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# Some Growth Properties and Length at First Maturity of Big Scale Sand Smelt (*Atherina boyeri* Risso, 1810) in İznik Lake, Turkey

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***ABSTRACT***

In this study, the length at first maturity and growth characteristics of the big scale sand smelt (*Atherina boyeri* Risso 1810) were investigated in İznik Lake. Catching trials were conducted on a monthly basis at 4 different stations of the lake between March 2014 and February 2015 and beach seine net with 6 mm of codend mesh size was used in the samplings. The overall sex ratio of the subsample was founded as 1:1.46 (F:M; 1180 females, 1729 males). The fork length range were 3.3-11.2 cm for females and 2.9-9.7 cm for males. The growth equations were found as $TW=0.005FL^{3.160}$ and $TW=0.006FL^{3.067}$ for female and male respectively. *Allometric (+)* growth has been shown in both sex groups. According to the logistic regression model results, length at first maturity ($L_{50}$) was estimated as 4.62 and 4.25 cm fork length for female and male respectively. While the growth properties of the species shown similarity with other habitats of populations, the values of length at first maturity ($L_{50}$) shown some differences.

**Keywords:** Growth type, length–weight relationship, introduced species, *LWR*

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**İznik Gölü'ndeki Gümüş Balığı (*Atherina boyeri* Risso, 1810)'nın Bazı Büyüme Özellikleri ve İlk Üreme Boyu**

**Öz:** Bu çalışmada, İznik Gölü'ndeki Gümüş Balığı (*Atherina boyeri* Risso, 1810)'nın ilk üreme boyu ve bazı büyüme özellikleri araştırılmıştır. Avcılık çalışmaları gölün 4 farklı istasyonunda Mart-2014 ve Şubat-2015 döneminde aylık olarak 6 mm örtü göz açıklığına sahip ığrıp kullanılarak yürütülmüştür. Alt örnekleme bireylerinin eşey oranı 1:1,46 (Dişi:Erkek, 1180 dişi, 1729 erkek) olarak belirlenmiştir. Örneklerin çatal boy aralığı dişilerde 3,3-11,2 cm ve erkeklerde de 2,9-9,7 cm olarak bulunmuştur. Büyüme denklemi dişi ve erkek bireyler için sırasıyla $TW=0{,}005FL^{3,160}$ ve $TW=0{,}006FL^{3,067}$ olarak hesaplanmıştır. Her iki eşey grubu da allometrik (+) büyüme göstermiştir. Lojistik regresyon modele göre ilk üreme boyu ($L_{50}$) dişiler için 4,62 cm ve erkekler içinde 4,25 cm olarak tahmin edilmiştir. Türün büyüme özellikleri, diğer habitatların popülasyonları ile benzer özellik gösterirken, ilk üreme boyu bazı farklılıklar göstermiştir.

**Anahtar kelimeler:** Büyüme tipi, boy-ağırlık ilişkisi, aşılanmış tür, *LWR*

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## Introduction

*Atherina boyeri* is an euryhaline species that can also live in the seas, downstream of rivers, river mouths and lagoons. It has increased its spread in the inland waters of Turkey creating crowded populations recently (Ekmekçi et al. 2013). The Lake İznik is a typical example of this spreading. After its first seen in 1988, *A. boyeri* became one of the economic species of the lake in a short period of time and its production has shown a steady upward trend over the years (Doğan 2009). Altun (1991) reported of *A. boyeri* in İznik Lake at first time (Gaygusuz 2006). Annual production first started with 60 t (Doğan 2009) and then increased to 1150 t in 2018 (TurkStat 2020). There are some regulations such as minimum landing size, close season and etc. being in practice for managing of other local species, but these regulations do not apply for the fishing of these species due to considered as harmful species (Anonymous, 2020). Nevertheless, *A. boyeri* has succeeded in increasing of population in the lake significantly. According to Ekmekçi et al. (2013), this is caused by life cycle characteristics of *A. boyeri* such as short life

span, early sexual maturation and long reproductive period.

