The First Data on the Biology of *Anatolichthys meridionalis* (Actinopterygii, Aphaniidae): an Endemic and Endangered Fish of Turkey (Dalaman River Basin)

Salim Serkan Güçlü*

Faculty of Eğirdir Fisheries, Isparta University of Applied Sciences, Isparta, Turkey

*e-mail: salimguclu@isparta.edu.tr

Received October 1, 2021; revised March 11, 2022; accepted March 21, 2022

Abstract—Species belonging to the Aphaniidae, extant as well as fossil, are widely distributed along the late-period Tethys Sea coast lines. Among the mentioned genera, *Anatolichthys* is the genus that includes the 13 species. Anatolia has been a center in the diversity of *Anatolichthys*. The study is one of the first studies on the growth of the species. On this occasion, in study, it was aimed to examine the growth parameters of the *Anatolichthys meridionalis* Akşiray, 1948 population, which is an endemic and endangered species in Anatolia. The population structure of endemic species *Anatolichthys meridionalis* in Gökpınar Spring (Dalaman River basin-Turkey) (37.34° N, 29.44° E) was studied, using 108 fish in October 2019 and September 2020. The growth and reproductive characteristics of *A. meridionalis* were examined in the study. Males made up 42.59%, females 57.41% of the population. The length-weight relationship and Von Bertalanffy growth equation were $W = 0.0112L^{3.4638}$, $R^2 = 0.9793$, $L_t = 22.97 (1 - e^{-0.0304 (t+2.834)})$, respectively. Average growth performance and condition factor are calculated as 1.21 and 1.84, respectively. The gonadosomatic index was found in a maximum value (12.742%) in July and a minimum value (0.545%) in January. Reproduction time was found to be in between of July and September. The mean fecundity and mean egg diameter were found as 147.94 ± 28.03 number/individual/year and 1.35 ± 0.04 mm, respectively. The first maturation was found to be at age 1. First maturity length ($L_m$) was estimated at 23.95 mm for females and 22.04 mm for males.

Although the study shows that the species has no problem in finding food and is a population with a wide age range, the presence of invasive species in the habitat, the habitat is directly affected by pollution from agricultural activities, water is drawn by pumps for agricultural activities, and it is narrowly distributed and endangered species, *A. meridionalis* and its habitat Gökpınar Spring should be protected.

Keywords: Anatolia, endemic species *Anatolichthys meridionalis*, fecundity, growth, killifish

DOI: 10.1134/S19950829222050182

INTRODUCTION

Species belonging to the Aphaniidae, extant as well as fossil, are widely distributed along the late-period Tethys Sea coast lines. Today, species belonging to the Aphaniidae family are found in North Africa, South-Western Asia and Europe (Wildekamp et al., 1999; Freyhof and Yoğurtçuoglu, 2020). 19 species belonging to 4 genera (*Anatolichthys*, *Aphanius*, *Kosswigichthys*, *Paraphanius*) of Aphaniidae family spread in Anatolia (Freyhof and Yoğurtçuoglu, 2020). Among the mentioned genera, *Anatolichthys* is the genus that includes the most species; *Anatolichthys villwocki*, *A. transgrediens*, *A. iconii*, *A. anatolicae*, *A. fontinalis*, *A. sureyanus*, *A. splendens*, *A. saldae*, *A. marassantensis*, *A. maeandricus*, *A. irregularis*, *A. danfordii* and *A. meridionalis*. In this context, Anatolia has been a center in the diversity of *Anatolichthys* (Freyhof and Yoğurtçuoglu, 2020).

Many studies have been conducted to determine the molecular taxonomic and population characteristics of *Anatolichthys* species. However, most of the studies aimed at determining the ecological characteristics did not go beyond the studies of the length-weight relationships (Birecikligil et al., 2016; Yoğurtçuoglu and Ekmekçi, 2015; Krankaya et al., 2014; İnnal et al., 2019). There are 2–3 studies that reveal all bio-ecological characteristics of species belonging to the genus (Güçlü et al., 2007; Güçlü, 2012; Yoğurtçuoglu and Ekmekçi, 2013; Yoğurtçuoglu et al., 2020).

*A. meridionalis* Akşiray, 1948 is an endemic cyprinodontid restricted to a few populations found in a few springs in the Dalaman River basin (Burdur-Denizli province), Lake Gölhisar, Yeşilova (Burdur), Kocapınar and Kırpinar springs (Antalya) (Freyhof et al., 2017; Freyhof and Yoğurtçuoglu, 2020). The species is of great importance in determining the zoo-geographic distribution of other species in Anatolia.
and understanding the status of tetis remains (Hrbek et al., 2002; Hrbek and Meyer, 2003). However, there are no studies on the biology of the species so far. Especially for endemic species, before determining the conservation status and management, it is necessary to reveal their biology, particularly life history characteristics. For this purpose, in this study, the first data about the biology of A. meridionalis has been tried to be revealed.

