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Population status of Endemic fish *Anatolichthys maeandricus* (Cyprinodontiformes: Aphaniidae) in lakes and springs of West Anatolia under drought and intense anthropogenic influence

Salim Serkan Güçlü* and Büşra Çelik

Faculty of Eğirdir Fisheries, Isparta University of Applied Sciences, Isparta-Republic of Türkiye;
e-mails: salimguclu@isparta.edu.tr, busra.celikua32@gmail.com

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ABSTRACT

In the Mediterranean Anatolia, the Lakes Region and Konya Closed Basin are the richest regions in terms of endemic fish with 55 species. An important place among them is occupied by the Oriental killifish genus *Anatolichthys* (Cyprinodontiformes: Aphaniidae). Many of them are still poorly understood. In these regions, global warming (droughts) and anthropogenic impact are serious threats to freshwater fishes. We have studied little explored populations of endemic *A. maeandricus* in Işıklı Lake and Işıklı Spring (Büyük Menderes River basin), influenced by both factors. Sampling was carried out seasonally (August, October 2021, February and April 2022), with a total of 233 and 157 specimens. Age ranges, male to female proportions, length and weight ranges were determined for two populations. The Von Bertalanffy growth equations were calculated for the populations in Işıklı Lake and Işıklı Spring, respectively, as $Lt=22.58\ (1\text{-}e^{-0.0408(t+0.303)})$ and $Lt = 27.60\ (1\text{-}e^{-0.0304(t+0.554)})$. The content of the digestive tract and stomach was examined. *Gammarus* sp. and Chironomid organisms were dominant in food of fish from both habitats. Although the growth parameters appear to be positive, drought and habitat destruction can be expected to endanger this endemic species in the near future. By our observations, over the past ten years, the habitat of the species has been severely restricted, and this situation has also affected other endemic fish species in the region. For these reasons, it is an urgent to protect the habitat of endemic fishes first and then the species themselves.

Key words: *Anatolichthys maeandricus*, Aphaniidae, Büyük Menderes River Basin, global warming, nature destruction, Oriental killifish

Популяционный статус эндемичной рыбы *Anatolichthys maeandricus* (Cyprinodontiformes: Aphaniidae) в озерах и ключах Анатолии в условиях засухи и интенсивного антропогенного воздействия

Салим Серкан Гючлю* и Бюшра Челик

Факультет рыболовства Эгирдир, Университет прикладных наук, Испарта, Турция;
e-mails: salimguclu@isparta.edu.tr, busra.celikua32@gmail.com

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РЕЗЮМЕ

В Средиземноморской Анатолии Озерный район и Закрытый бассейн Конья – наиболее богатые регионы в отношении разнообразия эндемичных рыб, которых насчитывают 55 видов. Значимое место

* *Corresponding author / Автор-корреспондент*

среди них занимают виды рода *Anatolichthys* (Cyprinodontiformes: Aphaniidae). Многие из эндемиков плохо изучены. В то же время пресноводные рыбы этих регионов подвержены серьезным угрозам вследствие глобального потепления (засухи) и антропогенных воздействий. Нами исследованы малоизученные популяции эндемичного вида *A. maeandricus* в озере Ишиклы и роднике Ишиклы (бассейн реки Бюйюк Мендерес), находящиеся под влиянием обоих факторов. Отбор проб проводился сезонно (август, октябрь 2021 г., февраль и апрель 2022 г.), общим количеством 233 и 157 экз. Возрастные диапазоны, соотношение полов, размерно-весовые характеристики были определены для каждой из популяций. Уравнения роста фон Берталанфи рассчитаны для популяций озера Ишиклы Lt=22,58 ($1-e^{-0,0408(t+-0,303)}$) и источника Ишиклы Lt = 27,60 ($1-e^{-0,0304(t+0,554)}$). Исследовали состав питания. В пище рыб обоих местообитаний доминировали *Gammarus* sp. и хирономиды. Хотя параметры роста – положительные, можно ожидать, что засуха и деградация среды обитания поставят под угрозу этот эндемичный вид уже в ближайшем будущем. По нашим наблюдениям, за последние десять лет ареал вида сильно сократился, и эта ситуация затронула и другие эндемичные виды рыб региона. По этим причинам необходимо принимать срочные меры по охране среды обитания эндемичных видов.

Ключевые слова: *Anatolichthys maeandricus*, Aphaniidae, бассейн реки Бюйюк Мендерес, глобальное потепление, деградация среды обитания, *киллифиш*

INTRODUCTION

Approximately half of the inland fish in Turkey consists of endemic species. The Lakes Region and Konya Closed Basin in Anatolia are the richest regions in terms of endemic fish with 55 species (Çiçek et al. 2018). Among them, species belonging to the oriental killifish genus *Anatolichthys* Kosswig et Sözer, 1945 constitute an important place. The genus includes 13 species, *A. villwocki* Hrbek et Wildekamp, 2003, *A. transgrediens* (Ermin, 1946), *A. iconii* (Akşiray, 1948), *A. anatoliae* (Leidenfrost, 1912), *A. fontinalis* (Akşiray, 1948), *A. sureyanus* (Ney, 1937), *A. splendens* Kosswig et Sözer, 1945, *A. saldae* (Akşiray, 1955), *A. marassantensis* (Pfleiderer, Geiger et Herder, 2014), *A. maeandricus* (Akşiray, 1948), *A. irregularis* (Yoğurtçuoğlu et Freyhof, 2018), *A. danfordii* (Boulenger, 1890) and *A. meridionalis* (Akşiray, 1948). In the Lakes Region, 11 of them are present (*A. splendens* became extinxt). In this respect, Anatolia is a center in the distribution of the genus *Anatolichthys* (Freyhof and Yoğurtçuoğlu 2020; Güçlü and Güçlü 2022).

