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Comparative Analysis of Otolith Features of Tarek (*Alburnus tarichi* (Güldenstädt, 1814)) from Different Lakes across Van Basin (Van, Erçek, Nazik, Aygır) (Turkey)

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ABSTRACT

In the present study, a comparison of the otolith morphology of *Alburnus tarichi*, collected from different localities throughout Van Basin was carried on. A total of 351 specimens of *A.tarichi* collected by trammel nets from four different localities (Van, Erçek, Nazik, Aygır) during the period April-May 2015 were examined. Fork length and body weight of the specimens ranged between 9.9-24.6 cm and 8.4-176.5 g, respectively. Lagenar otoliths were removed discriminating as left and right. Otolith length (*OL*), otolith breadth (*OB*) and otolith weight (*OW*) were collected. Comparisons of right-left otolith measurements were tested by paired t test. Comparisons of otolith breadth, length and weight of *A. tarichi* among all localities were tested by ANOVA. There were no significant difference in terms of otolith length and weight between right and left otoliths but there were statistically significant difference in terms of otolith breadth between the specimens collected in Lake Van and Lake Erçek. There were no differences between right and left otolith measurements in Lake Nazik and Lake Aygır. Comparing all localities together, otolith length, breadth and weight were different from each other for four localities. The power model was applied to estimate the relationships between the otolith measurements and fish length.

Keywords: *Alburnus tarichi*, Lake Van, Lake Erçek, Lake Nazik, Lake Aygır

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Van Gölü Havzası'nda Farklı Göllerden (Van, Erçek, Nazik, Aygır) (Türkiye) Örneklenen İnci Kefali (*Alburnus tarichi* Güldenstädt, 1814))'nin Otolit Özelliklerinin Karşılaştırmalı Analizi

Öz: Bu çalışmada, Van Gölü Havzası'nda farklı lokalitelerden örneklenen *Alburnus tarichi*'nin otolit morfolojisi karşılaştırılması gerçekleştirilmiştir. Nisan-Mayıs 2015'te dört farklı habitattan (Van, Erçek, Nazik, Aygır) 351 *A. tarichi* bireyi fanyalı ağlar aracılığıyla örneklenmiş incelenmiştir. Örneklerinin çatal boyları ve ağırlıkları sırası ile 9,9-24,6 cm, 8,4-176,5 g arasındadır. Lagenar otolitler sağ ve sol ayrımı yapılarak çıkarılmıştır. Otolit boyu (*OL*), otolit eni (*OB*) ölçülmüş, otolitler tartılmıştır (*OW*). Sağ-sol otolit ölçümlerinin karşılaştırılması bağımlı örneklem t testi ile test edilmiştir. *A. tarichi*'nin tüm lokaliteler arasındaki otolit eni, otolit boyu ve ağırlığı karşılaştırmaları ANOVA ile test edilmiştir. Van Gölü ve Erçek Gölü örneklerinde sağ ve sol otolitler arasında otolit boyu ve otolit ağırlığı bakımından fark yok iken otolit eni bakımından önemli farklılık tespit edilmiştir. Nazik Gölü ve Aygır Gölü örneklerinde sağ ve sol otolit ölçümleri arasında herhangi bir farklılık yoktur. Tüm lokaliteler bir arada değerlendirildiğinde otolit boyu, otolit eni ve otolit ağırlığı dört habitatta birbirinden farklıdır. Otolit ölçümleri ve balık boyu arasındaki ilişkilerin ortaya çıkarılmasında eğrisel model kullanılmıştır.

Anahtar kelimeler: *Alburnus tarichi*, Van Gölü, Erçek Gölü, Nazik Gölü, Aygır Gölü

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Introduction

Otolith morphology varies markedly between species, however separate stocks of the same species, often identical physically, can sometimes be discriminated through subtle differences in otolith morphometrics (Mapp et al. 2017). Otoliths, often used in studies comparing intraspecific and interspecific variations, are under the control of environmental, physiological and genetic factors (Javor et al. 2011). Otolith morphometry and biometrics can be a useful tool for identification of population characteristics, aging and feeding studies as well as stock assessments (Harvey et al. 2000; Jawad et al. 2011; Hüssy et al. 2016; Bostanci et al. 2017). The stock concept is one of the most fundamental in fishery management. The morphological characteristics of fish otoliths have been taken into account in recent years in stock separation studies (Tuset et al. 2003; Zengin et al. 2015; Renán et al. 2016; Bostanci et al. 2017; Kumar et al. 2017; Mapp et al. 2017). The difference in otolith measurement values among the populations will contribute to the stock sorting studies to be performed thereafter. In this study, it is proposed that stock separation can be performed by using otolith properties.