MATERIALS AND METHODS

The study was carried out in Gökpinar Spring (Dalaman River basin-Turkey) (37.34° N, 29.44° E). Monthly samples were carried out in October 2019 and September 2020 with drift nets of tulle of 2 mm mesh size and 108 individuals were caught from Gökpinar Spring. Sampling could not be done only in April 2020 due to covid-19 epidemic restrictions. Fish species found in the same locality are Gasterosteus aculeatus, Gambusia holbrooki and Oncorhynchus mykiss. Specimens were measured to the nearest 0.01 cm total length (TL) and weighted to the nearest 0.01 g total weight (W). 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.

Female and male distributions were determined according to age. The overall ratio of males to females was evaluated with $\chi^2$ test (0.05) (Düzgün et al., 1995). Total length and weight in cm frequency distributions for all specimens were calculated. The relation of weight to total length was established using the exponential regression equation

$$W = aTL^b,$$

where $W$ was the body weight in g, $TL$ the total length in cm, “$a$” is intercept and “$b$” is regression coefficient. The coefficient of determination ($R^2$) was also estimated (Ricker, 1975). The growth of the A. meridionalis population was estimated with the following Von Bertalanffy growth equations:

$$L_t = L_\infty \left(1 - e^{-k(t-t_0)}\right),$$

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, “$t_0$” the hypothetical age and “$a$” and “$b$” constants (Le Cren, 1951). The statistical significance level of the coefficient of determination ($R^2$) and 95% confidence intervals (95% CI) of $b$ were also estimated (Zar, 1999). Comparison of the difference of slope value from $b = 3$ (isometric growth) for all species, Pauly’s $t$-test was performed (Pauly, 1984).

Pauly’s $t$-test was calculated as:

$$t = \frac{Sd_{\log TL}}{Sd_{\log W} \sqrt{1 - r^2}} \sqrt{n - 2},$$

where $Sd_{\log TL}$ is the standard deviation of the log TL values, $Sd_{\log W}$ is the standard deviation of the log W values, $n$ is the number of fish species used in the computation. The value of $b$ is different from 3 if $t$ value is greater than the tabled $t$ values for $n - 2$ degrees of freedom (Pauly, 1984). Measured total length and calculated total length in Von Bertalanffy growth equation were evaluated with $t$ test (0.05). Average growth performance ($O'$, phi prime) was calculated with the formula (4) (Gayanilo et al., 1988):

$$O' = \log k + 2\log L_\infty$$

Fulton’s coefficient of condition factor was calculated by $Cf = (W/TL^3) \times 100$ (Sparre and Venema, 1992). The gonadosomatic index (GSI) was calculated as:

$$GSI = GW/W \times 100,$$

where GW was the gonad weight and W the total body weight of the fish (Gibson and Ezzi, 1980). Spawning period was determined from monthly evaluation of GSI. Fecundity was estimated by gravimetrically from the number of mature oocytes in 31 ripe females (spawning stage). The diameters of eggs were measured by means of a microscopic micrometer (Nikolsky, 1980). The method used to estimate the maturity level of mature females was based on fitting of the sigmoid, logistic curve. Estimation of the length at first sexual maturity is as follows (De Martini et al., 2000): Firstly, it was plotted $L$ against $\ln[(1 - P_x)/P_x]$ at first sexual maturity is as follows (De Martini et al., 2000): Firstly, it was plotted $L$ against $\ln[(1 - P_x)/P_x]$ of the sigmoid, logistic curve. Estimation of the length maturity level of mature females was based on fitting of the sigmoid, logistic curve. Estimation of the length maturity level of mature females was based on fitting of the sigmoid, logistic curve. Estimation of the length maturity level of mature females was based on fitting of the sigmoid, logistic curve.

RESULTS

The age of the fish ranged from I to IV years. The dominant age groups are I and II age groups (Table 1–3). Of the total fish examined, 46 (42.59%) were male and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female. The overall ratio of males to females was 0.74 : 1.00 and 62 (57.41%) female.