In the previously studies about the *A. boyeri*, **growth properties** (Leonardos and Sinis 2000; Bartulović et al. 2004; Patimar et al. 2009; Çetinkaya et al. 2011; Lorenzoni et al. 2015; Boudinar et al. 2016; Gençoğlu and Ekmekçi 2016); **reproductive properties** (Bartulovic et al. 2006; Küçük et al. 2012; Bouriga et al. 2014; Yagci et al. 2015; Gençoğlu and Ekmekçi 2016); **feeding properties** (Chrisafi et al. 2007; Apaydın Yağcı et al. 2018; Aydin Uncumusaoglu et al. 2018); **embryonic development** (Dulčić et al. 2008); **genetic properties** (Francisco et al. 2006; Milana et al. 2012; Işıklıkaya 2017); **gear selectivity** (Rodríguez-Climent et al. 2012; Cilbiz et al. 2020) and **migrations** (Rosecchi and Crivelli 1995) were investigated. Present study acceptable as original in terms of used current method in evaluating of the data and used much greater number of examples, by comparing of the previously studies.

This study was carried out for estimating of length at first maturity and some growth properties of *A. boyeri* which is an introduced fish species of Turkey's inland waters. It is hopefully that gained results are contribute to understanding of growth and reproduction strategies of species and managing of natural stocks.

## Materials and Methods

The study was conducted in İznik Lake where is one of the most important *A. boyeri* producer (Figure 1) of Turkey. As a tectonic origin, İznik Lake locates southeastern part of the Marmara region in Turkey. Altitude is 85 m and maximum depth was determined as a little bit more than 70 m at near south coast. Lake's surface area is 285 km$^2$ and length is 32 km (Ceribasi 2018). Lake located between 40°23′ - 40°30′N latitudes and 29°20′ - 29°42′ E longitudes (Yağci and Ustaoğlu 2012)

Fishing trials were carried out at 4 different stations of the lake between March-2014 and February-2015 with monthly period. For obtaining of maximum length distribution, we used a special rigged beach seine with 6 mm codend mesh size in the sampling process.

Entry size of trial beach seine was almost 20 m$^2$ (width and height were 10 m and 2 m respectively). Further information about the geometry and characteristics of the used beach seine can be found Cilbiz et al. (2020). The fork lengths of the fish were determined by measuring board with mm precision and total weights were determined by using *A&D EJ-410* model portable balance with g precision. The sex was determined by macroscopically (Özeren 2009; Gençoğlu and Ekmekçi 2016). The length-weight relationship was explained by the formula $W=aL^b$ according to Froese (2006) and in the calculations only individuals whose sexes could be determine were used ($W$: Total body weight in g; $L$: Fork length in cm). 'basicTrendline' R package was used for gaining of model parameters and length-weight graph of *A. boyeri* (Mei et al. 2018).

