



Relationships between Otolith Dimensions and Body Length of Five Cyprinid Fish Species from Lake Skadar, Adriatic Catchment of Montenegro

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Abstract: This study examined the relationship between the lapillus otolith morphometric variables (length, height and weight) and body growth of five cyprinid fish species: *Alburnus scoranza* Bonaparte, 1845, *Chondrostoma ohridanum* S. Karaman, 1924, *Rutilus albus* Marić, 2010, *Rutilus prespensis* (S. Karaman, 1924) and *Squalius platyceps* Župančič, Marić, Naseka & Bogutskaya, 2010 from Lake Skadar, Montenegro. The nonlinear regression model proved to be more suitable for the examined cyprinid fish species. There were no statistically significant differences found between left and right otoliths for all examined fish species. The otolith variable most strongly related to fish size for *A. scoranza*, *R. albus* and *R. prespensis* was otolith length, while for *C. ohridanum* and *S. platyceps* the variable most strongly related to fish size was otolith weight. This study provides the first comprehensive results regarding the relationship between the lapillus otolith morphometric variables and body length of the examined fish species.

Key words: Balkan, lapillus otolith, shape and size of otolith, somatic growth

Introduction

Lake Skadar is the largest Balkan lake and a region widely recognised as a European biodiversity hotspot (GASTON & DAVID 1994). It is one of the key biodiversity areas in the Mediterranean (DARWALL et al. 2014). The freshwater ichthyofauna of Lake Skadar consists of 59 species; 44 of them are native to the watershed and 15 are introduced. Seven species are endemic (MARIĆ 2019).

The otolith is a biomineralised crystalline-organic complex composed mainly of calcium carbonate; it functions as a hearing and balancing organ in teleosts (CAMPANA 1999). It has been suggested that the species-specific variations in otolith morphology is determined by synergistic influences of both genetic

and environmental components (MONTEIRO et al. 2005, VIGNON & MORAT 2010). By using the relationship between fish length and otolith dimensions it is possible not only to identify fish species and fish stock but also to estimate characteristics such as fish size, age, prey size (from stomach samples and analysis of digestive tract content) and feeding habits (DEGHANI et al. 2015).

Despite the increase in otolith morphology studies throughout the world, the morphology of otoliths and their relationship with body length remains largely unknown for freshwater fishes of Montenegro. Available data only refer to the relationships between otolith dimensions and body length of European eel from the Adriatic catchment of Montenegro (KANJUH et al. 2018).

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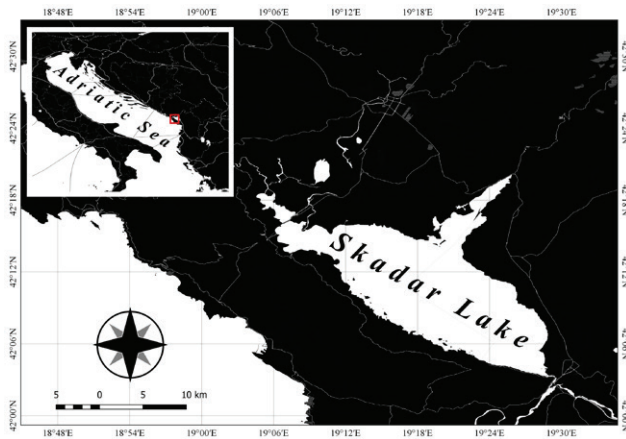


Fig. 1. Map of the study area.

The aim of the present study was to describe, for the first time, the relationship between lapillus otolith growth and somatic growth for five fish species from Montenegro, for which no previous estimates were available in the international literature, including in the electronic data bank Fish Base (FR-OESE & PAULY 2016).