Morphometric measurements and otolith morphometry may differ between populations of the same species living in different habitats (Reichenbacher et al. 2009; Zengin et al. 2015). Bostancı et al. (2015) investigated otolith shape and morphometry of Alburnus tarichi in Lake Van. However, to the authors' knowledge, no previous studies on otolith morphometry of lake Ercek, Nazik or Aygır have been carried on. Also, when the relationship between otolith length and fish length in a species is determined, the total, fork or standard length of a fish from its otolith length can be estimated, or vice versa (Battaglia et al. 2010; Yilmaz et al. 2014; Mahenna et al. 2016; Bostanci et al. 2017) and the otolith morphology is an additional characteristic among these species-specific criteria (Hossucu et al. 1999). The relationship between the fish size and otolith dimensions is of great importance (Jawad et al. 2011; Zan et al. 2015; Zengin et al. 2017) in studying prey-predator relationships population management studies, and archaeological research (Harvey et al. 2000; Tuset et al. 2008). This study aims to compare the otolith features of *A. tarichi* inhabiting Lake Van, Erçek, Nazik and Aygır. *A. tarichi* lives only in Van basin. Tarek, which is economically important, has an important place in Turkey inland fish production with an average production of 10,000 tons (TUIK 2014). It migrates to reproduce to different freshwater overcoming natural obstacles. This migration is followed by traditional festivals and it is also an important species in terms of tourism. *A. tarichi* is an endemic species, it is economically important and its conservation status is NT (Near Threatened) according to IUCN. So, in order to ensure the continuity of the species, stock separation studies are important to keep in place as well as the biological properties. The results of this study will present important data on stock separation and future fisheries management of the *A. tarichi* inhabiting four different habitats. Additionally, this paper provides the first information on the otolith morphometry inhabiting Lake Erçek, Aygır, Nazik.

Materials and Methods

Study material

A. tarichi (Figure 1) is endemic to Van Basin in Turkey (Elp et al. 2014). It is an economically important species migrating for spawning to river inlets and returning to the lake after the spawning season (Elp and Çetinkaya 2000). Its IUCN Red List Status is NT (Near Threatened) (Freyhof 2014).

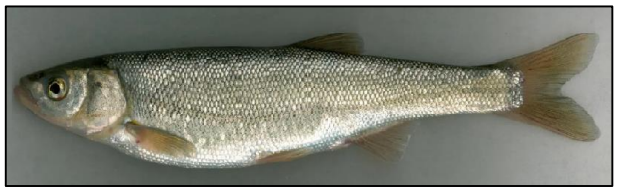

Figure 1. *Alburnus tarichi* (Güldenstädt, 1814) from Lake Van.

Study area

Different researches refer that *A. tarichi* is distributed in Lake Van, Erçek, Nazik, Aygır and Koçköprü Dam Lake (Kuru 1975; Kocabaş 1999; Çetinkaya 2000; Geldiay and Balık 2007; Elp et al. 2014). Samples were obtained from Lake Van, Erçek, Nazik, Aygır. Lake Van, the largest lake in Turkey, covers 3574 km^2 in surface area with a mean depth of 171 m (450 m maximum, altitude 1646 m) (Kempe et al. 1978). Due to the highly salty-alkaline waters of the lake, it is commonly known as a 'soda lake' and thus cannot be used for drinking water (salinity 0.224% (Çiftçi et al. 2008), pH 6.3-7.7 (Göller ve Sulak Alanlar Eylem Planı 2017). The proportions of chemical compounds in the water are; 42% NaCI, 34% $NaCO_3$, 16% Na_2S0_4, 3% $KS0_4$ and 2.5 % $MgC0_3$. Because of this feature, the lake has a great reserve as a source of soda production (Çiftçi et al. 2008). Lake Van is the largest source of water that *A. tarichi* lives in (Elp et al. 2014). In Van Lake, *A. tarichi* is the only fish species that is able to live. Lake Erçek is the second largest lake in Van Basin. Lake Erçek, like Lake Van, has salty-alkaline waters. This lake is volcanic lava hard lake. It is not a deep lake, with a maximum depth of 30 m. Naturally no

