Back-Calculation of Total Lengths of *Luciobarbus mystaceus* (Pallas, 1814) from Scale and Otolith Measurements

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Abstract: In this study, the total lengths of *Luciobarbus mystaceus* species at previous ages were estimated from scale and otolith lengths by using back-calculation methods. For this purpose, 20 fish samples with 4-7 years in age, 37.1-47.4 cm in total length and 426.1-874.1 g in weight were obtained from a commercial fisherman in Keban Dam Lake. By using the back-calculation methods, the mean total length values for each ages calculated from scale lengths and otolith lengths were estimated as $L_1=7.7$, $L_2=14.9$, $L_3=21.4$, $L_4=28.1$, $L_5=30.3$, $L_6=33.5$, $L_7=35.7$ cm and $L_1=7.5$, $L_2=14.5$, $L_3=19.2$, $L_4=26.3$, $L_5=29.6$, $L_6=33.3$, $L_7=33.9$ cm respectively. The total lengths of fish calculated from scale and otolith measurements for all age groups were always determined smaller than observed total lengths of fish. There was a significant differences between calculated and observed lengths, but did not differ between total fish lengths calculated from scale and otolith measurements.

Key words: *Luciobarbus mystaceus*, back-calculation, fish length, Scale, Otolith.

Pul ve Otolit Ölçümlerinden *Luciobarbus mystaceus* (Pallas, 1814)'un Toplam Boyunun Geri Hesaplanması

Özet: Bu çalışmada, *Luciobarbus mystaceus* türünün daha önceki yaşlardaki toplam boyları pul ve otolit boylarından geri hesaplama yöntemleri kullanılarak tahmin edilmiştir. Bu amaçla, Keban Baraj Gölü'ndeki ticari bir balıkçıdan yaşları 4-7, toplam boyları 37,1-47,4 cm ve toplam ağırlıkları 426,1-874,1 g arasında olan 20 balık elde edildi. Geri hesaplama yöntemleri kullanılarak, pul boyu ve otolit boyundan her bir yaş için tahmin edilen ortalama toplam boy değerleri sırasıyla; $L_1=7,7$; $L_2=14,9$; $L_3=21,4$; $L_4=28,1$; $L_5=30,3$; $L_6=33,5$; $L_7=35,7$ cm ve $L_1=7,5$; $L_2=14,5$; $L_3=19,2$; $L_4=26,3$; $L_5=29,6$; $L_6=33,3$; $L_7=33,9$ cm olarak hesaplanmıştır. Tüm yaş grupları için pul ve otolit ölçümlerinden hesaplanan toplam balık boylarının, daima gözlenen toplam balık boylarından daha küçük olduğu belirlenmiştir. Hesaplanan ve gözlenen balık boyları arasında anlamlı bir fark var iken, pul ve otolit ölçümlerinden hesaplanan toplam balık boyları arasında fark yoktur.

Anahtar kelimeler: *Luciobarbus mystaceus*, geri hesaplama, balık boyu, pul, otolit**.**

1. Introduction

Age determination and growth estimation in fish are very important for sustainable fishery and fish stock management. There are more information about age determining and growth in fish [1-8]. In growth estimation studies on fish, it is not always possible to capture smaller fish due to the selectivity of fishing tools or fishing regulations of government. Therefore, the back-calculation method is widely used in estimating the growth of smaller fish that are absent or not enough in the dataset. The method is based on the assumption that the growth of the fish is proportional to the growth of the bony structures such as scale, otoliths etc. The growth rings in the chosen bony structure are used in calculating the lengths of fish at previous ages. The critical comparison of back-calculation methods used for estimation of fish growth have been done [9-13]. On freshwater fish inhabiting eastern part of Turkey, some studies have been done using the back-calculation methods to estimate fish lengths at previous ages on *Capoeta trutta* from [14], *Barbus rajanorum mystaceus* [15] and *Acanthobrama marmid* [16] from Keban Dam Lake and on *Capoeta umbla* from Hazar Lake [17]. The present study was aimed to estimate total lengths of *Luciobarbus mystaceus* species at previous ages by using back calculation methods from scale and otolith measurements.

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2. Materials and Methods

Total 20 individual of *Luciobarbus mystaceus* species were obtained from commercial fishermen fishing in the Keban Dam Lake between October and November 2017. They were transferred fish systematic laboratory of Firat University Fisheries Faculty. First, total lengths and body weights of them were determined nearest ± 1 mm and 0.1 g and precision respectively. Sagittal otoliths and a few scales from the region under the first dorsal fin were removed, cleaned and kept in 96% alcohol [1] for microscopic examination. The ages of fishes were determined from both sagittal otoliths and scales. Then the lengths of each yearling age ring (annulus) were measured nearest 0.001 mm precision by using image analysis software (LAS V4.8) connected to Leica S8APO microscope. The total lengths of fish at previous ages were estimated using Fraser-Lee back-calculation method [18, 19] for scale and Dahl-Lea back-calculation method [20, 21] for otoliths.