The following Von Bertalanffy growth equation was obtained for all $L_t = 22.97 (1 - e^{-0.0304 (t+2.834)})$ (Fig. 2). The differences between observed and expected total lengths were statistically not significant in all age
Monthly changes in GSI are plotted in Fig. 3. Spawning occurred between July and September. The GSI values reached a maximum in July (12.742%) and declined rapidly thereafter, reaching a minimum in January (0.545%) (Fig. 3). The first maturation was found to be at age I. First maturity length ($L_m$) was estimated at 23.95 mm for females and 22.04 mm for males (Fig. 4). Average fecundity per individual was found to be 147.94 ± 28.03 number/individual/year (minimum 18 number/individual/year, maximum 355.78 number/individual/year) (Fig. 5, Table 5). Average egg diameter was measured 1.35 ± 0.04 mm.

The total length-weight relationships were calculated for female, male and all of the *A. meridionalis* samples. The length-weight relationships are visually represented (Fig. 6, Table 6). The estimates of parameter $b$ in the length-weight relationships are 3.5064 (males), 3.4568 (females) and 3.4638 (all specimens). The determination coefficient ($R^2$) values were close to for all specimens (Fig. 6, Table 6). The mean value of the condition factor are 1.85 (females), 1.83 (males) and 1.84 (all specimens) (Table 6).

**DISCUSSION**

Many studies have been conducted to determine the molecular taxonomic and population characteristics of *Anatolichthys* species. However, most of the studies aimed at determining the ecological characteristics did not go beyond the studies of the length-weight relationships. There are 2–3 studies that reveal all bio-ecological characteristics of species belonging to the genus (Table 7).
In this study, the age of *A. meridionalis* ranged from I to IV. The age range of small fish species is limited (Nikolsky, 1980). Despite this, the age range of the population is wide.

Nikolsky (1980) suggested that the situation in a wide range of age distribution in a population is to be accepted as an indication of enough level in the food of the water system. The decrease of individuals in old age groups in the population will cause increase of individuals in young age groups, decreasing the food competition. And it is also an indication of the addition of new individuals to the population, due to success in reproduction.

### Table 3. Weight and age composition of females and males of *A. meridionalis*

| Weight (class range), g | Age class | Total |
|------------------------|-----------|-------|
|                        | I         | II    | III  | IV  |        |
|                        | ♀         | ♂     | ♀    | ♂   |        |
| 0.094–0.294            | 141       | 11    |      |     | 25     |
| 0.295–0.495            | 14        | 6     | 1    | 13  | 35     |
| 0.496–0.696            | 10        | 2     | 9    |     | 21     |
| 0.697–0.897            | 10        | 2     | 1    |     | 13     |
| 0.898–1.098            | 2         | 5     |      |     | 7      |
| 1.099–1.299            | 1         |       |      |     | 1      |
| 1.300–1.500            |           | 1     | 1    | 1   | 3      |
| 1.501–1.701            |           |       | 1    | 1   | 2      |
| 1.702–1.902            |           |       |      |     |        |
| 1.903–2.103            |           |       |      |     | 1      |
| Σ                      | 28        | 17    | 23   | 15  | 108    |

|M ± SD (min–max)|
|---------------|----------|
|♀            | 0.27 ± 0.02 (0.10–0.45) |
|♂            | 0.22 ± 0.02 (0.09–0.36) |
|♀            | 0.70 ± 0.03 (0.44–0.91) |
|♂            | 0.43 ± 0.01 (0.35–0.51) |
|♀            | 1.02 ± 0.04 (0.85–1.26) |
|♂            | 0.64 ± 0.07 (0.49–1.46) |
|♀            | 1.65 ± 0.14 (1.44–1.93) |
|♂            | 1.51 ± 0.18 (1.32–1.70) |
|♀            | 0.91 ± 0.06 (0.10–1.93) |
|♂            | 0.70 ± 0.07 (0.09–1.70) |

*M ± SD*—average weight + standard deviation.

### Table 4. Measured average total length and calculated average total length values by age groups in Von Bertalanffy growth equation of *A. meridionalis*

| Age group | Observed average length, cm | Expected average length, cm | t-test |
|-----------|-----------------------------|----------------------------|--------|
| I         | 2.40                        | 2.52                       | p > 0.05 |
| II        | 3.10                        | 3.13                       | p > 0.05 |
| III       | 3.41                        | 3.73                       | p > 0.05 |
| IV        | 4.20                        | 4.30                       | p > 0.05 |