other fish species live in the lake (Çetinkaya 1993). *A. tarichi* was transferred to this lake in 1984 from Lake Van. Lake Nazik is the largest freshwater lake in the basin. Lake Nazik and Lake Aygır contain freshwater in contrast to Lake Van and Lake Erçek. Lake Nazik comes after Lake Erçek in terms of size. Lake Erçek is tectonic origin (Çetinkaya 1993). *Capoeta kosswigi*, *Carassius gibelio*, *Cyprinus carpio* besides *A. tarichi* live in this lake. Lake Aygır is a typical maar lake formed by volcanic eruption. Maar lakes are caused by a phreatomagmatic eruption, an explosion caused by groundwater coming into contact with hot lava or magma (Doğu and Deniz 2015). *C. kosswigi*, *C. carpio* and *A. tarichi* live in this lake. Study areas are shown in Figure 2.

Figure 2. Study area (Lake Van, Lake Erçek, Lake Nazik, Lake Aygır).

Sample collection

Specimens of Lake Van (100 individuals), Erçek (86 individuals), Nazik (80 individuals) and Aygır (85 individuals) were sampled in April-May 2015. Fishermen trammel nets (18-22 cm in long, mess with 20 mm) were used for sampling. All samples were obtained from fishermen. Fork length and body weight of each individual were measured in situ to the nearest ±0.1 cm and weighted to the nearest ±0.1 g. Stations of locations for each lake are summarized Table 1.

Otolith measurement and image analysis

Lagenar otoliths (Figure 3) were removed as left and right discrimination for each fish sample. Lagenar (*asteriscus*) otoliths were photographed on distal side using Leica DFC295. Otolith breadth (*OB*) and length (*OL*) (± 0.001 mm) were determined by Leica Application Suit Ver. 3.8 Imaging Software. Otolith length (*OL*) is the horizontal distance between the anterior and the posterior tips of the otolith (Harvey et al. 2000). Otolith breadth (*OB*) is the vertical distance from the dorsal to the ventral otolith edge (Battaglia et al. 2010). Otolith weight (*OW*) was detected using Precisa precision scales (±0.0001 g). Left and right otolith measurements (*OL*, *OB* and *OW*) were tested by normality test. If the data were normally distributed, the comparisons of right-left otoliths measurements were tested by paired t test (parametric). If any of the comparative data were not normally distributed, the comparisons of right-left otoliths measurements were tested by Willcoxon test (non-parametric paired t test). Comparisons of otolith breadth, length and weight of *A. tarichi* between localities were tested by ANOVA. Tukey Test was used for pairwise comparisons (Zar 1999). All analysis were made using SPSS 20.0 Packet Programme and MINITAB 15.0 version.

Table 1. Stations of study area

Number of individuals	Stations	Coordinates
100	Lake Van 1. Station	38°34'09.77"N 43°12'22.22"E
	Lake Van 2. Station	38°33'07.46"N 43°14'55.96"E
	Lake Van 3. Station	38°32'10.09"N 43°17'12.64"E
86	Lake Erçek 1. Station	38°37'26.10"N 43°34'53.00"E
	Lake Erçek 2. Station	38°41'54.96"N 43°35'57.47"E
80	Lake Nazik 1. Station	38°51'10.89"N 42°15'06.38"E
	Lake Nazik 2. Station	38°51'03.15"N 42°19'11.60"E
	Lake Nazik 3. Station	38°53'16.00"N 42°18'53.89"E
85	Lake Aygır 1. Station	38°50'21.96"N 42°49'00.95"E
	Lake Aygır 2. Station	38°49'57.75"N 42°49'16.44"E
	Lake Aygır 3. Station	38°50'08.80"N 42°49'41.49"E