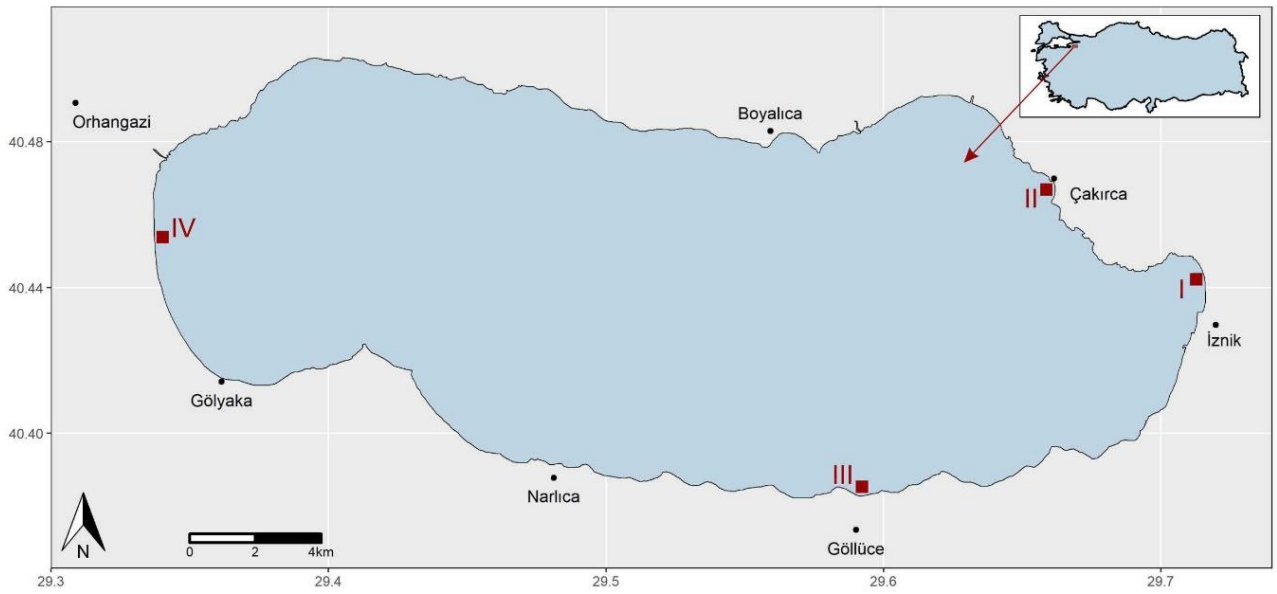


**Figure 1**. İznik Lake and sampling stations

The growth type was identified by using *t-test*, relevant procedure explained by Pauly (1984) in scope of an equation that given below.

$$t = \frac{Sd_{logFL}}{Sd_{logTW}} \frac{|b-3|}{\sqrt{1-r^2}} \sqrt{n-2}$$

Where $Sd_{logFL}$ is the standard deviation of the *logFL* values, and $Sd_{logTW}$ the standard deviation of the *logTW* values, n being the number of fishes used in the calculation. To make a decision for the growth type (isometric or allometric), obtained *t* value was compared with respective tabled critical value. Estimating of size at gonad maturity ($L_{50}$), the logistic approach was adopted. In the calculations, *sizeMat R* package (Torrejon-Magallanes 2019) by way of RStudio *v1.2.5001* program (RStudioTeam 2015) was used.

## Results

1180 females (3.3-11.2 cm length range), 1729 males (2.9-9.7 cm length range) and a total of 2938 specimen include in juveniles were used for determine of the length-weight relationship. Quite wide length range was gained specific to this species. The model parameters of the length-weight relationship are given in Table 1. It was found that growth in all sex groups showed *allometry (+)*.

**Table 1**. Length–weight relationship model parameters of *A. boyeri*

| Sex | n | Length range | Parameters of the relationship | | | | | $t_s$ |
|---|---|---|---|---|---|---|---|---|
| | | (*FL*, cm) | *a* | *b* | *95% CI of b* | $r^2$ | *p* | |
| **Female** | 1180 | 3.3-11.2 | 0.005 | 3.160 | 3.137-3.182 | 0.97 | <0.001 | 14.88[a] |
| **Male** | 1729 | 2.9-9.7 | 0.006 | 3.067 | 3.035-3.099 | 0.96 | <0.001 | 5.89[b] |
| **Both sex** | 2938 | 2.6-11.2 | 0.005 | 3.159 | 3.137-3.182 | 0.96 | <0.001 | 15.04[c] |

[a]($t>t_{0.05}$, 1211=1.64); [b]($t>t_{0.05}$, 1727=1.64); [c]($t>t_{0.05}$, 2938=1.64)

Length-weight relationship graph of *A. boyeri* is given in Figure 2 for different sex groups. In general, different sexes show similar growth type up to 6-7 cm fork length (by overlapped regression lines). It can be seen that after 7-8 cm, females of the same length class gain more weight compared to males.