### Table 5. Average total length, weight and gonad weight and fecundity values of female individuals with eggs according to age of *A. meridionalis*

| Age group | n  | TL ± SH      | W ± SH       | GW ± SH      | F ± SH      |
|-----------|----|--------------|--------------|--------------|-------------|
| I         | 14 | 2.25 ± 0.09  | 0.97 ± 0.14  | 0.11 ± 0.02  | 135.36 ± 21.47 |
| II        | 11 | 3.32 ± 0.05  | 0.79 ± 0.04  | 0.08 ± 0.01  | 117.18 ± 27.51 |
| III       | 3  | 3.78 ± 0.09  | 1.18 ± 0.14  | 0.13 ± 0.03  | 139.01 ± 36.92 |
| IV        | 3  | 4.20 ± 0.03  | 1.60 ± 0.10  | 0.12 ± 0.02  | 200.22 ± 26.25 |
| Σ         | 31 | 3.38 ± 0.07  | 1.14 ± 0.11  | 0.11 ± 0.02  | 147.94 ± 28.03 |

*W*—weight, g; *GW*—gonad weight, g; *TL*—total length, cm; *SE*—standart error; *n*—number of samples; *F*—number/individual/year.
Fig. 1. Total length (a) and weight (b) in frequency distributions for *A. meridionalis*. F—female, M—male, F + M—all specimens.

The sex ratio of females to males of *A. meridionalis* is 0.74 : 1.00 ($\chi^2$, $p < 0.05$). This ratio found in the research is unlike the 1.00 : 1.00 ratio which gives it to a range 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 differences might be due to the shorter life and earlier maturation of the males, sexual differences in growth, mortality rates, or reproductive energy costs. Also, it is suggested that dominance of one sex relative to the other could be due to different behaviors leading to an easier catch of one sex and differences in mortality of sexes (Ghafouri et al., 2019). The fact that the M : F ratio was out of the expected

Table 6. The total length–weight relationships parameters and condition factor (female, male and all specimens) of *A. meridionalis*

| Sex    | $a$   | $b$   | $R^2$ | 95% Confidence interval $b$ (±$SE$) | Pauly's $t$-test | $P$   | $C_f$ | Growth type |
|--------|-------|-------|-------|-----------------------------------|-----------------|-------|-------|-------------|
| Female | 0.0112| 3.456 | 0.9817| 3.333–3.577 (±0.061)              | 7.523           | <0.001| 1.85  | + Allometry |
| Male   | 0.0109| 3.506 | 0.9749| 3.334–3.675 (±0.085)              | 5.938           | <0.001| 1.83  | + Allometry |
| All    | 0.0112| 3.463 | 0.9738| 3.365–3.559 (±0.049)              | 9.426           | <0.001| 1.84  | + Allometry |

$C_f$—fulton’s coefficient, $SE$—standart error.
Fig. 2. $L_\infty$ value according to Von Bertalanffy growth equation of *A. meridionalis*.

Fig. 3. GSI values by months of *A. meridionalis* population in Gökpınar (Sampling could not be done in April 2020 due to covid-19 epidemic restrictions).

In our study, the number of females is dominant. Especially during the spawning period (between May and September), it has been observed that males mate with more than one female. This will provide a very important advantage for the breeding success of the species in the habitat and will be a determining factor for a developing population. In addition, it is seen that female individuals have greater total length than male individuals at all ages (Table 2). As a result, their weight is dominant at all ages (Table 3).
Fig. 4. Length at first maturity of male and female *A. meridionalis* population in Gökpınar Spring. Vertical black arrows indicate first maturity ($L_m$).

Fig. 5. Fecundity values by months of female individuals with eggs of *A. meridionalis* population in Gökpınar Spring (Sampling could not be done in April 2020 due to covid-19 epidemic restrictions).

Differences in growth parameters may be due to ecological differences between research regions, water temperature, water quality and the amount of nutrients in the environment (Atar and Mete, 2009). The differences between the observed and expected total lengths were statistically not significant ($t$ test, $p > 0.05$) of *A. meridionalis* (Table 4). It is seen that the population reaches 22.97 cm, which is $L_\infty$, at the age of approximately 140 years. Differences about $L_\infty$; it is thought that it may change depending on the species difference, water temperature, environment and nutrition (Table 7). Other studies have been related to *Anatolichthys* that distribution in natural lakes and dams. In large lentic systems, water temperatures change according to the seasons and can reach high temperatures in the summer months. However, our study was conducted in a spring water whose water temperature is 15–16 degrees throughout the year. Therefore, the water temperature of the *A. meridionalis* habitat is lower than other habitats. It is stated that the value of $L_\infty$ increases inversely with the decrease in temperature (Nikolsky, 1980).

