



Length-weight Relationships and Condition Factors of Five Species of the Genus *Barbus* Cuvier & Cloquet, 1816 (Actinopterygii: Cyprinidae) from Western Anatolia, Turkey

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Abstract: The aim of study is to determine the length-weight relationships, condition factors and total length in frequency distributions of five species of the genus *Barbus*. Specimens were collected from 24 locations, including one lentic system (Küçükler Reservoir) and 23 lotic systems (Büyük Menderes, Gediz, Sakarya, Susurluk, Dalaman Rivers and their tributaries; Eşen, Tersakan, Yuvarlakçay, Kargı, Zeytinli, Tuzla and Gönen streams) in the western Anatolia. Fish samples were collected in June 2010, April-July 2019 and June-July 2020. Length-weight relationships, condition factors and total length in frequency distributions were estimated for five *Barbus* spp. (*Barbus xanthos*, *B. pergamonensis*, *B. oligolepis*, *B. niluferensis* and *B. escherichii*). Computed exponent b , R^2 and condition factor values ranged from 2.4495 to 3.3881, 0.9027 to 0.9966 and 0.94 to 1.52, respectively. New maximum lengths are provided for two species: Susurluk River-Simav Stream, *B. oligolepis*, 329.75 mm and Susurluk River-Nilüfer Stream, *B. niluferensis*, 173.81 mm. New maximum weights are provided for two species: Eşen Stream, *B. xanthos*, 196.58 g and Gediz River, *B. pergamonensis*, 95.07 g. The present study includes first records of LWRs parameters for two endemic species (*B. xanthos* and *B. pergamonensis*) in western Anatolia.

Key words: Western Anatolia, LWRs parameters, endemic, barbel

Introduction

In the study of fish species and populations, it is of great importance to know their biological characteristics in order to manage properly their resources (EAGDERI et al. 2020). Length and weight, at both population level and individual level, are basic morphological characteristics in fish biology. The weight of fish is closely related to their length and determines whether somatic growth is isometric or allometric. Length-weight relationships (LWR) are widely used for fisheries management and conservation (LECREN 1951, PITCHER & HART 1982, FROESE 2006, FROESE et al. 2011). They are commonly used for weight estimation from length for individual fish (TSOUMANI et al. 2006) and calculation of condition

factors to compare observed and expected length-weight values (LECREN 1951, FROESE 2006, GAYGUSUZ et al. 2013).

The genus *Barbus* Cuvier & Cloquet, 1816 comprises 34 fishes species widely distributed from the south-eastern Caspian Sea basin to eastern Spain. The species diversity of *Barbus* in Europe has been well known since the publication by KOTTELAT & FREYHOF (2007). Totally, five species of *Barbus* have been reported from western Anatolia inland waters. These are *Barbus xanthos* Güçlü, Kalaycı, Küçük & Turan, 2020 from Eşen, Tersakan, Büyük Menderes and Dalaman rivers; *B. escherichii* Steindachner, 1897 from the Sakarya River; *B. niluferensis* Turan, Kottelat & Ekmekçi, 2009 from the Susurluk River; *B. oligolepis* Battalgil, 1941 from streams and rivers

