

RELATIONSHIPS OF OTOLITH SIZE TO TOTAL LENGTH OF THE BURBOT (*LOTA LOTA*) FROM THE DANUBE RIVER

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ODNOS VELIČINE OTOLITA I TOTALNE DUŽINE KOD MANIĆA (*LOTA LOTA*) IZ DUNAVA

Apstrakt

Otoliti se rutinski koriste pri determinaciji vrsta, za određivanje starosti i rasta riba. Sve ove informacije su od velikog značaja za upravljanje i gazdovanje ribljim populacijama, kao i za istraživanja vezana za predator-plen odnose. Odnos između dimenzija otolita i dužine još uvek je nepoznat za većinu naših vrsta riba. Za ispitivanje ovog odnosa, odabran je manić (*L. lota*) koji je poznat kao dobra indikatorska vrsta degradacije sredine; kao vrsta koja je rani indikator uticaja klimatskih promena na hladnovodne vrste riba; kao vrste koja je u poslednje vreme (10-tak godina) postala predmet privrednog ribolova u Dunavu; kao vrsta koja predstavlja redovan i uobičajen plen u ishrani kormorana tokom njihove sezone prezimljavanja. Ispitivan je odnos dužine, širine i težine otolita i totalne dužine tela adultnih primeraka manića. Odnos sva tri morfološka parametra otolita i dužine bio je linearan, visoko korelisan ($r^2 > 0.700$) i statistički značajan (ANOVA, $P < 0.05$). Dobijeni rezultati ukazuju da je odnos širine otolita i totalne dužine tela najbolji prediktor procene dužine adultnih manića ($r^2 > 0.800$). Nije utvrđeno postojanje statistički značajnih razlika determinisanih odnosa za leve i desne otolite (t-test, $P < 0.05$) i određene su zajedničke jednačine regresione prave: $Y = 6.494X - 14.545$ za odnos dužina otolita – dužina tela, $Y = 13.964X - 11.762$ za odnos širina otolita – dužina tela i $Y = 17.006 + 0.559X$ za odnos težina otolita – dužina tela. Dobijene jednačine omogućavaju izračunavanje totalne dužine adultnih manića na osnovu kompleta podataka o morfološkim karakteristikama otolita.

Ključne reči: manić, otolit, totalna dužina
Keywords: burbot, otolith, total length

INTRODUCTION

Otoliths (ear stones) are calcareous structures in the form of aragonite in a protein matrix and commonly are used for determination of the taxon, age and size of fishes. Bony fishes have three pairs of otoliths (the sagittae, asteriscus and lapillus) placed in paired otic capsules on either side of the skull. In general, the sagittae are the largest and characterized with distinct growth rings, therefore being most frequently used by fisheries biologists for fish aging and growth studies. If a relation between otolith size and fish length exists it can be reliable tool in studies on length frequency distributions of fish stocks and commercial landings, as well as in predator-prey studies with aim to estimate original length and weight of consumed prey (Ross *et al.* 2005; Tarkan *et al.* 2007). The otolith size - fish length relationships and their significance may vary among species or among different stocks of the same species, as well as between different sizes of fish of the same species (Hunt, 1992).

The burbot (*Lota lota*), the only freshwater species among cods, is a Palearctic predator fish commonly found in rivers of the Danube basin throughout Serbia, where it inhabits both the lowland (cyprinid) and highland (salmonid) waters. Until recently, a burbot commercial fishery has developed on Danube and it became routinely fished during winter months. Moreover, it is considered as an excellent indicator species of the habitats degradation, as well as an early indicator of climate change on coldwater fish species (Edwards *et al.* 2011). Further, it is documented that burbot represents common food item of cormorants during their wintering season on the European waters (Keller, 1995). However, the status of burbot populations in Serbian waters is largely unknown and little biological information has been collected regarding them. The aim of the present study is to develop predictive relationships between morphological measures of sagittae and total length of the burbot (*Lota lota*) from the Danube, thus providing a useful tool for studies on fisheries and management issues related to this species. Additionally, these relationships may be used in studies on food habits of piscivores.