Length–weight relationship parameters are important parameters for the management and proper utilization of fish populations. The exponent $b$ in the length–weight relationship in the present study varies between 2 and 4, but often is a value close to 3; a value of 3 indicates isometric growth and values other than 3 indicate allometric growth (Tesch, 1971). According
to Le Cren (1951), the $b$ value in the length–weight relationship also changes according to the seasons depending on the gonad development of the fish. The exponents of the total length–weight relationship of *A. meridionalis* show positive allometry (Table 6). Usually a reduced length range and the abundance of smaller fish can result in a higher $b$ value because small and juvenile fish usually have a more “pumpkin”-shaped body and become more fusiform with age (Froese, 2006). In studies performed with other *Anatolichthys* species, generally positive allometric growth was observed (Table 6). The relationship of total length–weight of samples regression coefficient $R^2 = 0.9793$ for all specimens. This situation exhibits unimportant deviation expected regulation increase in relationships of total length–weight. The regression coefficient $R^2$ value is generally similar to other studies (Table 7).

Spawning occurred between July and September (Fig. 3). The first maturation was found to be at age I. First maturity length ($L_m$) was estimated at 23.95 mm for females and 22.04 mm for males (Fig. 4). This situation is similar to the GSI values (May–September) and hence breeding times of the endemic *Anatolichthys danfordii* species that spread in the Kızılirmak River basin (Yoğurtçuoğlu and Ekmekçi, 2013). Spawning in batches allows relatively large eggs to be laid, which have a higher possibility of survival (Wootton, 1990). Also, repeated spawning with a prolonged reproduction period can be expressed as an adaptation to prevent food competition between juveniles and adult individuals (Nikolsky, 1980). Early sexual maturation, short life cycle, repeated spawning and laying of eggs having rich yolk content is a common reproductive strategy exhibited by fish living under labile systems (Yoğurtçuoğlu and Ekmekçi, 2013). Yoğurtçuoğlu et al., 2020, said that, the gonadosomatic index and the duration of hydrated eggs of *Anatolichthys transgrediens* in the Açığer (Turkey) showed that reproduction continued from February to May in both habitats; nonetheless, a second spawning event occurred during July and August in the unstable habitat. In stable and unstable habitats in Açığer, *A. transgrediens* determined their first maturity length ($L_m$) as for females was 24.5 and 23.0 mm and for males 21.6 and 20.1 mm, respectively (Yoğurtçuoğlu et al., 2020).

Several factors, such as the size and age of the females, life history strategy, food supply, water temperature and other environmental factors affect the fecundity (Thrope et al., 1984). The mean absolute fecundity of this fish (147.94 number/individual/year) is higher than that given for some other species of *Anatolichthys*; 45 and 39, stable habitat, unstable habitat in *A. transgrediens* (Yoğurtçuoğlu et al., 2020).
### Table 7. Comparison of growth parameters of *Anatolichthys* species reported by different studies in Turkey

