# Population structure of Killifish, *Aphanius anatoliae* (Cyprinodontidae) endemic to Anatolia in Lake Eğirdir-Isparta (Turkey)

**Salim Serkan Guclu**

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**Abstract**

The population structure of *Aphanius anatoliae* in Lake Eğirdir-Isparta-Turkey was studied, using 522 fish monthly in 2008. This study were observed in the number of individuals of each sex, age, weight and size compositions. In addition, the total length-weight relationship was calculated as well as the Von Bertalanffy growth equation. A study of the food uptake throughout the year has been carried by examination of the content of the digestive track. Males made up 51.92%, and females 48.08% of the population. The length-weight relationship and Von Bertalanffy growth equation were estimated as $W= 0.0232\ e^{0.098L}$, r=0.8262, $L_t = 54.51\ (1 - e^{-0.279\ (t+1.345)})$, respectively. Bacillariophyta, *Gammarus pulex* and aquatic insecta are the major food items for *Aphanius anatoliae*.

**Keywords:** Anatolia, Killifish, Endemic, Growth, Feeding

Süleyman Demirel University, Eğirdir Fisheries Faculty, 32500 Eğirdir - Isparta / Turkey
Corresponding author's email: salimguclu@sdu.edu.tr

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## Introduction

The Cyprinodontiform fishes of the genus *Aphanius*, extant as well as fossil, are widely distributed along the late-period Tethys Sea coast lines. Fossil finds are known from many locations between southern Germany and Kirchisiah. Their present-day distribution has also been influenced by glacial and interglacial period differences in the Mediterranean Sea level (Wildekamp et al., 1999). The genus *Aphanius* consists of 9 species comprising two major clades occur in Anatolia; *A.asquamatus, A.mento, A.fasciatus, A.danfordii, A.villwocki, A.anatoliae, A.splendens, A.transgradiens* and *A.sureyanus* (Wildekamp et al., 1999; Hrbek and Meyer, 2003). *A. anatoliae* Leidenfrost, 1912 is found in the freshwater springs and small rivers around, and flowing into, the lakes Tuz, Eğirdir, Beyşehir and several rivers, pools and swamps around Konya and eastward to Niğde. It is also found in the spring area of the Menderes River and in its lower drainage system near Selçuk (Wildekamp et al., 1999). Typical habitation is close to the shore in fresh to slightly brackish waters. Several populations of *A.anatoliae* around Lake Tuz and southwestern Anatolia are now considered extinct, or endangered due to pollution or disapperance of the water resulting from pumping for agricultural use (Wildekamp et al., 1999; Hrbek and Wildekamp, 2003).

Wildekamp et al. (1999) studied the species and subspecies of the genus *Aphanius* in Turkey. Molecular phylogeny and historical biogeograpy of the *Aphanius* species complex of Central Anatolia have been studied by Hrbek et al. (2002). The phylogeny of Eurasian killifishes and genetic relationships between Anatolian species and subspecies of *Aphanius* have been studied Bardakçı et al. (2004) and Hrbek and Meyer (2003). Güçlü et al. (2007) researches population structure and growth features of *Aphanius sureyanus* in Burdur Lake. Karslı and Aral (2010) investigated some biological features of *Aphanius chantrei* population in Sırakaraagaçlar Stream (Sinop-Akliman). Güçlü and Küçük (2008, 2011) researches population structure and reproduction biology of *Aphanius mento* in Kırkgöz Spring (Antalya).

So far, most of the researches related to *A.anatoliae* species have been focused on molecular phylogeny, taxonomy of species and population features of other *Aphanius* species. *Aphanius* is an important genus which reflect the effect on aquatic fauna of geological isolation in Anatolia. Genus of *Aphanius* are given important clues in the zoogeogrophical and bio-ecological studies. In the present study, information on the population structure of *A.anatoliae* in the Lake Eğirdir is presented.