Materials and Methods

We analysed the otoliths of 30 specimens of five cyprinid fish species: *Alburnus scoranza* Bonaparte, 1845, *Chondrostoma ohridanum* S. Karaman, 1924, *Rutilus albus* Marić, 2010, *Rutilus prespensis* (S. Karaman, 1924) and *Squalius platyceps* Župančić, Marić, Naseka & Bogutskaya, 2010. Fish were collected from Lake Skadar (Adriatic catchment of Montenegro) during 2018 (Fig. 1). The specimens were caught using electric gear (Ultrasonic Inverter DC-12V LJ-4025NP). Fish total length (TL) was measured to the nearest 0.1 cm. The lapillus otoliths were removed, then washed in freshwater and stored in 70% alcohol. After drying, each otolith was placed on a microscopic plate, convex side facing up, and measured to the nearest 0.001 mm under Carl Zeiss Axio Scope A1 microscope and computer-connected camera system. Two morphometric characteristics were measured: the otolith length (OL, mm) and otolith height (OH, mm) (Fig. 2). The otolith weight (OW) was recorded by Mettler Toledo XPE206 analytic balance to the nearest 0.01 mg. Differences between the left and right otolith were tested using paired t-test. The relationships between otolith measurements (length, height and weight) and fish size were determined using both a linear ($Y = bX + a$) and nonlinear ($Y = aX^b$) regression models, where Y was otolith length, X was fish length, a was the intercept and b was the slope. The

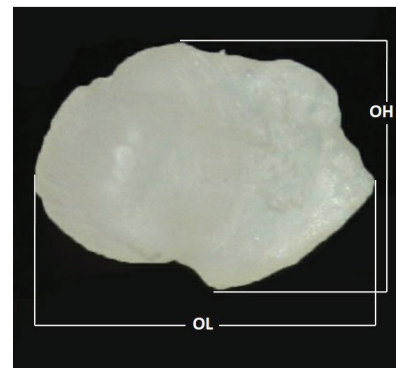


Fig. 2. Measurement axis of the lappilus otolith of *Alburnus scoranza* from Lake Skadar, Montenegro. The otolith length (OL, mm) and otolith height (OH, mm) are shown.

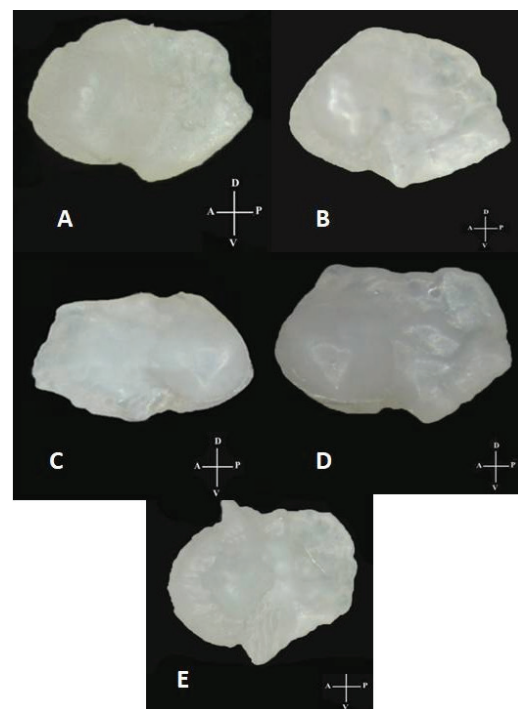


Fig. 3. Images of the lappilus otolith of five cyprinid fish species from Lake Skadar: A. *Alburnus scoranza*. B. *Chondrostoma ohridanum*. C. *Rutilus albus*. D. *Rutilus prespensis*. E. *Squalius platyceps*.

t-test was used to compare the slopes with a value corresponding to isometry (ZAR 1999). The strength of each relationship was evaluated from the determination coefficient (r^2). The statistical procedure was completed using SPSS Statistics 20 and STATISTICA 7.0.

Results

The nonlinear regression model proved to be more suitable for the examined cyprinid fish species. Sample size, minimum, maximum, and mean to-

Table 1. The descriptive statistics of fish total length (TL, cm) and weight (W, g) of five cyprinid fish species from Lake Skadar, Montenegro. Shown are minimum (Min), Maximum (Max), mean value and standard deviation (SD)