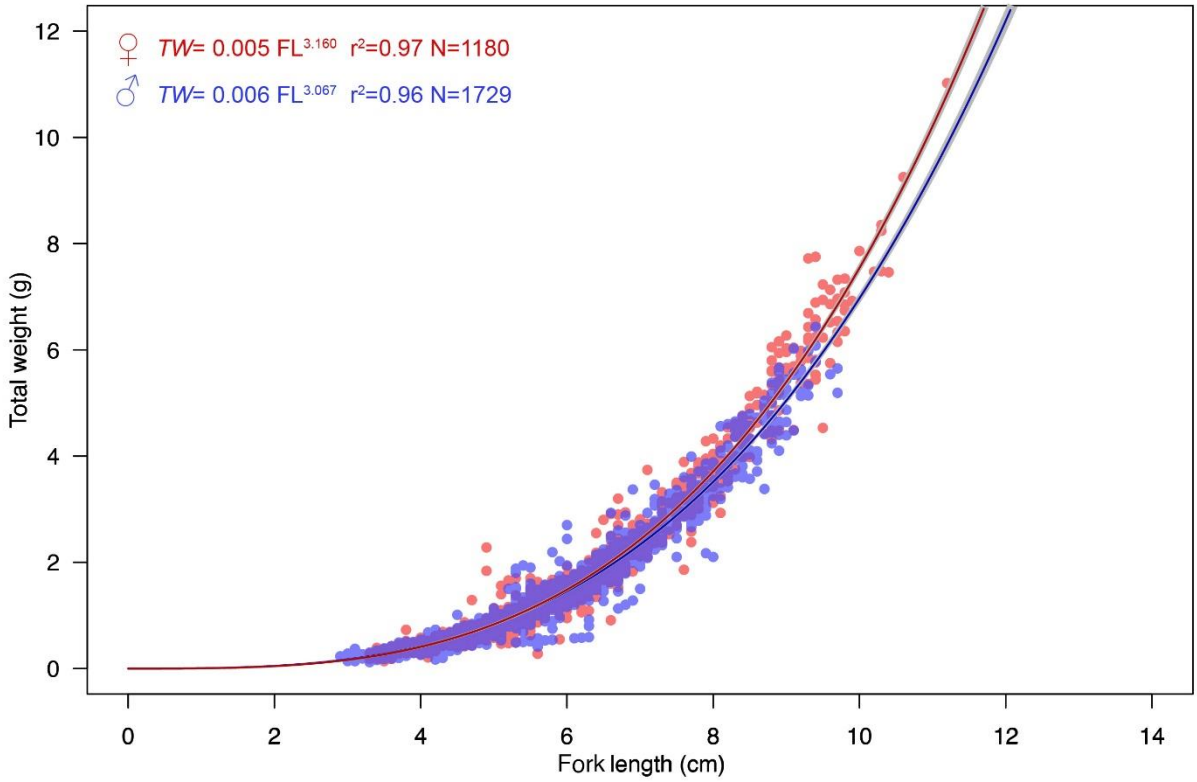


**Figure 2**. Length-weight relationship of *A. boyeri* for both sex group

903 females and 1366 males *A. boyeri*, whose sex and gonad development status could be determined, in the 2.6-11.2 cm fork length range were used to estimate the length at first maturity. Parameters

related to the $L_{50}$ reproduction length are given in Table 2. Estimated $L_{50}$ lengths according to both *Bayesian* and *Frequentist* approaches were found very close to each other. The $L_{50}$ lengths were found as 4.62 cm (*FL*) for female and 4.25 cm (*FL*) for male. From this point of view, it could be said that the $L_{50}$ length of male was shorter than females (Figure 3).

**Table 2**. Mean size at first maturity and relevant parameters of *A. boyeri*

| **Parameters** | **Female** | | | **Male** | | |
|---|---|---|---|---|---|---|
| | Frequentist reg. | | Bayesian reg. | Frequentist reg. | | Bayesian reg. |
| | Original | Bootstrap | Bootstrap | Original | Bootstrap | Bootstrap |
| ***A*** | -13.93 | -14.01 | -13.79 | -17.74 | -17.73 | -17.57 |
| ***B*** | 3.01 | 3.03 | 2.99 | 4.17 | 4.19 | 4.14 |
| $L_{50}$ | 4.62 | 4.62 | 4.60 | 4.25 | 4.25 | 4.24 |
| $R^2$ | 0.77 | 0.77 | 0.77 | 0.83 | 0.83 | 0.83 |