## Materials and methods

Lake Eğirdir is located at latitude 38°15′N and longitude 30°52′E in the Lake District (southwest Turkey) and second largest freshwater lake of Turkey. Lake Eğirdir has a tectonic origin and is 918 m above sea level. It has of surface area of approximately 482 $km^2$ and the deepest part of this lake is 13 m (with mean depth of 8-9 m). The middle part of the lake is narrower, like a channel. The shallower

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part in the north is called Hoyran. Tectonic in origin, an important part of the potential water supply is provided by its own sources. Main water sources of the lake are underground springs, small streams and rain waters. Especially, most of the streams transport domestic, agricultural and industrial wastes to the lake. Today, there are 15 fish taxa (10 native, 5 non-native) in Lake Eğirdir. It was determined that, among the endemic species of Lake Eğirdir, Handlirsch's minnow (*Pseudophoxinus handlirschi*) is extinct (EX), Ereğli minnow (*Hemigrammocapoeta kemali*) disappeared and Eğirdir minnow (*Pseudophoxinus egridiri*) and Eğirdir barb (*Capoeta pestai*) are critically endangered (CR) (Küçük et al., 2009). The major fish species in the lake are the carp silver crucian carp (*Carassius gibelio*), Anatolian killifish (*A.anatoliae*), Caucasian dwarf goby (*Knipowitschia caucasica)* and big-scale sand smelt (*Atherina boyeri*).

Monthly samples were collected from the Lake Eğirdir between April 2007 and March 2008 with drift nets of tulle of 2 mm mesh size. The fish were preserved in 4% formaldehyde (v/v) and transported to the Fish Biology Laboratory at Eğirdir Fisheries Faculty. In this study, a total of 522 specimens were examined. The total lengths of all fish were measured with 0.01 mm sensitive calipers, whereas weights were recorded with an electronic balance at the nearest 0.01 g. The age was determined from scales taken from the left side of the body, between the end of the pectoral fin and the beginning of the dorsal fin. Observations were made using a stereoscope with transmitted light. The overall ratio of males to females was evaluated with $\chi^2$ - test (0.05) (Düzgüneş et al., 1995). The relation of weight to total length was established by the exponential regression equation, $W = a * TL^b$, where W is the weight in g, TL the total length in cm, a and b the parameters to be established (Ricker, 1975). The growth of the *A.anatoliae* population was estimated with the following Von Bertalanffy growth equations: $L_t = L_\infty (1 - e^{-K(t - to)})$, where $L_t$ is the total length in cm at age "t", $L_\infty$ the average asymptotic length in mm, K the body growth coefficient, "to" the hypothetical age and "a" and "b" constants (Kara, 1992). Food selection was expressed as the percent distribution of the monthly consumed food types. Food organisms in the alimentary canal were identified using various textbooks (Smith, 2001; Demirsoy, 2003).

**Results**

The age of the fish ranged from I to IV years (Table 1). Of the total fish examined, 271 (51.92%) were males and 251 (48.08%) females. The overall ratio of males to females was 1.07 : 1.00 and $\chi^2$ analysis showed this to be not significant (P>0.05) (Table 1). The age distribution shows for age classes (Table 2). The following Von Bertalaffy growth equation was obtained for all: $L_t = 54.51 (1 - e^{-0.279 (t+1.345)})$. The differences between observed and expected total lengths were statistically not significant in in all age groups (t – test, P > 0.05).

The total length-weight relationships were calculated for all of the *A.anatoliae* samples. The length-weight relationships are visually represented (Fig.

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1).The monthly stomach contents is presented as the percent distribution of organisms identified from the alimentary canal (Table 3). Aquatic insecta, Amphipoda (*Gammarus pulex*) and Bacillariophyta are the major food resources for *A. anatoliae*. The population *of A.anatoliae* living in the water column were determinated that summer and autumn months mainly benthic, winter and spring months were the preferred style of nutrition zooplanktonic.