The power model was applied to estimate the relationships between the otolith measurements (*OB*, *OL*, *OW*) and fork length (*FL*).

$$y = a.x^b$$

y is otolith measurement and *x* is fork length. The parameters *a* and *b* were estimated through the linear regression analysis based on logarithms,

$$log\ Y = log\ a + b\ log\ X \text{ (Zar 1999).}$$

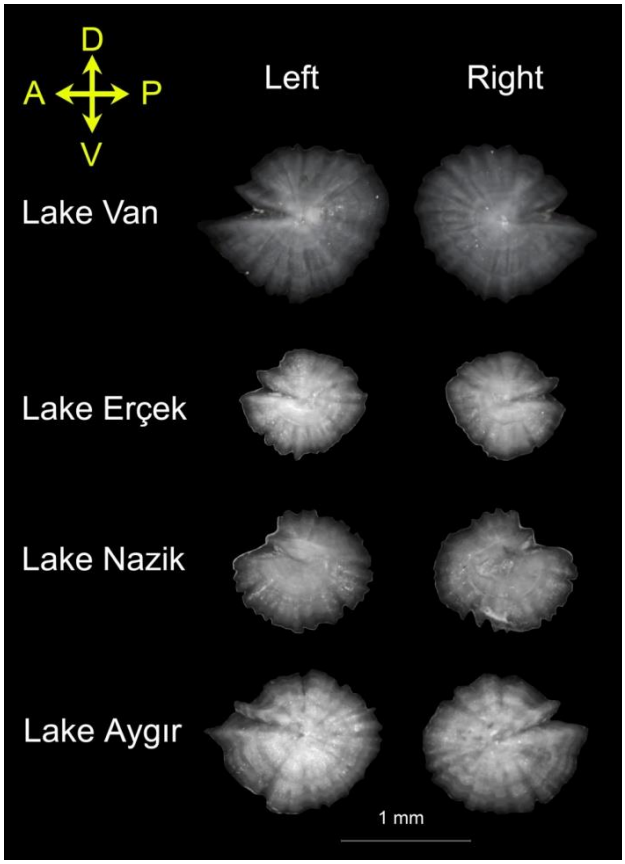

Figure 3. Lagenar otoliths of *A. tarichi*.

Results

The main descriptive statistics for fork length, body weight, otolith length, breadth and weight for each lake were summarized in Table 2.

When right and left otolith were compared, there was no significant difference in terms of otolith length and weight (P>0.05), but there was a statistically significant difference in terms of otolith breadth (P<0.01) in Lake Van. Similarly, difference of right and left otoliths in Lake Erçek was not statistically significant in terms of otolith length and weight (P>0.05), but there was a statistically significant difference in terms of otolith breadth (P<0.01). There were no differences between right and left (P>0.05) otolith measurements in Lake Nazik (otolith breadth, length, weight). Right and left otolith measurements of individuals inhabiting Lake Aygır were statistically similar to each other (P>0.05). Comparisons between right and left otoliths for *A. tarichi* are given in Table 3.

When all localities (Lake Van, Erçek, Nazik, Aygır) were evaluated together, otolith breadth, length and weight were different from each other for four localities (ANOVA, P<0.001). All localities were compared using pairwise comparison and we found that they were significantly different from each other in terms of otolith measurements among localities (Tukey, P<0.001).