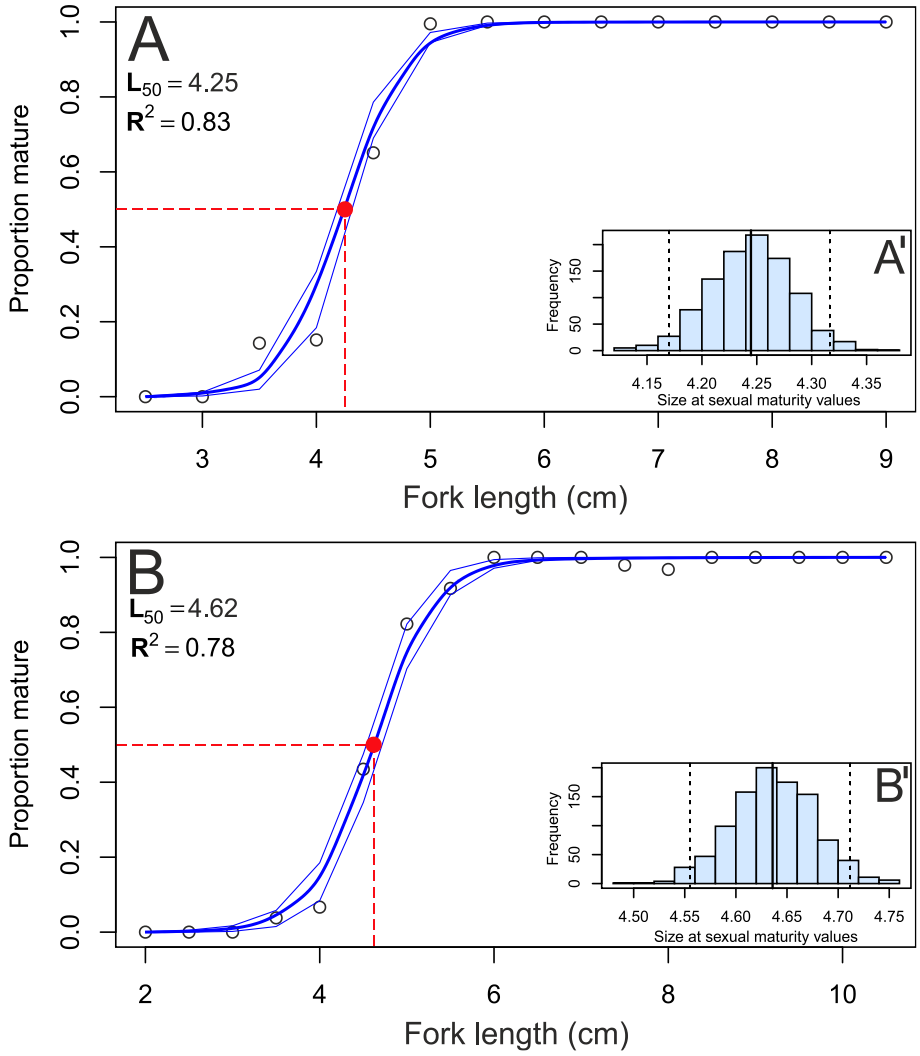


**Figure 3**. Maturity ogives of *A. boyeri* sampled from İznik Lake (A: $L_{50}$ value and it's confidence intervals (A') for male; B: $L_{50}$ value and it's confidence intervals (B') for female)

## Discussion

Despite routine monthly fishing trial during March to September, any fish could not be caught between from October to February. According to Işıklıkaya (2017), the reason for this is the water temperature: the species can adapt to difficult conditions, however, if the water temperature drops below 8 ºC, the species almost stops feeding; temperature below 4 ºC causes life-threatening conditions for the species. Therefore, in the winter months, the species migrates from the freshwater systems connected to the sea towards the sea, and in lakes not connected to the sea, it gathers in warmer, deeper regions. In this circumstance, beach seines are extremely ineffective for fishing of the *A. boyeri*.