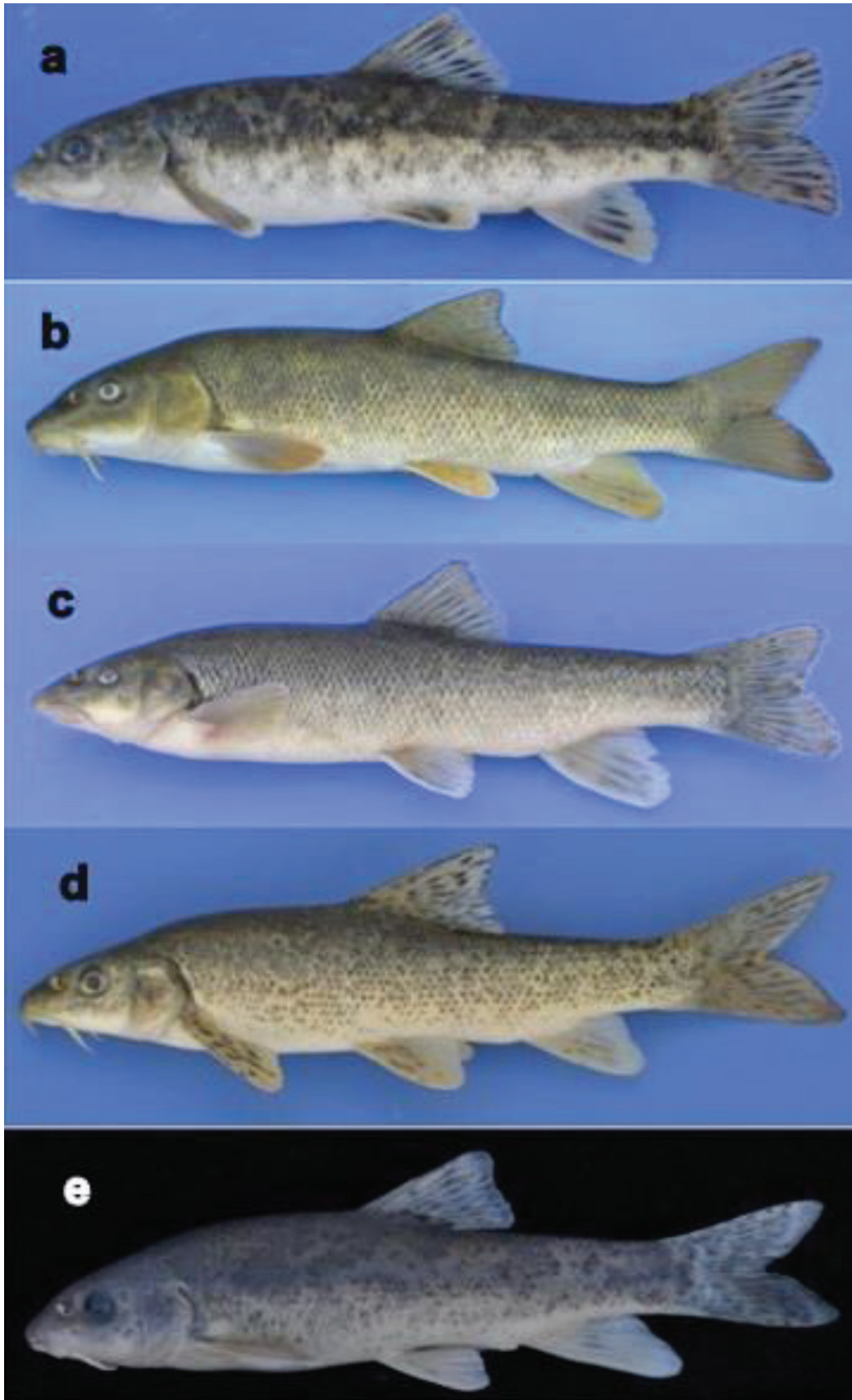


Fig. 1. a. *Barbus niluferensis*, Nilüfer Stream, 131 mm SL; b. *Barbus oligolepis*, Tuzla Stream, 171 mm SL; c. *Barbus xanthos*, Eşen Stream, 190 mm; d. *Barbus escherichii*, Sakarya River, 141 mm SL; e. *Barbus pergamonensis*, Gediz River, 176 mm SL.

Table 1. Sampling stations in the Western Anatolia.