| Species             | Locality                        | Ref. | N   | Age range | TL (range) | M : F | L∞         | k       | t₀       | Ø'       | a        | b        | R²        | Cf       |
|---------------------|---------------------------------|------|-----|-----------|------------|-------|------------|---------|---------|----------|---------|---------|----------|---------|
| *A. iconii*         | Lake Eğirdir                    | 1    | 522 | I–IV      | 16.70–50.28| 1.07 : 1.00| 54.51 | 0.279    | -1.345  | -        | 0.0136   | 3.1894   | 0.6864   | -        |
| *A. transgrediens*  | Lake Acıgöl                     | 2    | 160 | –         | 2.30–3.40  | 0.11 : 1.00| -       | -        | -       | -        | 0.0237   | 2.732    | 0.936    | -        |
| *A. marassantensis* | Kızılırmak River                | 3    | 45  | –         | 1.70–4.60  | -       | -        | -        | -       | -        | 0.019    | 2.987    | 0.96     | 1.92     |
| *A. danfordii*      | Hirfanlı Reservoir, Kızılırmak River basin | 4 | 758 | –         | 1.47–6.68  | -       | -        | -        | -       | -        | -2.1538  | 3.668    | 0.95     | 1.72     |
| *A. fontinalis*     | Lake Karaevli, Burdur           | 5    | 107 | –         | 2.00–5.30  | -       | -        | -        | -       | -        | 0.0094   | 3.256    | 0.961    | 1.07     |
| *A. danfordii*      | Sirakaraağaçlar Stream, Sinop   | 6    | 452 | 0–II     | 1.80–5.00  | 1.02 : 1.00| 5.149 | 5.945    | 0.502   | -        | 0.0139   | 3.1641   | 0.987    | -        |
| *A. sureyanus*      | Lake Burdur                     | 7    | 460 | 0–IV     | 0.95–4.95  | 1.54 : 1.00| 7.52  | 0.16     | -1.69   | -        | 0.0078♂ | 3.4903♂ | 0.9669♂  | 0.93     |
| *A. danfordii*      | Hirfanlı Reservoir, Kızılırmak River basin | 8 | 2234 | 0–II    | 1.29–6.86  | 0.83 : 1.00| 6.12♂ | -0.19♂  | 2.76♂   | -        | 0.000004 | 3.44     | 0.977    | -        |
| *A. iconii*         | Lake Eğirdir                    | 9    | 166 | –         | 2.30–5.57  | -       | -        | -        | -       | -        | 0.0091   | 3.28     | 0.973    | -        |
| *A. marassantensis* | Hirfanlı Reservoir, Kızılırmak River basin | 9 | 385 | –         | 2.39–6.60  | -       | -        | -        | -       | -        | 0.0111   | 3.40     | 0.965    | -        |
| *A. saldae*         | Lake Salda                      | 9    | 76  | –         | 3.87–6.01  | -       | -        | -        | -       | -        | 0.0121   | 2.86     | 0.953    | -        |
| *A. sureyanus*      | Lake Burdur                     | 9    | 53  | –         | 2.37–4.67  | -       | -        | -        | -       | -        | 0.0090   | 3.11     | 0.954    | -        |
| *A. transgrediens*  | Lake Acıgöl                     | 9    | 113 | –         | 1.78–5.41  | -       | -        | -        | -       | -        | 0.0095   | 3.30     | 0.983    | -        |
| *A. vilbocci*       | Özyurt Creek–Ankara             | 9    | 180 | –         | 1.60–7.04  | -       | -        | -        | -       | -        | 0.0117   | 3.26     | 0.982    | -        |
| *A. asquamatus*     | Lake Hazar–Elazığ               | 9    | 87  | –         | 2.24–3.83  | -       | -        | -        | -       | -        | 0.0061   | 3.44     | 0.973    | -        |
| *A. fontinalis*     | Lake Salda                      | 9    | 50  | –         | 2.13–5.62  | -       | -        | -        | -       | -        | 0.0094   | 3.36     | 0.982    | -        |
| *A. iconii*         | Lake Eğirdir                    | 10   | 206 | I–IV     | 2.1–4.2   | 1.31 : 1.00| -       | -        | -       | 0.0152   | 2.7132   | 0.92     | -        |
| *A. saldae*         | Lake Salda                      | 10   | 525 | I–IV     | 2.80–5.20  | 5.56 : 1.00| -       | -        | -       | 0.0133   | 2.5869   | 0.91     | -        |
| *A. sureyanus*      | Lake Burdur                     | 10   | 350 | 0–IV     | 1.2–4.5   | 0.41 : 1.00| -       | -        | -       | 0.0077   | 3.2207   | 0.96     | -        |
| *A. transgrediens*  | Lake Acıgöl                     | 10   | 165 | I–V      | 2.0–6.1   | 1.54 : 1.00| -       | -        | -       | 0.0118   | 3.0274   | 0.97     | -        |
| *A. meridionalis*   | Gököpinar Spring, Dalaman River basin | This study | 108 | I–IV | 1.91–4.28 | 0.74 : 1.00 | 22.97 | 0.0304 | -2.834  | 1.21     | 0.0112   | 3.4638   | 0.9793   | 1.84     |

Ref—References: 1—(Güçlü, 2012); 2—(Sarı et al., 2017); 3—(Birecikligil et al., 2016); 4—(Krankaya et al., 2014); 5—(İnal et al., 2016); 6—(Karşı and Oral, 2010); 7—(Güçlü et al., 2007); 8—(Yoğurtçuğlu and Ekmekçi, 2013); 9—(Yoğurtçuğlu and Ekmekçi, 2015); 10—(İnal et al., 2019).
CONCLUSIONS

Therefore, the A. meridionalis species and its habitat in a narrow special area Gökpınar Spring should be protected. It is seen that O. mykiss, which shares the same habitat in the environment and escapes from the near trout aquaculture farms or is deliberately released to the environment, may soon start to put pressure on the species. As a result, A. meridionalis, with its growth rates and reproductive characteristics, appears as a species that has a highly competitive ability to survive in the Gökpınar Spring with two other species, G. aculeatus and invasive O. mykiss and G. holbrooki.