Fraser-Lee back-calculation equation: $Ln = a + (L-a) * (Sn/S)$

Dahl-Lea back-calculation equation: $Ln = L * (Sn/S)$

Ln = back-calculated length of the fish at age "n"

L = total length of fish at the time of capture

Sn = length of scale radius or otolith at age "n"

S = length of scale radius or otolith of fish at the time of capture

a = intercept from the regression of body length on mean scale length

The results were statistically examined by means of SPSS Ver.22 programme (IBM Cooperation).

3. Results

In this study, 20 fish samples belong to *L. mystaceus* species obtained from Keban Dam Lake were used. They were 4-7 in age group, 37.1-47.4 cm in total length and 426.1–874.1 g in body weight. The regression analysis between total length and scale radius length of fish indicated that fist formation of scale started while the fish were 16.9 mm in total length. The total fish lengths of the previous ages estimated by using the back calculation methods from the scales and otolith measurements are given in Table 1. The total fish lengths at previous ages calculated from scale and otolith measurements were found to be very close to each other (Table 1 and Figure 1). However, these calculated total lengths were significantly found smaller for all age groups compared with the observed total lengths (Figure 1).

Table 1. The total fish lengths at the previous ages (L_1-L_7) estimated by using back-calculation methods from scale and otolith measurements.

| Age	N	TL (cm)	Calculated from scales							Calculated from otoliths						
			L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_1	L_2	L_3	L_4	L_5	L_6	L_7
IV	4	37.1	7.3	12.1	16.5	20.1				6.7	12.6	19.0	24.5			
V	8	42.0	7.6	13.1	20.2	25.7	27.3			7.4	15.6	18.7	27.3	27.2		
VI	6	45.5	7.8	16.2	21.8	29.4	31.3	32.9		7.7	15.1	19.7	29.2	32.6	34.3	
VII	2	47.4	8.1	18.1	27.3	37.4	32.4	34.1	35.7	8.2	14.6	19.4	24.2	29.1	32.3	33.9
Mean			7.7	14.9	21.4	28.1	30.3	33.5	35.7	7.5	14.5	19.2	26.3	29.6	33.3	33.9
SD			0.4	2.8	4.5	7.3	2.7	0.8	-	0.6	1.3	0.4	2.4	2.7	1.4	-
SE			0.2	1.4	2.2	3.6	1.3	0.4	-	0.3	0.6	0.2	1.2	1.4	0.7	-
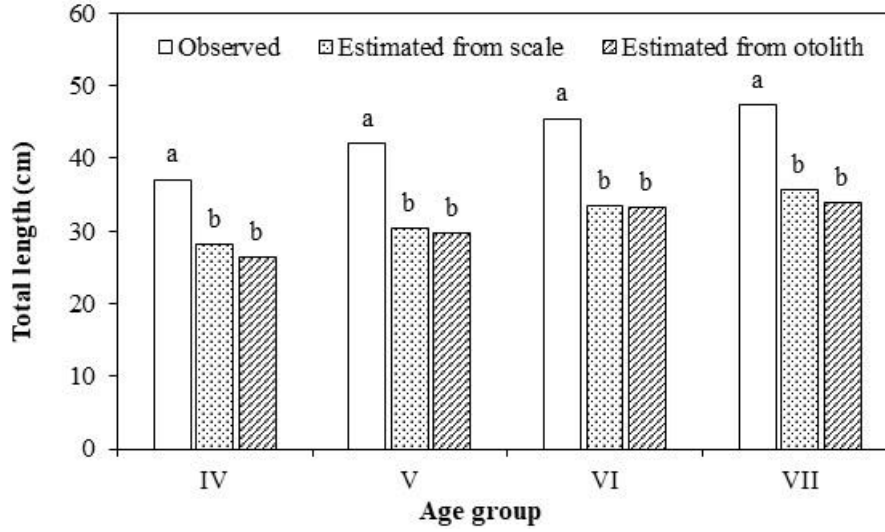
Figure 1. Observed and back-calculated total lengths of *L. mystaceus* from Keban Dam Lake. Different letters above the columns indicate significant differences ($P < 0.05$; Duncan's Multiple Range Test).

4. Discussion

In this study, 20 samples of *L. mystaceus* with 4-7 in age, 37.1-47.4 cm in length and 426.1-874.1 g in weight were examined to estimate the total lengths of fish at previous ages by using back-calculation methods from scale and otolith measurements. The total fish lengths at previous ages calculated from scale and otolith measurements were found to be very close to each other. However, the observed total lengths of fish for all age groups were always determined to be higher than the total lengths of fish calculated from both scale and otolith measurements. Similar to our result, some other studies have also been resulted that observed lengths were always higher than estimated lengths using back-calculation methods [14-17]. In addition, they were showed that the differences between calculated and measured lengths increased when earlier annuli length of scales and otoliths of older fish were used for back-calculation. The reason for this is that the bony structures measured do not show the same growth rate as the fish during the life of fish, and there may be difficulties in the age readings and measurements of bony structures.

In conclusion, back-calculation method provides important advantage to estimate the length of fish population at younger age groups that cannot normally be captured.

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