MATERIAL AND METHODS

A total of 76 burbot specimens were obtained from the commercial fisherman landings. Fish were caught in the Danube River at the Backa Palanka locality using hoop nets. The fish were measured for total length (TL) to the nearest 0.5 cm, weighed to the nearest 1.0 g and sex was determined. The sagittae were extracted, cleaned and stored dry in paper envelopes. Three morphometric characters were considered: maximum length of the otolith (anterior-posterior axis), maximum width of the otolith (dorsal-ventral axis), and weight of the otolith. Otoliths length and width were measured using a digital caliper with resolution to 0.01 mm. Otoliths were weighed using a Sartorius digital balance with resolution to 0.0001 g. Only intact otoliths with no missing parts or fractures were utilised in data processing and statistical analysis. Therefore, otolith pairs of 69 fish were examined and the left and right otoliths were considered separately. The relationships between otolith measures and fish length (TL), with fish length considered as the dependent variable, were determined using a least-squares linear regression. The significance of the linear regression was tested using an analysis of variance (ANOVA). Differences between regression coefficients for the relationships of fish length and the morphological measures of left and right otoliths were tested using *t*-tests. All statistical analysis was performed using Statistica 6.0 package (StatSoft).

RESULTS AND DISCUSSION

Fish ranged from 23.5 to 63 cm including subadults and adults. The ranges for length, width and weight were 5.17-10.25 mm, 2.4-4.99 mm, 11.3-78.3 mg and 5.23-9.99 mm, 2.4-4.98 mm and 11.3-75.9 mg for left and right otoliths, respectively (Fig. 1).

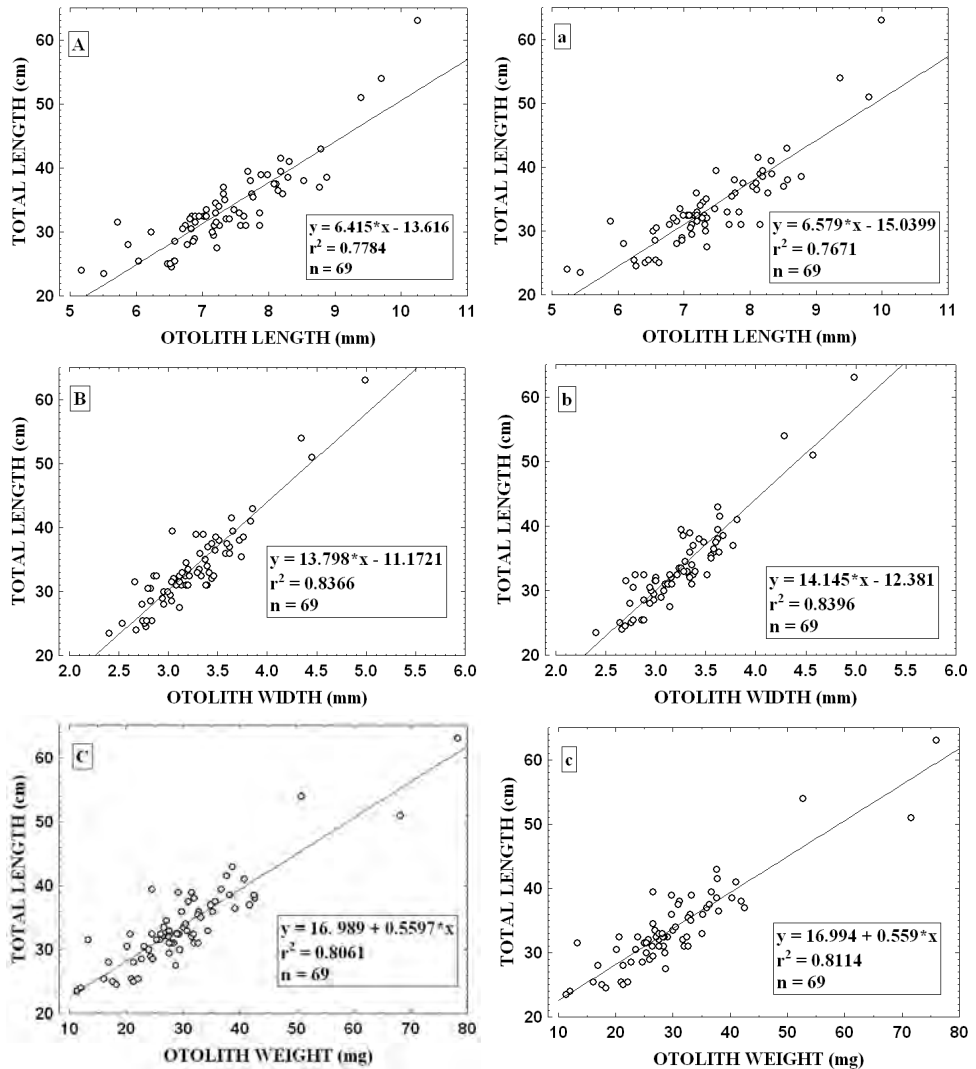


Figure 1. Linear relationships between otolith measures and total length of burbot (*L. lota*): A, B and C – left sided otoliths; a, b and c – right sided otoliths.