Species	TL (cm)			W (g)		
	Min	Max	Mean \pm SD (W)	Min	Max	Mean \pm SD (W)
<i>Alburnus scoranza</i>	12.5	15.8	14.08 \pm 0.705	15.5	30.8	22.26 \pm 3.433
<i>Chondrostoma ohridanum</i>	23.4	31.4	26.29 \pm 1.829	134.0	356.2	186.57 \pm 11.785
<i>Rutilus albus</i>	11.2	17.9	13.28 \pm 1.325	11.2	54.2	22.76 \pm 52.191
<i>Rutilus prespensis</i>	11.0	19.8	15.76 \pm 2.161	15.9	116.7	54.75 \pm 7.719
<i>Squalius platyceps</i>	27.2	40.0	33.61 \pm 0.384	219.5	650.0	410.66 \pm 25.307

Table 2. The descriptive statistics of otolith morphometric measurements: otolith length (OL, mm), otolith height (OH, mm) and otolith weight (OW, mg), of five cyprinid fish species from Lake Skadar, Montenegro. Shown are minimum (Min), Maximum (Max), mean value and standard deviation (SD)

Species	Parameters	Min	Max	Mean/SD
<i>Alburnus scoranza</i>	OL	1.53	1.98	1.71/0.104
	OH	1.03	1.49	1.25/0.106
	OW	0.001	0.003	0.002/0.0005
<i>Chondrostoma ohridanum</i>	OL	2.38	3.07	2.64/0.181
	OH	1.69	2.65	2.09/0.195
	OW	0.006	0.011	0.007/0.001
<i>Rutilus albus</i>	OL	1.59	2.43	1.99/0.383
	OH	1.33	1.93	1.54/0.124
	OW	0.002	0.005	0.003/0.0006
<i>Rutilus prespensis</i>	OL	1.66	2.71	2.29/0.269
	OH	1.26	2.09	1.72/0.205
	OW	0.002	0.007	0.004/0.001
<i>Squalius platyceps</i>	OL	3.05	4.76	4.07/0.384
	OH	2.79	4.13	3.25/0.327
	OW	0.014	0.29	0.003/0.005

tal lengths and weights, values of a and b with their respective 95% confidence limits and the coefficients of determination r^2 for each examined species are given in Table 1. The otolith images of five examined species are presented in Fig. 3. There were no statistically significant differences found between left and right otoliths ($P > 0.05$). The morphometric measurements of otoliths of the five examined fish species are given in Table 2. The variable most strongly related to fish size for *A. scoranza*, *R. albus* and *R. prespensis* were OL with 68.5%, 80.9%, 90.9% of the variability, respectively. For *C. ohridanum* and *S. platyceps* the variable most strongly related to fish size were OW, with 70.7% and 76.8% of the variability, respectively (Table 3).

Discussion

The relationships between the fish size and the lapillus otolith measurement were examined for the first time for five cyprinid fish species, all originating from the Lake Skadar. In this study, relationships between otolith length, height and weight and fish length were analysed using both linear and nonlinear function. The nonlinear regression model proved to be more suitable for the examined cyprinid fish species. The same regression model provided the best fit for *Abramis brama*, *Blicca bjoerkna*, *Carassius gibelio* and *Scardinius erythrophthalmus* from Lake Sadik from Turkey while linear regression model was the most appropriate model for *C. regium* (YILMAZ et al. 2015). Results of the present study suggest there are no statistically significant differences between left and right otoliths for the studied fish species. In terms of possible application of obtained results, standardisation of all future analyses would be done through selecting one otolith, left or right and using measurements from that one. Either body side's otoliths can be equally used for fish-size estimations since there is lack of statistically significant differences between left and right sagitta (BATTAGLIA et al. 2010, YILMAZ et al. 2015). There is dual regulation of otolith development – the form of the otolith is regulated by genetic conditions and the quantity of material deposited during the formation of the otolith is regulated by environmental conditions, mainly temperature (LOMBARTE & LLEONART 1993). Results of this study showed that the otolith length was the more closely related variable to fish length growth compared to otolith weight for *A. scoranza*, *R. albus* and *R. prespensis*. In contrast, for *C. ohridanum* and *S. platyceps*, the variable most strongly related to fish size was the otolith weight. TARKAN et al. (2007) showed that the lapillus length can be used as a predictor of fish length for five cyprinid species: *Vimba vimba*, *Rutilus rutilus*, *S. erythrophthalmus*, *B. bjoerkna* and *C. gibelio*; our findings are consistent with their re-