The Mediterranean Basin, including the Lakes Region and Middle Anatolia (Türkiye), is shown as one of the regions that will be most affected by global climate change. Drought and related habitat loss/destruction, pollution, the effect of predator-invasive species, water loss due to agricultural irrigation constitute the main threats to the species in the region (Çolak et al. 2022). It has been determined that the majority of *Anatolicthys* populations and habitats in the region have changed negatively (Güçlü and Güçlü 2022). While *A. fontinalis, A. sureyanus, A. saldae, A. meridionalis* and *A. transgrediens* species are the most affected species, it is predicted that the population and habitats of other species will be under great threat in the near future (Freyhof and Yoğurtçuoğlu 2020; Güçlü and Güçlü 2022).

The Büyük Menderes River basin, which borders the Lakes Region, is also adversely affected by arid and intense anthropogenic effects. One of the places where this effect is best observed is the Işıklı Lake wetland. Although there are many studies on biodiversity in the mentioned wetland, there is no ecological information about the *Anatolicthys maeandricus* species that is distributed in Işıklı Lake and its spring. In addition, there is no information about the status of this habitat due to drought and anthropogenic effects in recent years.

In the study, on the basis of our habitat observations, fish sampling and population studies of the last 10 years in the region, we assess the state of the populations of endemic *Anatolichthys maeandricus* in the Işıklı Lake and the Işıklı Spring, which are typical habitats for it, and are also subject to negative drought and anthropogenic impacts.

MATERIAL AND METHODS

Sampling sites. *Anatolichthys maeandricus* individuals (Fig. 1) were sampled seasonally (August and October 2021, February and April 2022) from Işıklı Spring (38°19'19"N; 29°51'07"E) and two locations

Fig. 1. *Anatolichthys maeandricus*: A – female, total length 5.0 cm; B – male, 4.0 cm.

of Işıklı Lake: on the north (Beydilli, 38°15'29"N; 29°55'17"E) and south-west (Sungurlu, 38°12'07"N; 29°51'27"E) (Fig. 2). In the lake, we used 5 and 15 mm mesh apertures in coastal friction, nets (grabbing) and scoops with 5 mm mesh. In the spring area, we used electro chock device and scoops.

Area studied. Işıklı Lake is a wetland located in the upper basin of the Büyük Menderes River with a maximum depth of 7 m. The lake is fed by Akçay, Işıklı Spring, groundwater and two major branches of Büyük Menderes River in the upper basin (Küfi Stream and Karadirek Stream) (Lahn 1948). The approximate lake area at normal water level is 64.53 km^2 and its height above sea level is 821 m (İlhan and Balık 2003). Işıklı Lake was a marshy area formerly located in the Çivril-Dinar tectonic depression basin (Lahn 1948). Since the lake area expands and damages the surrounding settlements and agricultural lands when there is abundant rainfall, the flood protection works initiated by DSI (State Hydraulic Works) in 1949 were completed in 1968, and the western, southern and eastern shores of the lake were surrounded by a dam (Yarar and Magnin 1997). After that, the lake became a dam lake. Işıklı Lake is today used as a reservoir to store water for large-scale irrigations in the surrounding plains. In the lake, *Chondrostoma meandrense* Elvira, 1987 (Leuciscidae, endemic), *Barbus xanthos* Güçlü, Kalaycı, Küçük et Turan, 2020 (Cyprinidae, endemic), *Gobio meandricus* Naseka, Erk'akan et Küçük, 2006 (Gobionidae, endemic), *Pseudophoxinus maeandricus* (Ladiges, 1960) (Leuciscidae, endemic), *Luciobarbus kottelati* Turan, Ekmekçi, İlhan et Engin, 2008 (Cyprinidae, endemic), *Cobitis simplicispina* Hanko, 1925 (Cobitidae, endemic), *Cyprinus carpio* Linnaeus, 1758 (Cyprinidae, native), *Esox lucius* Linnaeus, 1758 (Esocidae, native), *Tinca tinca* (Linnaeus, 1758) (Tincidae, native), *Carassius gibelio* Bloch, 1782 (Cyprinidae, exotic), *Carassius auratus* (Linnaeus, 1758) (Cyprinidae, exotic) and *Gambusia holbrooki* Girard, 1859 (Poeciliidae, exotic), fish species are distributed (Güçlü et al. 2013).