Table 2. Descriptive statistics of *A. tarichi*

Habitat	Parameter	Mean	S.d.	Min.	Max.	S.e.
Lake Van	Fork Length	17.7	1.279	14.4	21.2	0.127
	Body Weight	74.86	12.88	53.40	116.70	1.280
	Otolith Length	2.812	0.1783	2.331	3.291	0.0126
	Otolith Breadth	2.554	0.1589	2.223	3.032	0.0112
	Otolith Weight	0.0032	0.0001	0.0019	0.0050	0.0001
Lake Erçek	Fork Length	21.1	1.333	18.6	24.6	0.144
	Body Weight	115.29	19.32	81.10	116.70	2.080
	Otolith Length	2.969	0.2305	2.409	3.584	0.0172
	Otolith Breadth	2.655	0.2257	2.075	3.274	0.0172
	Otolith Weight	0.0035	0.0007	0.0022	0.0063	0.0001
Lake Nazik	Fork Length	14.8	2.112	9.9	20.0	0.236
	Body Weight	34.89	16.38	8.40	89.30	1.640
	Otolith Length	1.822	0.241	1.2	2.637	0.0190
	Otolith Breadth	1.611	0.198	1.120	2.234	0.0156
	Otolith Weight	0.0022	0.0007	0.0008	0.0051	0.0000
Lake Aygır	Fork Length	16.3	1.437	13.0	18.9	0.156
	Body Weight	48.75	12.76	21.90	68.40	1.280
	Otolith Length	2.023	0.175	1.499	2.424	0.0134
	Otolith Breadth	1.802	0.150	1.372	2.097	0.0114
	Otolith Weight	0.0029	0.0006	0.0014	0.0049	0.0000

Table 3. Comparison between right and left otoliths for *A. tarichi*

Locality	Variable	Statistical test	Significance
Lake Van	Right-left otolith length	Paired t test (parametric)	P> 0.05
	Right-left otolith breadth	Paired t test (parametric)	P< 0.01
	Right-left otolith weight	Wilcoxon test (non-parametric)	P> 0.05
Lake Erçek	Right-left otolith length	Paired t test (parametric)	P> 0.05
	Right-left otolith breadth	Paired t test (parametric)	P< 0.01
	Right-left otolith weight	Wilcoxon test (non-parametric)	P> 0.05
Lake Nazik	Right-left otolith length	Wilcoxon test (non-parametric)	P> 0.05
	Right-left otolith breadth	Wilcoxon test (non-parametric)	P> 0.05
	Right-left otolith weight	Wilcoxon test (non-parametric)	P> 0.05
Lake Aygır	Right-left otolith length	Wilcoxon test (non-parametric)	P> 0.05
	Right-left otolith breadth	Paired t test (parametric)	P> 0.05
	Right-left otolith weight	Paired t test (parametric)	P> 0.05

According to the regression coefficients between the relationship of fish length and otolith measurements, otolith length was found to be the best indicator for estimating the length of fish in Lake Erçek and Lake Aygır. Otolith breadth was found to be the best indicator for estimating the length of fish in Lake Van and Lake Nazik (Figure 4).

Discussion

Otoliths are considered a profound taxonomic tool in fish species identification due to their inter-specific variability (Battaglia et al. 2010). Otolith measurements such as the length and width are also important to estimate the size and mass of the fish being preyed upon, as often in studies on feeding ecology the only item remaining in the stomach of a predator is the otolith (Jawad et al. 2011).

In this study, when right and left otolith were compared, there was no significant difference in terms of otolith length and weight, but there was a statistically significant difference in terms of otolith breadth in Lake Van. Bostanci et al. (2015) used otolith shape and morphometry to identify four *Alburnus* species (*A. chalcoides*, *A. escherichii*, *A. mossulensis* and *A. tarichi*) in Turkish inland waters. One of these inland waters is Lake Van. Otolith shape and morphometry of *A. tarichi* inhabiting Lake Van was investigated and they have found that left and right asteriscus otolith pairs were not statistically different (P>0.05) in terms of otolith weight and otolith length but were statistically different (P<0.01) in terms of otolith width (Bostanci et al. 2015). These results are similar to the current study. There are also different studies which show no difference between right and left otoliths (Jawad et al. 2011; Zengin et al. 2015; Zengin et al. 2017).

