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The Estimation of Total Lengths in the Earlier Ages of Mirror Carp (*Cyprinus carpio* L., 1758) Using Back-Calculation Methods

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Abstract: In this study, the total lengths of the smaller mirror carp, that could not be caught, were estimated with the back-calculation methods using the scale and otolith lengths of larger fish. For this purpose, 50 fish samples were captured from Keban Dam Lake during October-November 2017 and October-December 2018. They were 4-9 in ages, 31.2-47.2 cm in total length and 442.5-1497.8 g in weight. The age of fish and the lengths of each age ring on scale and otolith were determined by using LAS V4.8 image analysis program attached to Leica S8APO microscope. The total lengths of fishes were calculated using Fraser-Lee and Dahl-Lea back-calculation equations for scale and otolith respectively. The mean total lengths calculated for all age groups from scale radius lengths and otolith lengths were L_1:16.1, L_2:21.3, L_3:27.3, L_4:30.5, L_5:35.7, L_6:36.7, L_7:42.9, L_8:45.3 ve L_9: 45.9 cm and L_1:14.2, L_2:17.8, L_3:22.8, L_4:25.5, L_5:33.1, L_6:36.0, L_7:41.0, L_8:41.4 ve L_9:44.0 cm respectively. In all age groups, total lengths of fish calculated from otolith lengths were found lower than total lengths of fish calculated from scale lengths.

Key words: Mirror carp, *Cyprinus carpio*, back calculation, fish length, scale, otolith

Geri Hesaplama Yöntemleri Kullanılarak Aynalı Sazanın (*Cyprinus carpio* L., 1758) Daha Önceki Yaşlardaki Toplam Boylarının Tahmini

Öz: Bu çalışmada, büyük boy aynalı sazanların (*Cyprinus carpio* Linnaeus, 1758) pul ve otolit ölçümlerinden geri hesaplama yöntemleriyle yakalanamayan küçük balıkların toplam boyları hesaplandı. Bu amaçla, yaşları 4-9, toplam boyları 31.2-47.2 cm ve ağırlıkları 442.5-1497.8 g arasında olan 50 adet balık örneği (20 adet Ekim-Kasım 2017 ve 30 adet Ekim-Aralık 2018 aylarında) Keban Baraj Gölünden yakalandı. Balıkların yaşı ile her bir yaş halkasına ait pul ışın boyları ve otolit boyları bilgisayar destekli Leica S8APO mikroskop yardımıyla LAS V4.8 imaj analiz programı kullanılarak belirlendi. Balık boyları pul için Fraser-Lee, otolit için ise Dahl-Lea geri hesaplama yöntemleri kullanılarak hesaplandı. Tüm yaş grupları için pul ışın boyları kullanılarak hesaplanan toplam balık boyu ortalama değerleri L_1:16,1; L_2:21,3; L_3:27,3; L_4:30,5; L_5:35,7; L_6:36,7; L_7:42,9; L_8:45,3 ve L_9: 45,9 cm olarak, otolit boyları kullanılarak hesaplanan toplam balık boyu ortalama değerleri ise L_1:14,2; L_2:17,8; L_3:22,8; L_4:25,5; L_5:33,1; L_6:36,0; L_7:41,0; L_8:41,4 ve L_9:44,0 cm olarak hesaplandı. Tüm yaş gruplarında otolit boylarından hesaplanan toplam balık boyları, pul ışını boylarından hesaplananlara göre daha düşük bulundu.

Anahtar Kelimeler: Aynalı sazan, *Cyprinus carpio*, geri hesaplama, balık boyu, pul, otolit

1. Introduction

There are many resources on the determination of age and growth in fish [1-9]. In fishery studies, it is important to have a sufficient number of fish samples at different sizes for accurate estimation of age and growth. However, sometimes it is not always possible to catch smaller fishes depending on the fishing method used and preferring a different habitat by the smaller fishes. Furthermore, fisheries legislation prohibits the capture of smaller fishes in order to protect the fish stocks. These situations make it difficult to obtain information about the age and growth of smaller fishes in a population. For this reason, the age and growth of smaller fishes, that cannot be sampled, are scientifically estimated from the measurements of some bony structures of the larger size individuals of the same species by using a suitable back-calculation method [10-15]. The critical comparison of back-calculation methods used for estimation of fish growth have been done [16-20].