Işıklı Spring are located approximately 8 km northwest of Işıklı Lake. Spring waters feed Işıklı Lake via the Küfi Stream and have high productivity.

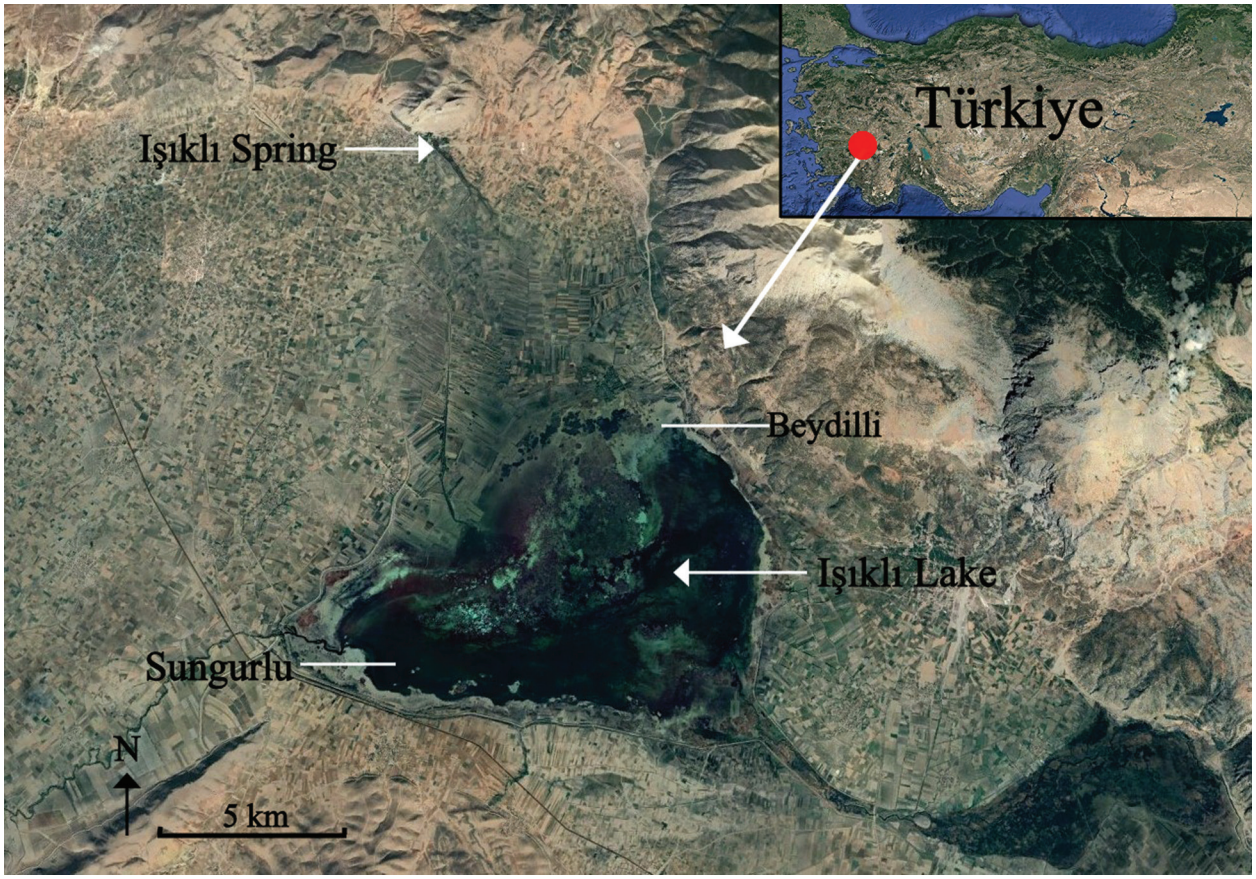

Fig. 2. Sampling areas in West Anatolia, Türkiye.

The source provides 22.9% of the amount of water entering the lake with the highest current amount. The spring waters were connected to the Küfi Stream in 1963 through a drainage channel (Ceylan 1998). In the spring, *Barbus xanthos* (endemic), *Chondrostoma meandrense* (endemic), *Garra menderesensis* Küçük, Bayçelebi, Güçlü et Gülle, 2015 (Cyprinidae, endemic), *Pseudophoxinus maeandri* (Ladiges, 1960) (Leuciscidae, endemic), *Gobio meandricus* (endemic), *Squalius carinus* Özuluğet Freyhof, 2011 (Leuciscidae, endemic), *Oxynoemacheilus germencicus* (Erk'akan, Nalbant et Özeren, 2007) (Nemacheilidae, endemic) and *Gambusia holbrooki* (exotic), fish species are distributed (Güçlü et al. 2013).

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

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.

The sexes were determined externally as the species showed sexual dimorphism. Female and male ratio were determined according to age. The overall ratio of males to females was evaluated with χ^2 test (0.05) (Düzgüneş et al. 1995). Total length and weight in frequency distributions for all specimens were calculated.