The relationships between all otolith morphometric measures and burbot size were linear and most of the variability were explained by obtained regression equations ($r^2 > 0.700$ in all cases; Fig. 1). All relationships were statistically significant (Tab.1), thus

confirming that the linear regression model appeared to adequately describe the relationships between otolith dimensions and fish length.

Table 1. Regression analysis of different morphometric measurements in burbot *sagittae* and total fish length.

Otolith dimensions	Sum of squares	d.f.	F ratio	r ²	P
Length (left sided)	2348.065	1	235.339	0.778	0.00
Length (right sided)	2313.855	1	220.620	0.767	0.00
Width (left sided)	2523.778	1	343.147	0.837	0.00
Width (right sided)	2532.736	1	350.740	0.840	0.00
Weight (left sided)	2431.783	1	278.622	0.806	0.00
Weight (right sided)	2447.503	1	288.170	0.811	0.00

Regression coefficients of each otolith measure to fish length were not significantly different for left and right oriented otoliths (Tab. 2). Based on these results, and according to Zar (1984), a common linear regression equation was calculated for each of the otolith measure to fish length relationship. Thus, the common linear regression equations are $Y = 6.494X - 14.545$, $Y = 13.964X - 11.762$ and $Y = 17.006 + 0.559X$ for otolith length-fish length, otolith width-fish length and otolith weight-fish length relationship, respectively.

Table 2. Results of paired sample *t*-tests comparing regression coefficients of relationships of left and right sagittal otoliths measures versus fish total length.

Otolith measure	Otolith orientation		t	P
	Left	Right		
Length				
slope	6.415	6.579	0.269	>0.05
intercept	-13.616	-15.0399	0.385	>0.05
Width				
slope	13.798	14.145	0.327	>0.05
intercept	-11.172	-12.381	0.376	>0.05
Weight				
slope	0.5597	0.559	0.015	>0.05
intercept	16.989	16.994	0.052	>0.05

Depending on species and ontogenetic stadium, the linear curvilinear and multivariate models could describe relations between otolith size and fish length (Hunt, 1992; Tarkan *et al.* 2007; Zorica *et al.* 2010; Škeljo and Ferri, 2012). Significant linear relationships were found between otolith length, width and weight and total length of adult burbot. Each of the considered otolith morphometrics was strongly correlated with fish length, indicating that both otolith weight and linear dimensions could be used as indicators for burbot length estimation. Our results are consistent with findings on other species that all three otolith size variables are appropriate for predicting size of fishes (Hunt, 1992; Zorica *et al.* 2010; Škeljo and Ferri, 2012). According to Zar (1984) the relationships with the highest coefficient of determination are considered as the best predictor. Therefore, of the considered otolith dimensions width is the most and length the least suitable character for estimation

length of burbot adults. Additionally, a strong relationship between otolith width and total length indicates that backcalculation of burbot growth rates based on otolith measurements is feasible, at least for the length ranges assessed here. The statistical testing on differences between left and right otolith are consistent with findings that in bilaterally symmetrical species the otolith pair do not vary markedly (Hunt, 1992; Loher *et al.* 2008). The lack of significant difference between otolith pairs allows the pooling both sided measurements, which is of special importance in estimating size of consumed burbot from measurements of otoliths recovered in stomachs or feces of piscivorous animals.

The common regression equations developed in the current study offer the opportunity of their use in future years to estimate burbot length from data sets of otolith measures. However, we recommend that the relationships be reviewed if data are collected from fish outside the range examined herein or from fish from different regions or different environment.

CONCLUSIONS

Results indicated that both weight and linear dimensions are linearly related to the total length of adult burbot, at least over the examined range of lengths.

Of the considered otolith dimensions, width is the most suitable character for estimation length of burbot adults.

Predicting size of burbot can be accomplished with fair reliability on the basis of developed regression equations.

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