphanius ginaonis* (Holly, 1929) from southern Iran is a valid species: evidence from otolith morphology. Environ. Biol. Fishes. 86 (4): 507-521. DOI: 10.1007/s10641-009-9549-5.
- STATISTICAL OFFICE OF MONTENEGRO – MONSTAT. 2019. Statistical Yearbook 2019. Statistical Office of Montenegro – MONSTAT, Podgorica.
- ŠKELJO, F. & J. FERRI. 2012. The use of otolith shape and morphometry for identification and size-estimation of five wrasse species in predator prey studies. J. App. Ichtyol. 28 (4): 524-530. <https://doi.org/10.1111/j.1439-0426.2011.01925.x>
- TEŠIĆ, M. 1962. About the greatest depths of the Adriatic Sea. Hidrografski godisnjak: 129-139.
- TORRES, G. J., A. LOMBARTE & B. MORALES-NIN. 2000. Variability of the sulcus acusticus in the sagitta otolith of the genus *Merluccius*. Fish. Res. 46: 5-13. DOI: 10.1016/S0165-7836(00)00128-4
- TUSET, V. M., A. LOMBARTE, A. J. GONZALES, F.J. PERTUSA & J.M. LORENTE. 2003. Comparative morphology of saggital otolith in *Seranus* spp. J. Fish Biol. 63 (6): 1491-1504. <https://doi.org/10.1111/j.1095-8649.2003.00262.x>
- UNEP-MAP-RAC/SPA. 2015. Adriatic Sea: Status and conservation of fisheries. By Farrugio, H. & Soldo, A. Edited by Cebrian, D. and Requena, S., RAC/SPA, Tunis, 58 pp.
- ZHUANG, L., Y. YE ZHENJIANG & C. ZHANG. 2014. Applications of otolith shape analysis to species separation in *Sebastes* spp. from the Bohai Sea and the Yellow Sea, northwest Pacific. Env. Biol. Fishes. 98 (2): 547-558. DOI: 10.1007/s10641-014-0286-z.
- ZORICA, B., G. SINOVIĆ & V. ČIKEŠ KEČ. 2010. Preliminary data on the study of otolith morphology of five pelagic fish species from the Adriatic Sea (Croatia). Acta Adriat., 51: 89-96.
- ZORICA, B., V. ČIKEŠ KEČ, N. VRGOČ, I. ISAJLOVIĆ, C. PICCINETTI, M. MANDIĆ, B. MARČETA & A.

- PEŠIĆ. 2020. A review of reproduction biology and spawning/ nursery grounds of the most important Adriatic commercial fish species in the last two decades. *Acta Adriat.*, 61 (1):89-100
- YILMAZ, S., O. YAZICIOGLU, S. SAYGIN (AYAYDIN) & N. POLAT. 2015. Relationships of otolith dimension with body length of European Perch, *Perca fluviatilis* L., 1758 from Lake Ladik, Turkey. *Pak. J. Zool.* 46 (5): 1231-1238.
- VALLISNERI, M., V. TROTTA, S. CAVICCHI & C. PICCINETTI. 2008. Sex specific somatic-otolith growth relationship in two Gadidae. *J. Fish Biol.* 72: 724-730. <https://doi.org/10.1111/j.1095-8649.2007.01708.x>
- VIGNON, M. 2012. Ontogenetic trajectories of otolith shape during shift in habitat use: interaction between otolith growth and environment. *J. Exp. Mar. Biol. Ecol.* 420–421: 26–32.
- VRGOČ, N., M. PEHARDA ULJEVIĆ, & S. KRSTULOVIĆ ŠIFNER. 2005. Assessment of demersal fish and shellfish stocks commercially exploited in Croatia. PHARE 2005 Project: EuropeAid/123624/D/SER/HR, Final output, p. 172.
- VRGOČ, N., E. ARNERI, S. JUKIĆ-PELADIĆ, S. KRSTULOVIĆ ŠIFNER, P. MANNINI, B. MARČETA, K. OSMANI, C. PICCINETTI & N. UNGARO. 2004. Review of current knowledge on shared demersal stocks of the Adriatic Sea. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GPC/REP//ITA/TD-12. *AdriaMed The. Doc.*, 12: 91 pp.

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## **Biometrija sagitalnih otolita tri pridnene vrste riba istočnog Jadrana (Crna Gora)**

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### **SAŽETAK**

Ispitana je morfologija otolita, biometrija i odnos veličine otolita i duljine tri pridnene vrste riba: trlja *Mullus barbatus*, arbun *Pagellus erythrinus* i oslić *Merluccius merluccius*. Na temelju relativnih veličina otolita *P. erythrinus* i *M. merluccius* imaju velike otolite, dok *M. barbatus* ima male sagitalne otolite. Odnosi između varijabli otolita i somatskog rasta riba opisani su linearnom funkcijom. Svi odnosi bili su statistički visoko značajni ( $p < 0,001$ ). Utvrđeno je da je duljina otolita (OL) pokazuje najveću povezanost s veličinom ribe, sa 61,2 – 95,3 % varijabilnosti, dok je masa otolita imala najniži koeficijent determinacije ( $r^2$ ).

Nisu pronađene razlike ni između lijevog i desnog otolita, niti između muških i ženskih otolita u tim odnosima. Za sve proučavane vrste utvrđeno je da odnosi duljine, visine i mase otolita u odnosu na ukupnu duljinu ribe imaju pozitivnu alometriju, što ukazuje da je nakupljanje otolita relativno brže od povećanja duljine tijela ribe. Izračunati su indeksi oblika faktora forme ( $F_F$ ), zaobljenosti ( $R_D$ ), omjera stranica ( $A_R$ ), kružnosti (C), pravokutnosti (R) i eliptičnosti (E) te su izračunati odnosi između duljine otolita (OL) i indeksa oblika.

**Ključne riječi:** somatski rast; sagitalni otolit; oblik i veličina otolita; oslić, trlja; arbun