OTOLITH MORPHOLOGY AND FISH SIZE RELATIONSHIPS FOR FIVE WRASSE SPECIES IN THE EASTERN ADRIATIC SEA

Frane Skeljo [1] and Josipa Ferri [1]*
[1] University of Split, Center of Marine Studies - josipa.ferri@unist.hr

Abstract
Sagittal otoliths of five wrasse species, *Coris julis* (Linnaeus, 1758), *Symphodus tinca* (Linnaeus, 1758), *Symphodus cinereus* (Bonnaterre, 1788), *Symphodus ocellatus* (Forsskål, 1775) and *Symphodus rostratus* (Bloch, 1791) were described and compared using morphometric parameters. General otolith shape is the same for all wrasse species, although sagittal morphological variations between the species and different length groups were observed. Results for all investigated species showed that the otolith length is the best indicator of fish total length.
Keywords: Adriatic Sea, Teleostei, Biometrics

Introduction
Otoliths are one of the most useful anatomic fish structures in various studies because of their characteristics (size, morphological specificity and microstructure) and dependence of these properties on the variation in environmental factors [1]. Such applications are widely used by researchers studying feeding ecology of fish predators, although are not just limited to ichthyology. The adequate identification of fish prey from otoliths is essential in feeding studies, where the relationship between otolith length and fish length or weight given by specific regressions can also be used to estimate the prey size or mass. The aim of this study was to investigate otolith morphology of five wrasse species, establish the relationship between otolith size and fish size and to evaluate the usefulness of the otolith shape factors in separation of different wrasse species.

Materials and Methods
Fish samples were collected from the middle eastern Adriatic coast using a beach seine (mesh size 28 mm), from June 2009 to October 2009. The total length (TL) of each wrasse specimen was measured to the nearest mm, weight was measured to the nearest gram, and sagittal otoliths were removed, cleaned and stored dry for afterwards examination. Maximum otolith length (OL), width (h), thickness (d) and weight (OW) were taken for each otolith and its morphology was described [2]. A linear multiple regression model was fitted to the data in order to predict the total fish length from the length, width, thickness and weight of the otolith. The predicitve regression equation took the form $Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots + b_ix_i$, where a=constant, b_n=regression coefficients and x_i=independent variables. Forward stepwise multiple regression (probability of alpha to enter <0.15) was used to determine which parameters would best predict total length in selected species.

Results and Discussion
In this study, otolith morphology of *Coris julis* (N=150) ranging from 5.5 to 21.5 cm TL, *Symphodus tinca* (N=144) ranging from 6.5 to 22 cm TL, *Symphodus cinereus* (N=127) ranging from 6.0 to 10.3 cm TL, *Symphodus ocellatus* (N=120) ranging from 5.8 to 9.5 cm TL and *Symphodus rostratus* (N=95) ranging from 7.2 to 11.5 cm TL was described. Based on changes observed in otolith morphology, four otolith categories for *C. julis* and *S. tinca* and two for *S. cinereus*, *S. ocellatus* and *S. rostratus* were distinguished. In general, otolith shape of investigated wrasse species is cuneiform while entire otolith margins are characterized only for *C. julis* and *S. ocellatus*. Anterior part of otolith, including rostrum and antirostrum is well developed in all species except *C. julis*, where antirostrum is poorly defined. On the other hand, *S. tinca* and *S. cinereus* otoliths have deep and acute notch and due to that can be easily distinguished from others. For all species, correlation between fish length and different otolith measurements was statisticaly significant at alpha level of 0.005, with otolith length showing the highest (0.70 – 0.96), and otolith thickness lowest (0.29 – 0.85) values of Pearson correlation coefficient. When a forward stepwise multiple regression model was fitted to the entire data set, the resulting equations excluded variables that did not significantly improve the regression: otolith width for *S. cinereus*, otolith weight for *S. tinca*, and both otolith thickness and weight for *S. rostratus*. For all equations, coefficient of determination (R^2) was reasonably high, ranging from 59.5% for *S. ocellatus* to 93.4 % for *C. julis* (Table 1). However, using only otolith length as prediction variable produces linear regession equations with only slightly lower R^2 values for all analyzed species, except *S. ocellatus* (Table 2). Therefore, use of a multivariate model is probably not justified given the additional work required to measure several parameters, with only slight improvement in the precision of estimated fish length.

Tab. 1. Results of stepwise variable selection using multiple regression model for fish length and otolith measurements

	Variable in model*					R^2 (%)
	Constant	Length (mm)	Width (mm)	Thickness (mm)	Weight (g)	
C. julis	-9,621	60	67	-79	8347	93,4
S. tinca	6,602	53,6	54	-57		87,8
S. rostratus	19,85	31,7	45,1			80,7
S. cinereus	47,6	27,6		-42	13782	62,1
S. ocellatus	38,31	32,4	25	-93	16263	59,5

* Values are coefficients of multiple linear regression equation;
R^2 - coefficient of determination

Tab. 2. Linear regression equations for fish length and otolith length

	Constant*	Length* (mm)	R^2 (%)
C. julis	-28,68	96,7	91,2
S. tinca	13,38	64,1	84,8
S. rostratus	29,63	53,1	74,8
S. cinereus	25,05	42,7	58,5
S. ocellatus	15,82	49,6	49,1

* Values are coefficients of linear regression equation;
R^2 - coefficient of determination

References
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