Mirror carp is the most common species of the carp family in the inland waters of Turkey. The various aspects of mirror carp population in Keban Dam Lake were investigated by researchers [21-24]. Some studies have been done using the back-calculation methods to estimate fish lengths at previous ages on *Capoeta trutta* [7], *Barbus rajanorum mystaceus* [25], *Acanthobrama marmid* [26] and *Luciobarbus mystaceus* [27] from Keban Dam Lake

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and on *Capoeta umbla* from Hazar Lake [28]. However, there is no any research on the estimation of fish lengths at previous ages the back-calculation methods. Therefore, the main aim of this study estimates the total lengths of mirror carp *(Cyprinus carpio)* species from Keban Dam Lake at previous ages by using two different back calculation methods for scale and otolith measurements. In addition, it will be determined that which bony structure is more reliable for back-calculation in the mirror carp.

2. Materials and Methods

In this study, 50 bigger mirror carp species (20 in the October-November 2017 and 30 in the October-December 2018) from Keban Dam Lake were caught from the area close to the dam embankment (Figure 1) by a commercial fisherman.

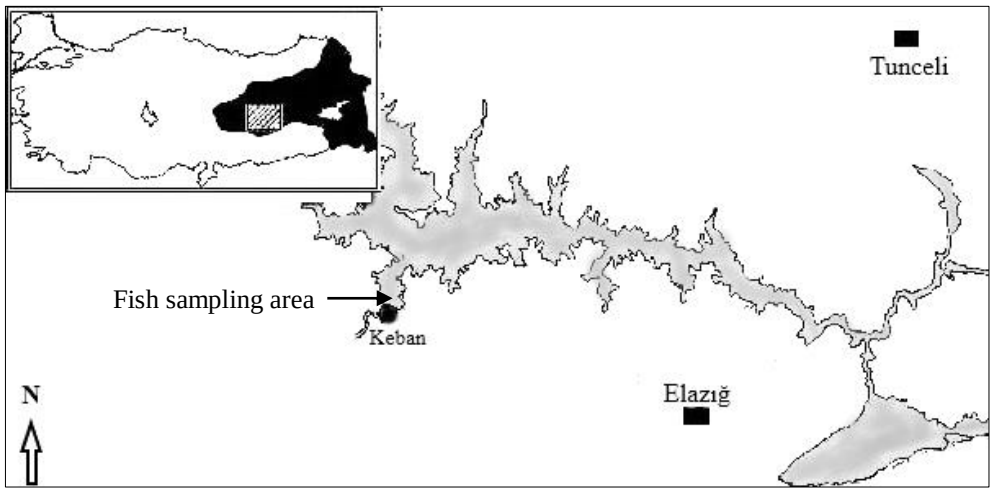

Figure 1. Fish sampling area in Keban Dam Lake

Fish samples were brought to the fish systematics laboratory of Fisheries Faculty of Firat University and the following procedures were applied.

- Total lengths and body weights were determined nearest ± 1 mm and 0.1 g precision respectively.
- Sagittal otoliths and some scales from just under the first dorsal fin were removed, cleaned and kept in 96% alcohol for microscopic examination.
- The ages of fishes were determined from both sagittal otoliths and scales.
- The lengths of each 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 calculated using Fraser-Lee back-calculation equation [29, 30] for scale and Dahl-Lea back-calculation equation [31, 32] for otoliths given below.

$$\text{Fraser-Lee back-calculation equation: } L_n = a + (L-a) \times (S_n/S)$$
$$\text{Dahl-Lea back-calculation equation: } L_n = L \times (S_n/S)$$

Where;
L_n= back-calculated length of the fish at age "n"
L= total length of fish at the time of capture
S_n= 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, 50 mirror carp species from Keban Dam Lake were used. They were 4-9 in age group, 31.2-47.2 cm in total length and 442.5–1497.8 g in body weight. The "a" value in Fraser-Lee back-calculation equation was found as 22.7 mm by using the regression analysis between total length and scale radius length of fish. This

value indicates the first formation of scale started while the fish were 22.7 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 and Figure 2. The total fish lengths at previous ages calculated from scale and otolith measurements were found smaller for all age groups compared with the observed total lengths (Figure 3).

Table 1. The distribution of 50 fish samples according to age groups, measured total lengths (TL) and total lengths (L_1-L_9) calculated using back-calculation methods from scale and otolith measurements.

Age groups	N	TL (cm)	Total lengths calculated from scale									Total lengths calculated from otolith								
			L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9
IV	5	32.1	16.7	19.0	24.7	26.9						12.1	15.5	19.3	24.7					
V	9	37.9	16.9	21.9	25.2	27.8	35.9					13.2	16.3	20.4	25.1	32.6				
VI	17	41.6	16.5	22.1	27.7	30.2	35.8	37.0				14.5	18.0	24.1	26.0	32.4	35.0			
VII	10	43.2	15.7	21.1	28.4	32.1	34.6	36.2	43.6			13.6	17.4	22.9	24.7	33.4	35.6	40.6		
VIII	6	45.8	15.4	22.3	29.1	32.8	35.8	37.5	42.8	44.9		15.2	20.0	24.1	26.6	32.8	36.0	41.5	41.6	
IX	3	47.2	15.2	21.5	28.9	33.1	36.2	35.9	42.2	45.6	45.9	16.5	19.8	26.2	26.1	34.5	37.4	40.9	41.2	44.0
Mean			16.1	21.3	27.3	30.5	35.7	36.7	42.9	45.3	45.9	14.2	17.8	22.8	25.5	33.1	36.0	41.0	41.4	44.0
SD			0.7	1.2	1.9	2.6	0.6	0.7	0.7	0.5	-	1.6	1.8	2.6	0.8	0.8	1.0	0.5	0.3	-