ACKNOWLEDGMENTS

I wish to thank, Ufuk Gürkan Yıldırım (Isparta) for great help in the field.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The author declares no conflicts of interest.

Statement on the welfare of animals. The care of experimental animals was consistent with the Republic of Turkey animal welfare laws, guidelines and policies approved by Isparta University of Applied Sciences Local Ethics Committee for Animal Experiments (permit reference number 2020/001).

REFERENCES

Atar, H. H. and Mete, T., Investigating of some growth features of red mullet (Mullus barbatus L. 1758) distributing in Mersin Bay, Biol. Sci. Res. J., 2009, vol. 2, no. 2, pp. 29–34.

De Martini, E.E., Uchiyama, J.H., and Williams, H.A., Sexual maturity, sex ratio, and size composition, De Martini, E.E., Uchiyama, J.H., and Williams, H.A., Sexual maturity, sex ratio, and size composition, Xiphias gladius, caught by the Hawaii-Based pelagic longline fishery, Fish. Bull., 2000, vol. 98, no. 3, pp. 489–506.

Düzgüné, O., Kesici, T., and Gürbüz, F., Istatistik Metodlar, Ankara: Ankara Üniversitesi Ziraat Fakültesi Yayınları, 1995.

Freyhof, J. and Yoğurtçuoğlu, B., A proposal for a new generic structure of the killifish family Aphaniidae, with the description of Aphaniops teimori (Teleostei: Cyprinodontiformes), Zoologica, 2020, vol. 81(1) 2020, no. 3, pp. 369–385, https://doi.org/10.1016/j.zootaxa.81.3.2

Freyhof, J., Özuluğ, M., and Saç, G., Neotype designation of Aphanius iconii, first reviser action to stabilise the usage of A. fontinalis and A. meridionalis and comments on the family group names of fishes placed in Cyprinodontidae (Teleostei: Cyprinodontiformes), Zoologica, 2017, vol. 4294, no. 5, pp. 573–585, https://doi.org/10.1016/zootaxa.4294.5.6

Froese, R., Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations, J. Appl. Ichthyol., 2006, vol. 22, no. 4, pp. 241–253.

Gayanilo, F.C., Soriano, M., and Pauly, D., A draft guide to thecompleat ELEFAN, ICLARM Software 2, 1988.

Ghafouri, Z., Kevany, Y., and Soofiian, N.M., Reproductive biology of Aphanius isfahanensis in the Zayandehrud River, central Iran, Environ. Biol. Fishes, 2019, vol. 102, pp. 19–25, https://doi.org/10.1007/s10641-018-0833-0

Gibson, R.N. and Ezzi, I.A., The biology of the scaldfish, Armoglossus laterna (Walbaum) on the west coast of Scotland, J. Fish Biol., 1980, vol. 17, no. 5, pp. 565–575.

Güçlü, S.S., Turna, I.I., Güçlü, Z., and Gülle, I., Population structure and growth of Aphanius anatolicae sureyanus Neu, 1937 (Osteichthyes: Cyprinodontidae), endemic to Burdur Lake, Turkey, Zool. Middle East, 2007, vol. 41, no. 1, pp. 63–70.

Güçlü, S.S., Population structure of Killifish, Aphanius anatolicae (Cyprinodontidae) endemic to Anatolia in Lake Eğirdir-Isparta (Turkey), Iran J. Fish. Sci., 2012, vol. 11, no. 4, pp. 786–795.

Hrbeck, T. and Meyer, A., Closing of the Tethys Sea and the phylogeny of Eurasian killifishes (Cyprinodontiformes: Cyprinodontidae), J. Evol. Biol., 2003, vol. 16, no. 1, pp. 17–36, https://doi.org/10.1046/j.1420-9101.2003.00475.x

Hrbeck, T., Kucuk, F., Frickey, T., Stöllting, K.N., Wildekamp, R.H., and Meyer, A., Molecular phylogeny and historical biogeography of the Aphanius (Pisces, Cyprinodontiformes) species complex of central Anatolia, Turkey, Mol. Phylogenet. Evol., 2002, vol. 25, no. 1, pp. 125–137, https://doi.org/10.1016/S1055-7903(01)00191-8

Innal, D., Aksu, M. and Giannetto, D., Length-weight relationships, population structure and body condition of Aphanius anatolicae (Cyprinodontidae) and Pseudophoxinus ninae (Cyprinidae) living in Karsaevi Lake (Burdur-Turkey), Rev. Hydrobiol., 2016, vol. 9, no. 2, pp. 73–83.