Fish size-otolith size relationships will be useful for researchers examining food habits of piscivores and size of fish in archaeological samples (Harvey et al. 2000). In this study, when the relationships between fish length and otolith measurements were evaluated, otolith length was found to be the best indicator for estimating the length of fish in Lake Erçek and Lake Aygır. Otolith breadth was found to be the best indicator for estimating the length of fish in Lake Van and Lake Nazik. Tarkan et al. (2007) investigated the biometric relationships between fish length and some bones (pharyngeal, opercula, cleitra) for *A.tarichi* inhabiting Lake Van. The results suggested that the biometric relationships between fish length and these bones were well suited for use in prey-predator studies of the *A.tarichi* (Tarkan et al. 2007). Bostanci et al. (2011) studied the relationships of otolith dimensions-fork length *A. tarichi* in Lake Van and reported that regression coefficients were 0.77, 0.74, 0.85 for *OL-FL*, *OB-FL*, *OW-FL*, respectively. Basusta et al. (2013) investigated otolith biometry-total length relationships in the population of Hazar Bleak, *Alburnus heckeli* (Battalgil, 1943) inhabiting Lake Hazar, Elazig, Turkey. They found a strong relationship between the otolith lengths and total length obtained ($R^2 = 0.9014$).

The otolith length (Waessle et al. 2003; Zengin et al. 2015), otolith breadth (Kumar et al. 2017) and otolith weight (Bostanci et al. 2011; Zengin et al. 2017) can be calculated as the best indicator for predicting fish size. Otolith biometry-fish length relationships have been determined for some freshwater and marine fishes (Harvey et al. 2000; Battaglia et al. 2010; İlkyaz et al. 2008; Mata et al. 2008; Mamry et al. 2010; Jawad et al. 2011; Basusta et al. 2013; Felix et al. 2013). However, the right and left otoliths may not provide the same results of prey fish length estimates (Harvey et al. 2000; Waessle et al. 2003; Kumar et al. 2012).