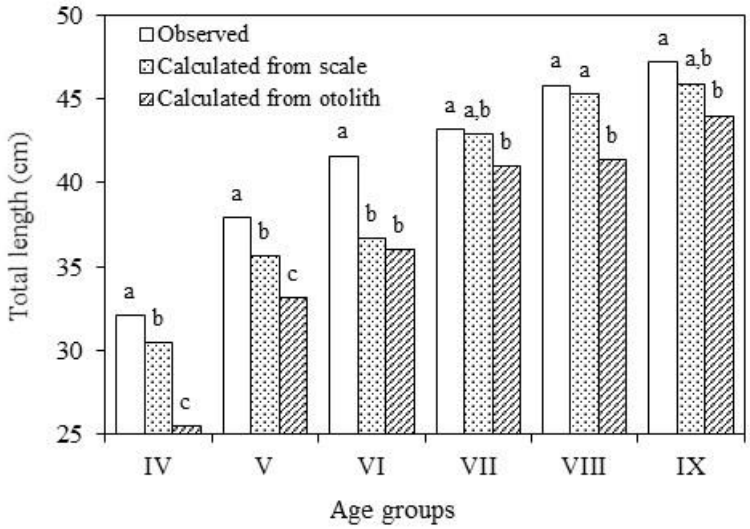

Figure 2. Observed and back-calculated total lengths of mirror carp from Keban Dam Lake. Different letters above the columns indicate significant differences ($P < 0.05$; ANOVA Duncan's Multiple Range Test).

As can be seen in Figure 3, while the gap between the measured values line and the calculated values lines is wider in the first early ages, this gap decreases in the older ages (Figure 3).

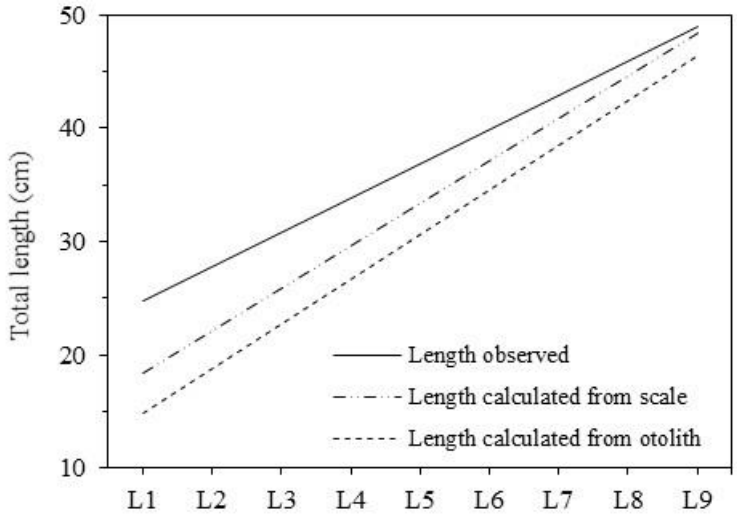

Figure 3. The comparison of total lengths (L_1-L_9) observed and calculated from scale and otolith measurements in mirror carp from Keban Dam Lake.

4. Discussion

In this study, 50 samples belong to mirror carp with 4-9 in age, 31.2-47.2 cm in length and 442.5-1497.8 g in weight were examined to estimate the total lengths of fish at earlier ages by using back-calculation methods from scale and otolith measurements. The total lengths of mirror carp at earlier ages calculated from scale and otolith measurements were found to be very close to each other. However, the measured total lengths of mirror carp for all age groups were always determined to be higher than the total lengths of mirror carp calculated from both scale and otolith measurements. Some studies have also been showed that measured total lengths were always higher than calculated lengths using back-calculation methods [7, 25, 26, 28]. In addition, they were showed that the gap between calculated and measured lengths increased when earlier annuli measurements of scales and otoliths obtained from older fishes 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. In addition, there is a difficulty in the age readings and measurements of annuli lengths of bony structures taken from the older individuals.

In conclusion, back-calculation methods provide an important advantage to estimate the length of smaller fishes that cannot normally be captured.

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