There are very limited study towards to determine of length at first maturity of *A. boyeri* (Table 3). In this studies, Bartulovic et al. (2006) reported $L_{50}$ maturation as 7.752 cm (*TL*) for female individuals in Mala Neretva River (Algeria); Gaygusuz (2006) studied $L_{50}$ maturation length of *A. boyeri* in İznik Lake according to Avşar (1988), $L_{50}$ lengths were reported by author as 4.0-4.4 cm (*TL*) for male and 3.5-3.9 (*TL*); $L_{50}$ maturation was found as 4.6 cm (*TL*) for female individuals in the study that carried out by Küçük et al. (2012) according to King (1995) in Lake Egirdir. When compare of our results with previous studies, they shown similarities with Küçük et al. (2012), but shown serious differences others. This could be due to (*I*) differences in habitat, (*II*) differences in used methods for evaluating of data, (*III*) the number of samples examined and the different ranges of length. According to Saborido-Rey (2016), maturity ogive is often described using a logistic function, in short-lived species with a relative high mortality. After maturation all individuals become sexually mature within a short size interval. Our results also support this idea. Maturation is completed in approximately 2 cm length range both in male and female individuals (3.5-5.5 cm *FL*, Figure 3).

Correct estimates of size at first maturity ($L_{50}$ - length at which 50% of the fish are mature) are useful for fish stock management (Fontoura et al. 2009). The length at first maturation ($L_{50}$) provides a scientific basis for the Minimum Landing Size application, which is effectively used by the fishery management authorities, especially giving each individual a chance to reproduce at least once in order to sustainability of the stock. However, it is not very clear what will be the purpose of using the data in *A. boyeri* specific. On one hand, it is reported to have the potential to cause serious damage to the ecosystem due to being invasive (Ekmekçi et al. 2013) but on the other hand it has become a serious source of income for the country and fishermen in the region. So, should the stock of *A. boyeri* be accepted and sustained as a commercial fish species of the lake? Or should it be fought against as an enemy? These questions need to be answered clearly. There are contradictory practices of the Ministry of Agriculture and Forestry. Implementations such as closed season and minimum landing size for other commercial inland water fish species are not available for the *A. boyeri*. On the other hand, there is a quota application for *A. boyeri* and in the fishing not allowed above the specified quota. The only obstacle to over-proliferation and complete invasion of the lake by *A. boyeri* not having any natural enemies in the Lake İznik is the commercial fishermen of Lake Iznik. In any case, it is necessary to ensure or even encourage fishermen to continue catching of this species.

¼ of total Turkey's *A. boyeri* production has been provided from İznik Lake. Almost all individuals are proceeding as a frozen and export to some European county such as Italy, England, France and Spain. This species is consumed crisps or finger fish. Due to hardening of scale and spine of larger individuals (larger than 6-7 cm total length) not preferred for crisps production, this circumstance is causes abnormal fishing pressure on young individuals. When the process continues in this way for years, it could lead to an increase in the proportion of individuals with higher egg productivity in the population.

In conclusion, it has been determined that *A. boyeri* living in Lake İznik show similar growth characteristics (+ *Allometry*) with other populations living in different habitats. It was found that the initial breeding length showed some differences with respect to habitats. The length at first maturity presented in this study was considered to be useful in stock management of the species. The spread of species between aquatic environments has continued for many years, either naturally or by human factor. The significant issue is to develop and accomplish implementation of national policies regarding stock management of invasive or introduced species.