**Table 1: Age and sex distribution of females (F), males (M) and all *A.anatoliae* from the Lake Eğirdir (N: Number of samples, N%: Percent of samples)**

| Age group | Females | | Males | | All | | M:F |
|---|---|---|---|---|---|---|---|
| | N | N% | N | N% | N | N% | |
| **I** | 23 | 4.40 | 32 | 6.13 | 55 | 10.54 | 1.39:1.00 (P>0.05) |
| **II** | 110 | 21.07 | 168 | 32.18 | 278 | 53.26 | 1.52:1.00 (P>0.05) |
| **III** | 100 | 19.16 | 69 | 13.23 | 169 | 32.57 | 0.69:1.00 (P<0.05) |
| **IV** | 18 | 3.45 | 2 | 0.38 | 20 | 3.83 | 0.11:1.00 (P<0.05) |
| **Total** | **251** | **48.08** | **271** | **51.92** | **522** | **100** | **1.07:1.00 (P>0.05)** |

**Table 2: Size and age composition of females (F) and males (M) of *A.anatoliae* from the Lake Eğirdir**

| Age Class | I | | II | | III | | IV | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Total Length(mm) | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | |
| **16.70-20.00** | | 4 | | | | | | | **4** |
| **20.01-23.31** | 4 | 4 | 1 | | | | | | **9** |
| **23.32-26.62** | 4 | 3 | | | | | | | **7** |
| **26.63-29.93** | 13 | 17 | 5 | 9 | | | | | **44** |
| **29.94-33.24** | 2 | 4 | 38 | 73 | | 2 | | | **119** |
| **33.25-36.55** | | | 58 | 73 | 12 | 20 | | | **163** |
| **36.56-39.86** | | | 8 | 11 | 50 | 40 | | | **109** |
| **39.87-43.17** | | | | 2 | 38 | 7 | 5 | 2 | **54** |
| **43.18-46.48** | | | | | | | 10 | | **10** |
| **46.49-49.79** | | | | | | | 2 | | **2** |
| **49.80-53.10** | | | | | | | 1 | | **1** |
| ∑ | **23** | **32** | **110** | **168** | **100** | **69** | **18** | **2** | **522** |
| | **TL ± sd (min-max)** | | | | | | | | |
| ♀ | 26.40±0.53 (21.00-29.51) | | 33.39±0.18 (29.54-36.24) | | 39.06±0.18 (36.24-42.71) | | 44.44±0.43 (42.91-50.28) | | 35.80±0.30 (21.00-50.28) |
| ♂ | 26.50±0.60 (16.70-29.61) | | 33.04±0.14 (29.61-36.40) | | 38.06±0.36 (36.41-43.06) | | 23.89±3.56 (18.85-28.93) | | 33.48±0.25 (16.70-43.06) |

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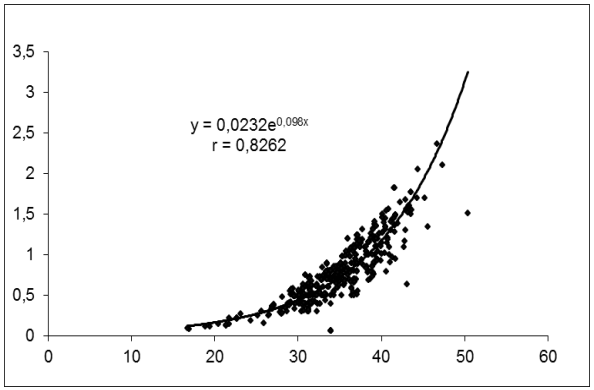


** the values should be presented in Figure as TL(mm) and vertical axis as W(g) And the power equation is better to be presnted to show the isometric or allometric growth, Namely: $W=a\ TL^{b}$