The relation of weight to total length established using the exponential regression equation $W = a.TL^b$, 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 *Anatolichthys maeandricus* population was estimated with the following Von Bertalanffy growth equations: $Lt = L\infty\ (1 - e^{-k\,(t\,-\,to)})$, where *Lt* 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 (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:

$$t = \frac{Sd_{\log TL}}{Sd_{\log W}} \frac{|b-3|}{\sqrt{1-r^2}} \sqrt{n-2}$$

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 (Ø', phi prime) was calculated with the formula $Ø' = \text{Log } k + 2 * \text{Log } L\infty$ (Gayanilo et al. 1988). Fulton's coefficient of condition factor was calculated by $Cf = (W/TL3) \times 100$ (Sparre and Venema 1998). The digestive tract and stomach contents (15 individuals seasonally) were examined and given as a percentage. A stereo microscope was used to identify food particles. (Edmondson 1959, Tanyolaç 2000).

RESULTS

A total volume of *Anatolichthys maeandricus* samples is 233 and 157 specimens from the Işıklı Spring and Işıklı Lake. The age ranges were determined as I–IV in Işıklı Lake and I–V in Işıklı Spring (Table 1). Dominated by fish of age groups I and II. In the Işıklı Lake population, 49.68% of the fish examined were males and 50.32% were females; in the Işıklı Spring, there were 43.78% males and 56.22% females. The general ratio of male to female individuals is 0.98: 1.00 ($p > 0.05$) in the population of Işıklı Lake; in the Işıklı Spring, it is 0.78: 1.00 ($p < 0.05$) (Table 1). The length and weight range of *A. maeandricus* was determined between 1.54–5.96 cm, 0.06–4.69 g in Işıklı Lake, and 1.73–4.97 cm, 0.07–4.60 g in Işıklı Spring.

The Von Bertalaffy growth equations of *A. maeandricus* populations are respectively, $Lt = 22.58\ (1-e^{-0.0408\ (t+-0.303)})$ and $Lt = 27.60\ (1-e^{-0.0304\ (t+0.554)})$ (Fig. 3). The differences between observed and expected total lengths were found to be statistically insignificant in all age groups (except Işıklı Spring population V age group) (Table 2). The average growth performance (Ø', Phi Prime) was calculated as 1.31 of Işıklı Lake and 1.36 Işıklı Spring.

Calculated total length-weight relationships of populations of *A. maeandricus* in Işıklı Lake and

Table 1. Age range and sex ratio in two populations of *Anatolicthys maeandricus.*

	Age groups	Females		Males		All specimens		M:F
		N	%N	N	%N	N	%N	
Işıklı Lake	I	35	22.29	54	34.39	89	54.69	1.54:1.00 (p<0.05)
	II	21	13.38	17	10.83	38	24.20	0.80:1.00 (p<0.05)
	III	8	5.10	5	3.18	13	5.28	0.63:1.00 (p<0.05)
	IV	15	9.55	2	1.27	17	10.83	0.13:1.00 (p<0.05)
	Total	79	50.32	78	49.68	157	100	0.98:1.00 (p>0.05)
		Females		Males		All specimens		M:F
		N	%N	N	%N	N	%N	
Işıklı Spring	I	61	26.18	28	12.02	89	38.20	0.45:1.00 (p<0.05)
	II	24	10.30	58	24.89	82	35.19	2.41:1.00 (p<0.05)
	III	22	9.44	16	6.87	38	16.31	0.72:1.00 (p<0.05)
	IV	16	6.87	–	–	16	6.87	0.00:16.00 (p<0.05)
	V	8	3.43	–	–	8	3.43	0.00:8.00 (p<0.05)
	Total	131	56.22	102	43.78	233	100	0.78:1.00 (p<0.05)

Note. M:F – males to females ratio; N – number of specimens; N% – percentage in sample.