Table 3. Regression parameters of the relationship between otolith dimensions and the total body length of five cyprinid fish species from Skadar Lake, Montenegro: TL – total body length, OL – otolith length, OH – otolith height, OW – otolith weight, a and b – regression coefficients, standard r^2 – coefficient of determination, p – level of significance

Species	Relationship	a	95% CL of a	b	95% CL of b	r^2	p
<i>Alburnus scoranza</i>	TL/OL	0.030	-0.019-0.008	0.817	0.495-1.138	0.685	0.000***
	TL/OH	0.044	-0.081-0.169	0.678	0.01-1.256	0.398	0.029*
	TL/OW	0.004	-0.016-0.047	1.484	0.039-2.928	0.361	0.054
<i>Chondrostoma ohridanum</i>	TL/OL	0.058	-0.028-0.144	0.685	0.420-0.954	0.685	0.000***
	TL/OH	0.134	-0.209-0.047	0.493	0.034-0.951	0.365	0.044*
	TL/OW	0.002	-0.12-0.032	1.421	0.903-1.938	0.707	0.000***
<i>Rutilus albus</i>	TL/OL	0.071	0.02-0.122	0.682	0.537-0.827	0.809	0.000***
	TL/OH	0.088	0.015-0.16	0.585	0.418-0.751	0.716	0.000***
	TL/OW	0.013	0.002-0.046	1.435	0.954-1.915	0.662	0.000***
<i>Rutilus prespensis</i>	TL/OL	0.042	0.012-0.071	0.789	0.655-0.922	0.909	0.000***
	TL/OH	0.051	0.002-0.15	0.698	0.506-0.89	0.804	0.000***
	TL/OW	0.076	0.008-0.045	1.986	1.625-2.346	0.901	0.000***
<i>Squalius platyceps</i>	TL/OL	0.081	-0.03-1.178	0.677	0.437-0.916	0.724	0.000***
	TL/OH	0.332	-0.28-0.939	0.393	0.075-0.712	0.416	0.022*
	TL/OW	0.062	-0.36-0.845	1.775	1.216-2.333	0.768	0.000***

sults for three examined species (*A. scoranza*, *R. albus* and *R. prespensis*). The otolith weight is the most susceptible to variations in growth and most closely related to fish metabolism changes; that can be the reason for the obtained differences for examined species (BOEHLERT 1985, PAWSON 1990, FLETCHER 1991). On the other side, high variability of otolith shape compromises the otolith length measurements (ZORICA et al. 2010), which will be further investigated. *Alburnus scoranza* is the examined species with the tiniest otolith, which can be due to the fact that this is planktivorous species. It is assumed that otolith contributes to lighter neurocranium, thus reducing energy consumption and making the pelagic fish species known as fast swimmers (PARMENTIER et al. 2001). According to LOMBARTE & CRUZ (2007), there is relationship between otolith size composition, habitat and depth. The similar shape of lappilus otolith is characteristic for *R. albus* and *C. ohridanum*, two species that inhabit similar benthic habitat (MARIĆ 2019). Benthic fish species are characterised by weaker swimming constraint, not acting as a restricting factor on the otolith development; thus, their otoliths are thicker (PARMENTIER et al. 2001).

The relationships between fish size and otolith measurements of examined fish species could provide useful information for the back-calculation of fish size (excluding weight) from otolith measurements. However, after calculating the length, the weight can also be calculated due to the param-

eters of length-weight relationships for examined fish species provided by MILOŠEVIĆ et al. (2012), MILOŠEVIĆ & MRDAK (2016) and MARIĆ & BURZANOVIĆ (2021). In European waters, the cyprinid family is the dominant family in fish communities. Increasing our knowledge regarding body and bone biometrics of cyprinids is therefore of great importance in the analysis of the nutrition of animals feeding on them (RADKE et al. 2000, BEYER et al. 2006). The data set presented in this study fills a knowledge gap for the Adriatic freshwater fauna, which is highly endangered; it provides significant records for the electronic data bank FishBase (FROESE & PAULY 2016).

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Received: 07.03.2021

Accepted: 20.04.2021