Innal, D., Güçlü, S.S., Ünal, M.C., Dogangil, B. and Giannetto, D., Age structure and length-weight relationships for four Aphanius species endemic to the Lake District (Central Anatolia, Turkey), Acta Zool. Bulg., 2019, vol. 71, no. 2, pp. 211–217.

Karsh, Z. and Aral, O., Population age, sex structure and growth of Aphanius danfordi (Boulenger, 1890) to Sirakaraağaçlar Stream, Turkey, J. Anim. Vet. Adv., 2010, vol. 9, no. 10, pp. 1427–1431.

Kırkaya, Ş.G., Ekmeç, F.G., Yalçın-Özdilek, Ş., Yorgurtçuoğlu, B., and Gençoğlu, L., Condition, length-weight and length-length relationships for five fish species from Hirfanlı reservoir, Turkey, J. FisheriesSciences.com, 2014, vol. 8, no. 3, pp. 208–213, https://doi.org/10.3153/jfsc.201426

Le, Cren E.D., The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis), J. Anim. Ecol., 1951, vol. 20, no. 2, pp. 201–219, https://doi.org/10.2307/1540

Nikolsky, G.V., Theory of Fish Population Dynamics as the Biological Background for Rational Exploitation and Management of Fishery Resources, Koenigstein: Otto Koeltz Sci. Publ., 1980.

Pauly, D., Fish Population Dynamics in Tropical Water: A Manual for Use with Programmable Calculators, ICLARM, 1984.

Ricker, W.E., Computation and interpretation of biological statistics of fish populations, Bull. Fish. Res. Board Can., 1975, vol. 191, pp. 1–382.

Sari, H.M., Kurtul, I., Aydin, E., and Ilhan, A., Length-weight relationships for an endemic species Aphanius transgrediens from Lake Acıgöl (Afyonkarahisar-Turkey), LimnoFish, 2017, vol. 3, no. 2, pp. 113–116, https://doi.org/10.17216/LimnoFish.288824

Sparre, P., Ursin, E., and Venema, S.C., Introduction to Tropical Fish Stock Assessment. Part I. Manual, Rome: FAO Fish. Tech. Paper., 1989, no. 306.
Sungur Birecikligil, S., Çiçek, E., Öztürk, S., Seçer, B., and Celepoğlu, Y., Length-length, length-weight relationship and condition factor of fishes in Nevşehir Province, Kızılırmak River Basin (Turkey), *Acta Biol. Turc.*, 2016, vol. 29, no. 3, pp. 72–77.

Tesch, F.W., Age and growth, in Methods for Assessment of Fish Production in Freshwaters, Ricker, W.E., Ed., Oxford: Blackwell, 1971, pp. 99–130.

Thrope, J.E., Miles, M.S., and Key, D.S., Development rate, fecundity and egg size in Atlantic salmon, *Salmo salar* L., *Aquaculture*, 1984, vol. 43, nos. 1–3, pp. 289–305. https://doi.org/10.1016/0044-8486(84)90030-9

Wildekamp, R.H., Küçük, F., Uğrullu, M., and Van Neer, W., Species and subspecies of the genus *Aphanius* Nardo, 1897 (Pisces: Cyprinodontidae) in Turkey, *Turk. J. Zool.*, 1999, vol. 23, no. 1, pp. 23–44.

Wootton, R.J., *Ecology of Teleost Fishes*, London: Chapman & Hall, 1990.

Yoğurtçuoğlu, B. and Ekmekçi, F.G., Life-history traits of *Aphanius danfordii* (Boulenger, 1890) (Pisces: Cyprinodontidae), endemic to Kızılırmak Basin (Turkey), *J. Appl. Ichthyol.*, 2013, vol. 29, no. 4, pp. 866–871. https://doi.org/10.1111/jai.12036

Yoğurtçuoğlu, B. and Ekmekçi, F.G., Length-weight and length-length relationships of eight endemic *Aphanius* species from Turkey, *J. Appl. Ichthyol.*, 2015, vol. 31, no. 4, pp. 811–813. https://doi.org/10.1111/jai.12789

Yoğurtçuoğlu, B., Uyan, U., and Ekmekçi, F.G., The influence of environmental instability on the reproductive strategy of the critically endangered Acıgöl killifish (*Aphanius transgrediens*), *J. Fish Biol.*, 2020, vol. 97, no. 1, pp. 246–256. https://doi.org/10.1111/jfb.14358

Zar, J.H., *Biostatistical Analysis*, New Jersey: Prentice Hall, 1999.