**Figure 1: The total length–weight relationships of *A.anatoliae* from the Lake Eğirdir (♀- ♂)**

**Table 3: The monthly percent distribution of organisms in the alimentary canal of *A.anatoliae* from the Lake Eğirdir**

| | M | J | J | A | S | O | N | D | J | F | M | A | ∑ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyanophyta | 0.68 | - | - | - | 0.45 | - | - | - | - | - | - | - | **0.09** |
| Chlorophyta | - | - | - | - | 1.11 | - | 9.68 | - | - | - | - | - | **0.90** |
| Bacillariophyta | 76.71 | 87.87 | 59.48 | 47.20 | 94.66 | 33.30 | 51.61 | 63.64 | 53.12 | 42.11 | 92.86 | 64.24 | **63.91** |
| Rotifera | - | - | 2.40 | 5.60 | 0.21 | - | - | - | - | - | - | - | **0.68** |
| Copepoda | 0.68 | - | - | - | - | - | - | 13.63 | 16.74 | 15.79 | 7.14 | 3.98 | **4.83** |
| Copepoda nauplii | 0.68 | - | - | - | - | - | - | - | - | - | - | 1.02 | **0.14** |
| *Alona* sp. | 0.68 | - | 2.40 | 8.30 | 0.67 | - | 6.45 | - | - | 5.26 | - | - | **1.98** |
| Chidulidae | 0.68 | - | - | - | - | - | - | - | - | - | - | - | **0.06** |
| Ostracoda | 1.38 | - | - | - | - | - | - | - | - | - | - | - | **0.12** |
| *Gammarus pulex* | 10.27 | 5.30 | 19.04 | 25.00 | 2.90 | 16.70 | 29.03 | 18.18 | 24.96 | 31.38 | - | 24.24 | **17.25** |
| *Asellus aquaticus* | 1.38 | - | - | - | - | - | - | 4.55 | 5.18 | 5.26 | - | 5.16 | **1.79** |
| Ephemeroptera imago | | 1.38 | - | - | - | - | - | - | - | - | - | - | **0.12** |
| Trichoptera imago | 2.06 | 6.83 | 9.49 | 8.30 | - | - | - | - | - | - | - | - | **2.22** |
| Trichoptera larvae | 0.68 | - | 2.40 | - | - | - | - | - | - | - | - | 0.68 | **0.31** |
| Diptera larvae | 0.68 | - | 2.40 | - | - | 16.70 | - | - | - | - | - | 0.68 | **1.71** |
| Pleocoptera imago | 2.06 | - | - | - | - | - | - | - | - | - | - | - | **0.17** |
| Empty stomach | - | - | 2.40 | 5.60 | - | 33.30 | 3.23 | - | - | - | - | - | **3.71** |

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## Discussion

In this study, the age of *A.anatoliae* from the Lake Eğirdir ranged from I to IV. Nikolsky (1980) suggested that, the situation in wide range of age distribution in a population are to accepted as a indication of enough level in the food of water system. The decrease of individual in old age groups in the population will cause increase of individual in young age groups, decreasing the food competition. The age of *Aphanius fasciatus* from Mesolongi and Etolikon Lagoon (Greece) ranged from 0-VI (Leonardos and Sinis, 1999), *Aphanius vladykovi* in Modar-Dokhtar Spring (Middle Zone of Iran) ranged from 0-II (Keivany and Soofiani, 2004), *Aphanius chantrei* from Sırakaraağaçlar Stream in Türkiye ranged from 0-II (Karslı and Aral, 2010), *A. sureyanus* from the Burdur Lake (Mediterranean Zone of Turkey) ranged from 0 to IV (Güçlü et al., 2007) and *Aphanius mento* from Kırkgöz Spring (Mediterranean Zone of Turkey) have a wide age range (0-VII) (Güçlü and Küçük, 2008). The age range of this study was different from *A. vladykovi* (Keivany and Soofiani, 2004), *A. chantrei* (Karslı and Aral, 2010), but similar to *A.sureyanus* (Güçlü et al., 2007), *A.fasciatus* (Leonardos and Sinis, 1999) and *A.mento* populations (Güçlü and Küçük, 2008). This situation may be caused by genetics structures of populations.