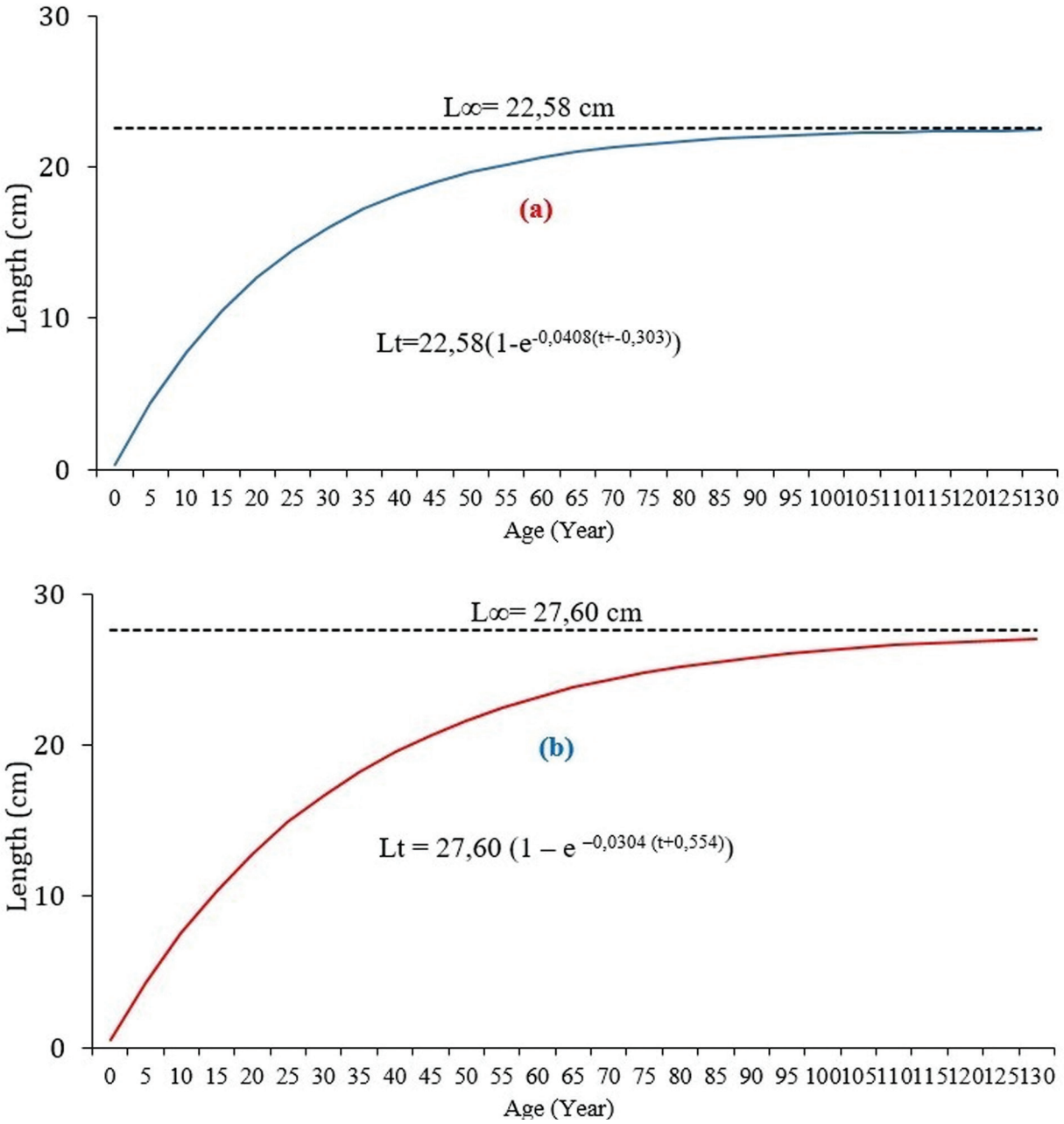

Fig. 3. Von Bertalanffy growth formula and curves for populations of *Anatolichthys maeandricus* from the Işıklı Lake (a) and Işıklı Spring (b).

Işıklı Spring are visually represented (Fig. 4, Table 3). The *b* value of of this relationship was calculated as 3.2194 in the population of Işıklı Lake and 3.3567 in the population of Işıklı Spring. The regression coefficient (R^2) values were found to be 0.9938 for Işıklı Lake and 0.9917 for Işıklı Spring (Fig. 4, Table 3). The mean value of the condition factor was calculated as 1.85 in Işıklı Lake population and 1.84 in Işıklı Spring population (Table 3).

In order to determine, the contents of the digestive tract and stomach were examined and were given as % (Table 4). It was determined that *Gammarus*

Table 2. Measured average length and calculated average length (cm) in two populations of *Anatolicthys maeandricus*.

Age groups	Measured average length (cm)		Calculated average length (cm)		t test
	Lake	Spring	Lake	Spring	
I	2.40	2.43	1.16	1.27	p>0.05
II	2.97	3.04	2.02	2.06	p>0.05
III	4.10	3.95	2.84	2.82	p>0.05
IV	4.73	4.69	3.63	3.56	p>0.05
V	–	5.32	–	4.28	p<0.05

Notes. I–V – age groups. The calculation is made according to the von Bertalanffy growth equation.