**Table 3**. Summary results of present and previously studies (*FL*, cm)

| **References** | **Locality** | **Sex** | **Length-weight relationship parameters** | | | | | | ***L*$_{50}$ Mat.** |
|---|---|---|---|---|---|---|---|---|---|
| | | | *N* | *Length range* | *a* | *b* | $R^2$ | Growth type | |
| **Bartulovic et al. 2006** | Mala Neretva River, HR | (♀) | 1200 | - | - | - | - | - | 7.752* |
| **Gaygusuz 2006** | İznik Lake,TR | (♂) | 278 | 3.0-10.0* | 0.0036 | 3.2780 | 0.97 | *A(+)* | *4.0-4.4** |
| | | (♀) | 839 | 4.7-11.9* | 0.0036 | 3.2679 | 0.99 | | *3.5-3.9** |
| | | (♀♂) | 1138 | 3.0-11.9* | 0.0032 | 3.3366 | 0.99 | | - |
| **Özeren 2009** | İznik Lake,TR | (♂) | 233 | 3.0-11.0* | 0.004 | 3.062 | 0.93 | *A(+)* | - |
| | | (♀) | 402 | 4.2-11.5* | 0.002 | 3.485 | 0.91 | *A(+)* | - |
| | | (♀♂) | 922 | 0.8-11.5* | 0.004 | 3.209 | 0.98 | *A(+)* | - |
| **Patimar et al. 2009** | Caspian Sea, IR | (♂) | 980 | 3.7-12.0* | 0.0053 | 3.0181 | 0.96 | *A(+)* | - |
| | | (♀) | 1278 | 4.4-12.8* | 0.0050 | 3.0628 | 0.96 | *A(+)* | - |
| **Çetinkaya et al. 2011** | İznik Lake,TR | (♂) | *NA* | *NA* | 0.0080 | 2.9819 | 0.99 | *NA* | - |
| | | (♀) | *NA* | *NA* | 0.0074 | 3.0508 | 0.99 | *NA* | - |
| | | (♀♂) | 237 | 2.1-10.6 | *NA* | *NA* | *NA* | *NA* | - |
| **Küçük et al. 2012** | Eğirdir Lake,TR | (♀) | 1433 | - | - | - | - | - | 4.6* |
| **Yagci et al. 2015** | Eğirdir Lake,TR | (♂) | *NA* | 1.6-9.8 | 0.0071 | 3.065 | 0.96 | *A(+)* | - |
| | | (♀) | *NA* | | 0.0055 | 3.269 | 0.96 | *A(+)* | *3.2* |
| | | (♀♂) | 1681 | | 0.0059 | 3.202 | 0.96 | *A(+)* | - |
| **Gençoğlu and Ekmekçi 2016** | Hirfanlı Dam Lake, TR | (♀) | 264 | 3.4-11.6* | $2x10^{-6}$ | 3.231 | 0.98 | *A(+)* | - |
| | | (♂) | 288 | 2.9-8.9* | $2x10^{-6}$ | 3.292 | 0.98 | *A(+)* | - |
| **Benzer and Benzer 2017** | Hirfanlı Dam Lake, TR | (♂) | 504 | 2.9-9.5* | 0.0174 | 2.624 | 0.93 | - | - |
| | | (♀) | 945 | | 0.0130 | 2.772 | 0.93 | - | - |
| | | (♀♂) | 1449 | | 0.0113 | 2.738 | 0.93 | *-A* | - |
| **Ilhan and Ilhan 2018** | Marmara Lake, TR | (♀♂) | 185 | 5.6-8.2* | 0.0059 | 3.118 | 0.92 | *A(+)* | *-A* |
| | Homa Lagoon, TR | (♀♂) | 172 | 3.7-9.9* | 0.0077 | 2.925 | 0.93 | *I* | - |
| **Kutsyn and Samotoy 2020** | Southwest Crimea, Black Sea | (♂) | 501 | 5.3-10.8 | 0.0090 | 2.81 | - | - | - |
| | | (♀) | 687 | 5.4-12.3 | 0.0070 | 2.95 | - | - | - |
| | | (♀♂) | 1188 | 5.3-12.3 | 0.0080 | 2.89 | - | - | - |
| **Present study** | İznik Lake,TR | (♂) | 1729 | 2.9-9.7 | 0.006 | 3.067 | 0.96 | *A(+)* | 4.25 |
| | | (♀) | 1180 | 3.3-11.2 | 0.005 | 3.160 | 0.97 | *A(+)* | 4.62 |
| | | (♀♂) | 2938 | 2.6-11.2 | 0.005 | 3.159 | 0.96 | *A(+)* | - |

*: *Total Length, TR: Turkey, DC: Algeria, HR: Croatia, IR: Iran, A: Allometric, I: Isometric*

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