Lokality	Altitude	Coordinates
Büyük Menderes River		
Akçay Stream	149 m	37°36'59.63"N 28°27'31.13"D
Şirindere Stream	212 m	37°55'45.15"N 27°46'40.57"D
Aksu Stream	249 m	37°48'53.05"N 28°11'40.45"D
Dandalas Stream	310 m	37°45'26.00"N 28°36'58.53"D
Banaz Stream	773 m	38°31'48.46"N 29°36'43.56"D
Küfi Stream	891 m	38°22'07.46"N 29°50'52.77"D
Dalaman River		
River estuary	19 m	36°48'51.78"N 28°47'33.14"D
Hüsniye Stream	642 m	37°04'12.50"N 29°08'50.98"D
Main tributary	839 m	37°20'11.06"N 29°22'52.01"D
Eşen Stream	199 m	36°44'51.65"N 29°23'15.37"D
Yuvarlakçay Stream	180 m	38°56'12.58"N 28°48'33.11"D
Tersakan Stream	16 m	36°47'28.06"N 28°49'44.99"D
Kargı Stream	21 m	36°42'23.72"N 29°02'53.71"D
Gediz River		
Main tributary	483 m	38°36'16.19"N 28°48'54.68"D
Küçükler Reservoir	1248 m	38°52'25.62"N 29°36'55.89"D
Susurluk River		
Simav Stream	53 m	39°47'48.47"N 28°10'35.51"D
Nilüfer Stream	233 m	40°08'18.53"N 28°57'56.95"D
Simav Stream	637 m	39°08'53.59"N 28°47'18.02"D
Sakarya River		
Göynük Stream	304 m	40°22'39.34"N 30°21'37.99"D
Emet Stream	569 m	39°27'44.67"N 29°15'26.81"D
Seydi Stream	885 m	39°21'46.98"N 31°06'55.06"D
Porsuk Stream	930 m	39°32'59.00"N 30°27'07.57"D
Zeytinli Creek	70 m	39°37'55.11"N 26°57'23.34"D
Tuzla Stream	105 m	29°30'07.61"N 26°19'46.12"D
Gönen Stream	211 m	39°48'51.54"N 27°13'47.38"D

in the Biga Peninsula and Susurluk River; and *B. pergamonensis* Karaman, 1971 from Gediz, Küçük Menderes, Bakırçay rivers and Madra Stream (TURAN et al. 2018, Güçlü et al. 2020).

There is no ecological study (length–weight relationships, condition factor and total length in frequency distributions) conducted on *B. xanthos* and *B. pergamonensis*. Studies on the other *Barbus* spp., i.e. *B. oligolepis*, *B. niluferensis* and *B. escherichii*, are limited.

The aim of the present study is the description of the LWR parameters, condition factors and total length in frequency distributions for five species of *Barbus* obtained from 24 locations in the western Anatolia (Turkey), which will be helpful for sustainable fishery management and conservation programs in the region.

Materials and Methods

Samples were collected from 24 locations, including one lentic system (Küçükler Reservoir) and 23 lotic systems: Büyük Menderes, Gediz, Sakarya, Susurluk, Dalaman rivers and their tributaries as well as Eşen, Tersakan, Yuvarlakçay, Kargı, Zeytinli, Tuzla and Gönen streams in the western Anatolia (Turkey) (Table 1). Totally, 914 individuals were caught. They belonged to five species of *Barbus*, i.e. *B. xanthos*, *B. niluferensis*, *B. escherichii*, *B. oligolepis* and *B. pergamonensis*, from western Anatolia (Fig. 1). Samplings were carried out in June 2010, April–July 2019 and June–July 2020 with electrofishing equipment in a 50-m transect in the lotic systems and with gill nets (35 x 1.5 m and 35 x 3.5 m) in the lentic system. Specimens were measured to the nearest 0.01 cm total length (TL) and weighted to the nearest 0.01 g total weight (W).

Length frequencies of the five species were prepared and the length–weight relationships were obtained using the exponential regression equation $W = a \cdot TL^b$, where W was the body weight in g, TL – the total length in cm, “a” is intercept and “b” is regression coefficient (RICKER 1975). 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:

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

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 cyprinid 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). Fulton’s coefficient of condition factor was calculated by $Cf = (W/TL^3) \times 100$ (SPARRE & VENEMA 1992).