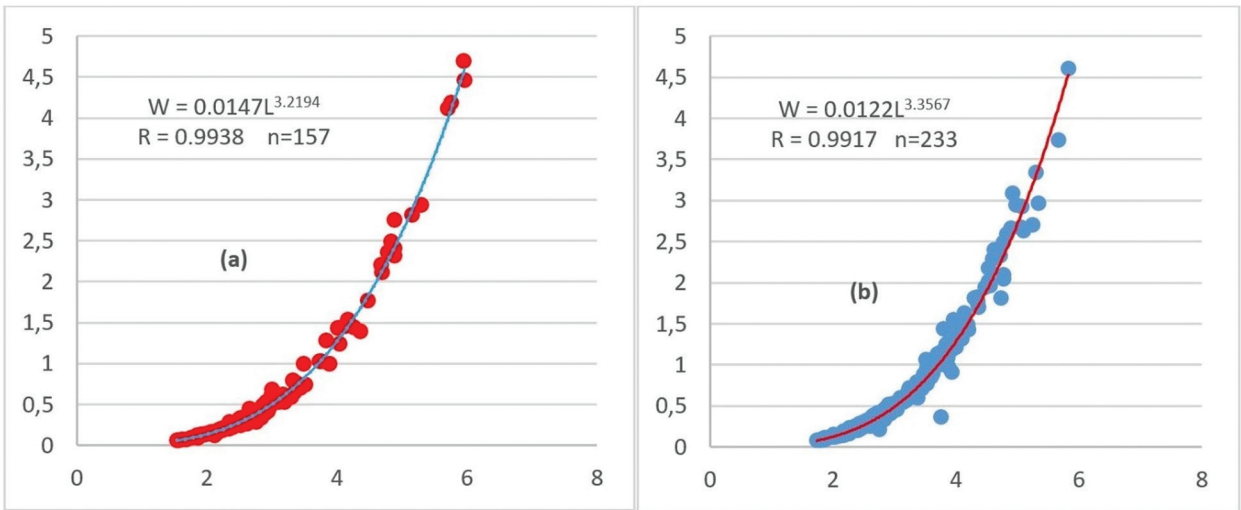

Fig. 4. Length-weight relationships for populations of *Anatolichthys maeandricus* from the Işıklı Lake (a) and Işıklı Spring (b).

Table 3. Length-weight relationship parameters and condition factors of populations of *Anatolicthys maeandricus* in Işıklı Lake and Işıklı Spring.

Locality	a	b	R^2	95% confidence interval b (±SE)	t-test	P	CF	Growth type
Işıklı Lake	0.0147	3.2194	0.9938	3.1858–3.2987 (±0.024)	5.892	<0.001	1.85	+ Allometry
Işıklı Spring	0.0122	3.3567	0.9917	3.2986–3.3812 (±0.071)	6.125	<0.001	1.84	+ Allometry

Notes. CF – condition factor; P – P value; SE – standart error.

sp. (24.56%), Chironomid (19.25%) and Diptera (10.20%) were generally found in the digestive tract of the Işıklı Lake population. In the digestive tract of the Işıklı Spring population, *Gammarus* sp. (66.25%) and Chironomid (20.83%) are dominant.

DISCUSSION

Many studies have been carried out to determine the molecular taxonomic and population characteristics of *Anatolichthys*. However, most of the studies on the determination of ecological characteristics didn't go beyond the studies of the length-weight relationship. There are 3–4 publications that reveal all the growth parametersof the species belonging to the genus (Table 5).

In this study, the ages of *Anatolichthys maeandricus* ranged from I to V. The age range of small fish species is limited (Nikolsky 1980). Nikolsky (1980) suggested that the status of a wide age distribution in a population should be regarded as an indicator of adequate levels of nutrients in the water system. Age ranges are similar to studies of other *Anatolichthys* species (Table 5).

Table 4. The content of the digestive tract (%) of *Anatolicthys maeandricus* in the populations of Işıklı Lake and Işıklı Spring.

	August 2021		October 2021		February 2022		April 2022		Total	
	Lake	Spring	Lake	Spring	Lake	Spring	Lake	Spring	Lake	Spring
Amphipoda										
Gammarus sp	5.48	51.47	–	94.83	69.77	53.84	4.55	72.37	24.56	66.25
Branchiopoda										
Bosmina sp	34.25	–	–	–	–	–	–	–	8.54	–
Daphnia sp	–	–	20	–	–	–	–	–	6.01	–
Bivalvia	–	–	–	–	4.65	–	–	–	1.02	–
Nematoda	1.37	1.47	20	–	2.33	–	–	–	8.36	0.12
Insecta										
Ephemeroptera	1.37	–	–	–	–	–	–	–	0.21	–
Chironomid	24.66	32.29	20	1.72	2.33	19.23	22.72	18.42	19.25	20.83
Diptera	–	–	20	–	6.25	–	–	1.32	10.20	0.13
Oligochaeta	5.48	7.35	–	–	2.33	7.69	13.64	1.32	8.35	1.36
Fish										
Vertebra	1.37	1.47	–	–	–	7.69	–	–	0.21	2.03
Scale	19.18	1.47	20	–	–	–	18.18	2.63	12.1	1.69
Others										
Plant Parts	6.85	–	–	–	4.16	–	–	–	0.98	–
Empty	–	1.47	–	3.45	6.25	11.54	–	3.95	0.21	7.59

While the ratio of *A. maeandricus* females to males is 0.98:1.00 in Işıklı Lake, it is 0.78:1.00 in Işıklı Spring. While Işıklı Lake M:F ratio is close to 1.00:1.00, which should be in nature, Işıklı Spring M:F ratio was observed differently. According to Nikolsky (1980), the sex ratio varies significantly from species to species; but in most species it is close to 1. Sex differences may be due to males living shorter and maturing earlier, sexual differences in growth, mortality rates, or reproductive energy costs. In addition, it is suggested that the dominance of one sex over the other may be due to different behaviors that lead to an easier capture of one sex and differences in mortality rates of the sexes (Ghafouri et al. 2019). The fact that the Işıklı Spring M:F ratio was out of the expected ratio in our study is probably due to the sampling method. The M:F ratio in our study was found to be compatible with some of the studies conducted with other *Anatolichthys* species and inconsistent with others (Table 5). These differences may be shaped by hunting gear, sample size and species. The number of females is also dominant in *A. maeandricus*. This will provide a crucial advantage for the species' reproductive success in the habitat and will be a decisive factor for a thriving population. In addition, it is seen that female individuals are larger in total length than male individuals at all ages.