The sex ratio of females to males of *A.anatoliae* of the Lake Eğirdir is 1.07:1.00 ($\chi^2$, P>0.05). This ratio found in the research is similar to ratio 1.00:1.00 give for a number of species (Nikolsky, 1980). According to Nikolsky (1980), sex ratio varies considerably from species to species, but in the majority of species it is close to one. The sex ratio of females to males is similar to *A. chantrei* (Karslı and Aral, 2010), *A.mento* (Güçlü and Küçük, 2008), but differences from *A. fasciatus* (Penaz and Zaki, 1985), *A. fasciatus* (Koutrakis and Tsikliras, 2003) and *A.sureyanus* (Güçlü et al., 2007). This situation may be caused by fishing apparatus and genetics structures of populations.

The total length values in the population of *A.anatolie*, *A.mento* (Güçlü and Küçük, 2008), *A.fasciatus* (Koutrakis and Tsikliras, 2003), *A. vladykovi* (Keivany and Soofiani, 2004), *A.iberus* from Mar Menor Coastal Lagoon (Verdiell et al., 2006), *A.iberus* from Segura River Basin (Andreu-Soler et al., 2006) and *A.chantrei* from Sırakaraağaçlar Stream in Turkey (Karslı and Aral, 2010) have similar, but are higher than *A.sureyanus* (Güçlü et al., 2007), *A.fasciatus* (Leonardos and Sinis, 1999) and *A.fasciatus* from Küçükçekmece Lagoon in Turkey (Gaygusuz et al., 2006). The difference may be caused by differences in the morphological features of the species and habitats.

The differences in between the observed and expected weights were statistically not significant (t test, P>0,05)

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of *A.anatoliae*. Von Bertalanffy growth formula values of *A.anatoliae* are similar to *A.mento* (Güçlü and Küçük, 2008), but differs from *A.fasciatus* (Leonardos and Sinis, 1999), *A.chantrei* (Karslı and Aral, 2010) and *A.sureyanus* (Güçlü et al., 2007). The may be caused by the habitats (Lake Eğirdir is a freshwater lake, Kırkgöz is a freshwater spring, Burdur Lake and Mesolongi-Etolikon Lagoon are brackish water) differences.

The relationships total length–weight of *A.anatoliae* samples correlation coefficient r= 0.8262 for combined sexes. This situation exhibits unimportant deviation expected regulation increase in relationships total length–weight. In this study relationship is similar to *A. vladykovi* (Keivany and Soofiani, 2004), *A.iberus* (Verdiell et al., 2006) and *A.iberus* (Andreu-Soler et al., 2006), *A.mento* (Güçlü and Küçük, 2008) but differences from *A. fasciatus* (Koutrakis and Tsikliras, 2003), *A.fasciatus* from (Gaygusuz et al., 2006) and *A.sureyanus* (Güçlü et al., 2007). These situation may be caused by the habitats and also by morphological differences.

Although the mount structure of *A.anatoliae* species (Lake Eğirdir) are the dorsal position, are fed by both benthic and pelagic. The main source of nutrition is *Gammarus pulex,* species belonging to Bacillariophyta and aquatic insecta. *Arctodiaptomus burduricus* and *Brachionus plicatilis* are the major food items for *A.sureyanus* from Burdur Lake (Turkey). *Hexartha fennica*, nauplius larvae and dipterean larvae contribute to the diet to a small extent, whereas cyclopoid copepods and dipterean imagos are minor food items for *A.sureyanus* (Güçlü et al., 2007). *Gammarus* sp. and *Palaemon* sp. are the major food resources for *A.mento* in the Kırkgöz Spring (Antalya-Turkey). Gastropods, fish larvae, odonata and nematods contribute to a small extent to the diet (Güçlü and Küçük, 2008).

In terms of finding food is not any problem and have a wide age range of the species show that a growing population of species. At a result of exhibits that the population of *A.anatoliae* is a developing population. The population has instantaneously increased and it became dominant, together with big-scale sand smelt (*A.boyeri*), presumably after the disappearance of the predatory effects of pike-perch (*Sander lucioperca*) since 2000's. It is suggested that the Lake Eğirdir for *A.anatoliae* is an ideal habitat and Lake Eğirdir should be a conserved area for a survival natural ecosyctems.

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