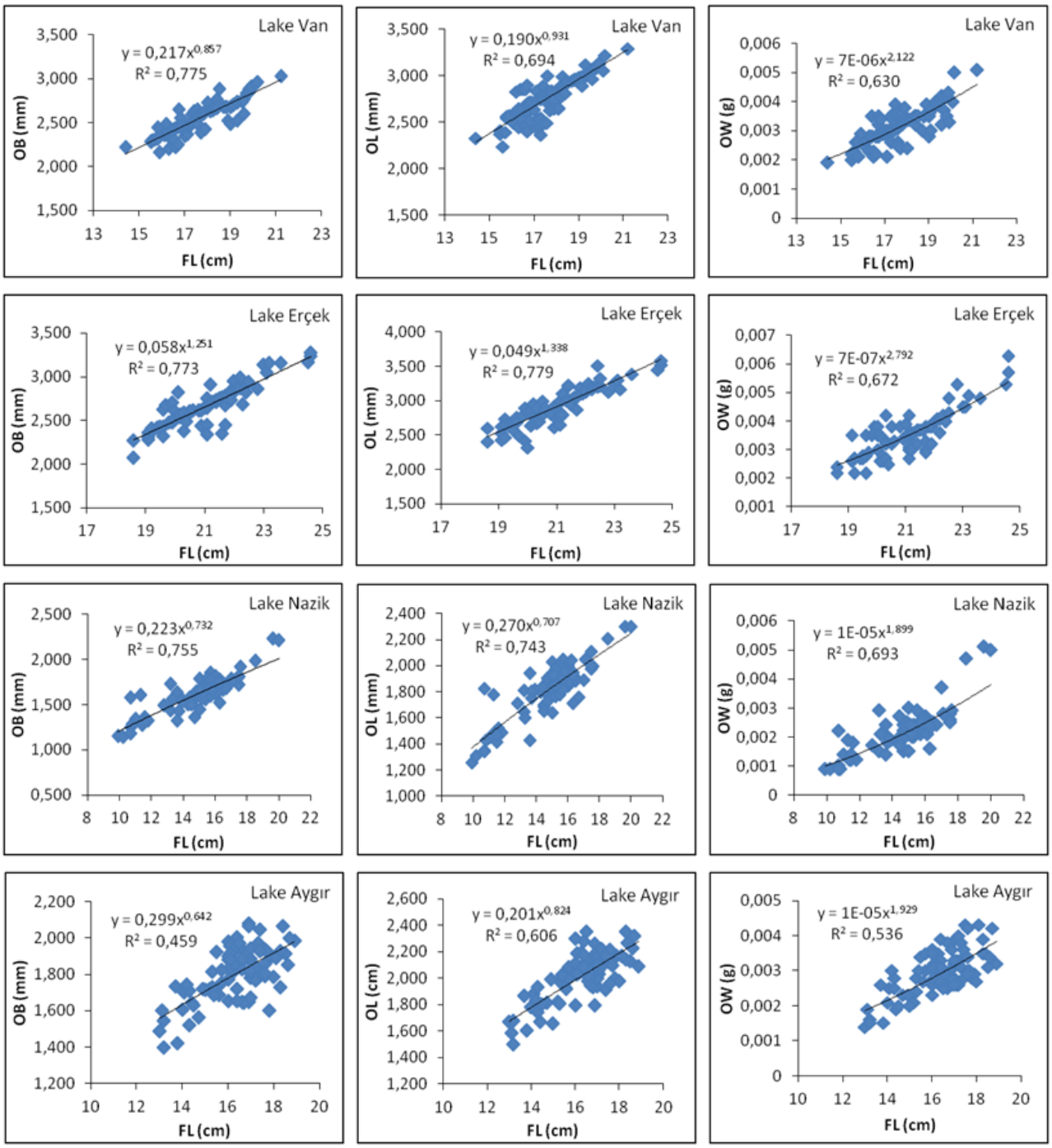

Figure 4. Fork length-otolith dimensions relationships for *A. tarichi* inhabiting Van Basin

The morphological and meristic characteristics of fish and their hard body parts have been shown as useful in stock identification studies (Kumar et al. 2017; Bostanci et al. 2017; Mapp et al. 2017). Otoliths are useful because their growth is related to increase in fish size and generally follow an allometric increase in dimensions (Chilton and Beamish 1982). Therefore, differences in the development patterns of otoliths have been associated with variations in growth rate and have been used for separation of stocks (Messieh 1972; Janusz 1990). The growth of individuals belonging to the same species may show some variations for different areas and stocks (Campana and Casselman 1993; Reichenbacher et al. 2009) or between sexes (Echeverria 1987). Furthermore, otoliths are exposed to chemical and mechanical abrasion in the digestive track of predators (Jobling and Breiby 1986; Granadeiro and Silva 2000) and their size may be underestimated. The current study is important for detection of otolith features of tarek inhabiting different localities. Otolith breadth, length and weight between localities were significantly different; this result is thought to occur due to the physicochemical properties of the habitats. While Lake Van and Lake Erçek have salty water feature,

Aygır and Nazik Lake have freshwater features. *A. tarichi* populations of Lake Erçek and Lake Van originated from Van Lake. It was transferred to Lake Erçek in 1984 from Lake Van. The difference in the otolith characteristics is thought to occur due to the fact that habitats have different characteristics. The habitat characteristics of the other populations (Lake Nazik and Lake Aygır) are different from each other (Elp et al. 2016) and have not interfered with each other for hundreds of years. This difference may be reflected in genetic traits and is thought to reflect the trace stock properties. When localities are compared with each other, there were significant differences among localities in terms of otolith measurements. The fact that otolith measurements of tarek show differences between populations will contribute to stock discrimination to be carried out thereafter. It is recommended that stock discrimination of tarek may be carried out using otolith features.

This study will be a preliminary work to be carried out thereafter in terms of investigation of otolith characteristics of *A. tarichi* which is an endemic species to Turkey inhabiting different localities of Van Basin and which is assessed as Near Threatened according to IUCN. These results are important in order to ensure the continuity of tarek which is important both in terms of tourism and economy. Also, there is no study on otolith morphometry of tarek living in Lake Erçek, Lake Nazik and Lake Aygır. This is the first information on otolith features of *A. tarichi* inhabiting Lake Erçek, Lake Nazik and Lake Aygır. There are no studies on the otolith characteristics of other species living in the Van Basin. Fish and fisheries are an integral part of most societies and make important contributions to economic and social health. Fishing of *A. tarichi* constitute about one fourth of the Turkish inland water fishery. The results of this study will contribute to future managements of *A. tarichi*.

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