Differences in growth parameters may be due to ecological differences between study areas, water temperature, water quality and amount of nutrients in the environment. The differences between observed and expected total lengths were found to be statistically insignificant in all age groups (except Işıklı Spring population V age group) (Table 2). While the Işıklı Lake population of the species is seen to have reached a maximal calculated length $L\infty$ of 22.58 cm, the Işıklı Spring population will reach a $L\infty$ of 27.60 cm (Fig. 3).

It is thought that differences of the $L\infty$ value may vary depending on fish species, water temperature, environment and feeding (Table 5). In large lentic systems, water temperatures change according to the seasons and can reach high values in summer. In our study, temperature differences between seasons are also clearly seen in Işıklı Lake. Water temperatures in the Işıklı Lake are: 23.1°C in May 2021, 11.0°C in

Table 5. Comparison of growth parameters of *Anatolichthys* species reported in different studies in Türkiye.

Species	Lokality	Ref.	N	Age Range	SL (cm)	M:F	L∞	k	t0	∅′	a	b	R2	CF
A. iconii	Eğirdir Lake	1	522	I–IV	1.67–5.03	1.07:1.00	54.51	0.279	–1.345	–	0.0136	3.1894	0.6864	–
A. transgrediens	Acıgöl Lake	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	4	758	–	1.47–6.68	–	–	–	–	–	–2.1538	3.668	0.95	1.72
A. fontinalis	Karaevli Lake, Burdur	5	107	–	2.00–5.30	–	–	–	–	–	0.0094	3.256	0.961	1.07
A. danfordii	Sırakaraağaçlar Stream	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	Burdur Lake	7	460	0–IV	0.95–4.95	1.54:1.00	7.52	0.16	–1.69	–	0.0078 ♂ 0.0076 ♀	3.4903 ♂ 3.4675 ♀	0.9669 ♂* 0.9787 ♀*	0.93
A. danfordii	Hirfanlı reservoir	8	2234	0–II	1.29–6.86	0.83:1.00	6.12 ♂ 12.66 ♀	–0.19 ♂ –0.09 ♀	2.76 ♂ 2.35 ♀	–	0.000004	3.44	0.977	–
A. iconii	Eğirdir Lake	9	166	–	2.30–5.57	–	–	–	–	–	00.0091	3.28	0.973	–
A. marassantensis	Hirfanlı reservoir	9	385	–	2.39–6.60	–	–	–	–	–	0.0111	3.40	0.965	–
A. saldae	Salda Lake	9	76	–	3.87–6.01	–	–	–	–	–	0.0121	2.86	0.953	–
A. sureyanus	Burdur Lake	9	53	–	2.37–4.67	–	–	–	–	–	0.0090	3.11	0.954	–
A. transgrediens	Acıgöl Lake	9	113	–	1.78–5.41	–	–	–	–	–	0.0095	3.30	0.983	–
A. villwocki	Özyurt Stream-Ankara	9	180	–	1.60–7.04	–	–	–	–	–	0.0117	3.26	0.982	–
A. asquamatus	Hazar Lake	9	87	–	2.24–3.83	–	–	–	–	–	0.0061	3.44	0.973	–
A. fontinalis	Salda Lake	9	50	–	2.13–5.62	–	–	–	–	–	0.0094	3.36	0.982	–
A. iconii	Eğirdir Lake	10	206	I–IV	2.1–4.2	1.31:1.00	–	–	–	–	0.0152	2.7132	0.92	–
A. saldae	Salda Lake	10	525	I–IV	2.80–5.20	5.56:1.00	–	–	–	–	0.0133	2.5869	0.91	–
A. sureyanus	Burdur Lake	10	350	0–IV	1.2–4.5	0.41:1.00	–	–	–	–	0.0077	3.2207	0..96	–
A. transgrediens	Acıgöl Lake	10	165	I–V	2.0–6.1	1.54:1.00	–	–	–	–	0.0118	3.0274	0.97	–
A. meridionalis	Gökpınar Spring, Dalaman River basin	11	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
A. maeandricus	Işıklı Lake	12	157	I–IV	1.54–5.96	0.98:1.00	22.58	–0.0408	–0.303	1.31	0.0147	3.2194	0.9938	1.85
A. maeandricus	Işıklı Spring	12	233	I–V	1.73–4.97	0.78:1.00	27.60	–0.0304	–0.554	1.36	0.0122	3.3567	0.9917	1.84

Notes. Ref – References: 1 – Güçlü 2012; 2 – Sarı et al. 2017; 3 – Birecikligil et al. 2016; 4 – Kırankaya et al. 2014; 5 – İnnal et al. 2016; 6 – Karslı and Oral 2010; 7 – Güçlü et al. 2007; 8 – Yoğurtçuoğlu and Ekmekçi 2013; 9 – Yoğurtçuoğlu and Ekmekçi 2015; 10 – İnnal et al. 2019; 11 – Güçlü 2022; 12 – present study.

October 2021, 2.5°C in February 2022 and 22.0°C in April 2022. In Işıklı Spring, the water temperature is at an almost constant temperature of 15–16°C (15.4°C in May 2021, 16.1°C in October 2021, 14.8°C in February 2022 and 15.0°C in April 2022) throughout the year. It is stated that the $L\infty$ value increases inversely with the decrease in temperature (Nikolsky 1980). However, the opposite of what Nikolsky, 1980 stated, occurred in our study.

The length-weight relationship of *A. maeandricus* showed positive allometry in Işıklı Lake and Işıklı Spring (Table 3). Usually a shorter size range and to be a lot of smaller fish can result in a higher b-value because small and juvenile fish often have a more "round" body and become more fusiform with age (Froese 2006). Positive allometric growth was observed in studies with other *Anatolichthys* species (Table 5). Length-weight relationship regression coefficient ($R2$) values of Işıklı Lake and Işıklı Spring populations were calculated as 0.9938 and 0.9917, respectively. This situation reveals that the increase in regulation in the total length-weight relationship shows an insignificant deviation. The regression coefficient $R2$ value is generally similar to other studies (Table 5).

It was determined that there are generally *Gammarus* sp. (24.56%), Chironomid (19.25%) and Diptera (10.20%) in the digestive tract of the Işıklı Lake

Anatolichthys maeandricus population. In the digestive tract of the Işıklı Spring population, *Gammarus* sp. (66.25%) and Chironomid (20.83%) are dominant. A total of 13 different organisms were detected in the stomach and digestive tract of *A. maeandricus*. This is proof that there is sufficient food in both the lake and the spring. With the relatively high dietary diversity, *A. meandricus* is similar to, for example, *A. sureyanus* from Lake Burdur (Güçlü et al. 2007), which feed on a variable organisms of phytoplankton, zooplankton and benthos. In contrast, the lake endemic *A. burduricus,* feeds on a limited diet, with zooplankton being the most consumed food.

The fact that *Anatolichthys maeandricus* feeds on both adult Diptera and its larvae found during the study indicates that this species can also feed in the sediment zone. In some periods, samples of diatoms and green algae accompanied by high amounts of mud and sand were found in the digestive tracts of fish. Similarly, in the study conducted on *A. iconii* in Lake Eğirdir (Güçlü 2012), it was determined that the main nutrients of the species were Bacillariophyta, *Gammarus pulex* and aquatic insects.

Anatolichthys maeandricus is found in the Büyük Menderes River Basin and forms dense populations in Işıklı Spring and Işıklı Lake. However, with the warming caused by global climate change in recent years, the region where the species spread has also taken a large share of drought. In May 2021, the water retention of the lake and spring was observed to be relatively good. However, there was an 8–10 m channel excavated parallel to the lake shore, which is opened for fishing boats to come out when the lake water is low and worsened the water regime. In the years 2021–2022, when the study was conducted, we observed periodic drought. A large part of Işıklı Lake dried up due to drought and low precipitation regime during sampling in August 2021. The drought continued partly in October 2021, although the level of the lake increased slightly in February 2022, with precipitation beginning in early winter and in April 2022. In addition to drought, habitat destructions have also been determined from time to time in Işıklı Lake. All these reasons may endanger the condition of fish species in Lake Işıklı.

Işıklı Spring, on the other hand, has been partially and slightly affected by drought, however direct habitat destruction is observed here. The Küfi Stream, which feeds the spring, was cut off by a dam and its entrance to the spring was prevented. In addition, during October 2021 sampling, it was observed that the water of the source was completely blocked because it was given for the supply of rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) farm with the creation of a small artificial stream. In addition, it can be assumed that *O. mykiss*, escaped from the trout farm or deliberately released into the environment, may soon begin to put pressure on *A. maeandricus*, as the habitat of the latter is very limited here (only a few hundred square meters). Another endangered fish, *Pseudophoxinus maeandri* (Ladiges, 1960), included in the IUCN Red List, which shares the same habitat is also affected by this situation. During the February 2022 sampling, this situation continued. Besides in the source base, all aquatic plants were cleaned, and concrete was poured and piles were driven. In the April 2022 sampling, it was observed that the source looked completely like a swimming pool. This habitat destruction at the source has put the existence of *A. maeandricus* in the source in great danger.

As a result, although the growth rates of *A. maeandricus* show positive values in Işıklı Lake and Işıklı Spring; presence of invasive *O. mykiss* species in the source, adverse effects of drought in the lake and habitat destruction at the source will adversely affect the future of the species and may cause the species to become extinct in the near future. In this respect, the necessity of protecting the localities where the species is distributed and the continuity of the follow-up of the species will emerge.

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