Results

Sample size, total length and weight range, parameters a and b, the 95% confidence limits of b, the correlation coefficient (R^2) and the condition factors are presented in Table 2. Total length frequency distributions are shown in Fig. 2.

Discussion

Currently, freshwater fish may be considered the most threatened group of vertebrates based on the

Table 2. Length–weight relationships parameters of *Barbus* spp. in Western Anatolia. Legend: n: number of individuals, TL: total length (mm), W: weight (g), ns: non-significant, Cf: Fulton’s coefficient, *¹ new maximum length, *² new maximum weight.

Species	n	TL range (min-max)	W range (min-max)	a	b	95% CI of b	Pauly’s t-test	P	R ²	Cf
<i>B. xanthos</i> (endemic, LC)										
Büyük Menderes River										
Küfi Stream	32	62.18-114.87	2.24-14.63	0.0069	3.2029	2.954-3.447	1.653	ns	0.9588	1.07
Banaz Stream	19	78.59-131.91	5.42-26.34	0.0101	3.0659	2.857-3.280	0.619	ns	0.9804	1.18
Aksu Stream	33	39.35-184.04	0.54-87.45	0.0089	3.1285	3.047-3.213	3.158	<0.001	0.9948	1.20
Dandalas Stream	45	61.66-192.73	2.61-74.07	0.0124	2.9912	2.841-3.022	1.540	ns	0.9901	1.06
Şirindere Stream	25	93.16-172.79	8.99-69.34	0.0045	3.3881	3.091-3.671	2.748	<0.001	0.9614	1.19
Akçay Stream	28	88.47-141.49	6.71-33.24	0.0072	3.1696	2.859-3.477	1.133	ns	0.9447	1.09
Dalaman River										
Main tributary	86	64.65-165.60	3.45-60.50	0.0128	2.9663	2.831-3.098	0.506	ns	0.9586	1.19
Hüsnüye Stream	58	61.86-206.78	2.54-106.85	0.0139	2.9193	2.802-3.031	1.42	ns	0.9790	1.14
River estuary	27	76.34-160.35	7.42-47.81	0.0357	2.5292	2.266-2.793	3.706	<0.001	0.9398	1.16
Eşen Stream	31	105.84-255.83	19.70-196.58* ²	0.0106	3.0946	2.210-3.098	1.582	ns	0.9739	1.52
Yuvarlakçay Stream	40	78.83-182.00	6.35-78.41	0.0075	3.2266	3.087-3.362	3.322	<0.001	0.9833	1.31
Tersakan Stream	40	52.19-214.17	1.60-108.97	0.0118	2.9767	2.967-2.990	2.247	ns	0.9961	1.11
Kargı Stream	29	50.32-196.96	1.41-95.50	0.0082	3.1333	3.060-3.210	3.717	<0.001	0.9962	1.11
<i>B. pergamonensis</i> (endemic, LC)										
Gediz River										
Main tributary	77	42.50-208.49	0.89-95.07* ²	0.0109	3.0397	2.958-3.119	0.991	ns	0.9869	1.20
Küçükler Reservoir	16	12.89-16.89	23.67-50.21	0.0785	2.2511	1.885-2.611	4.343	<0.001	0.9257	1.07
<i>B. niluferensis</i> (endemic, NT)										
Susurluk River										
Nilüfer Stream	33	92.08-173.81* ¹	9.24-70.36	0.0069	3.2314	3.037-3.420	2.455	<0.001	0.9751	1.26
Simav Stream	26	85.66-137.40	7.6-35.51	0.0138	2.9254	2.549-3.303	0.407	ns	0.9144	1.16
<i>B. escherichii</i> (endemic, LC)										
Sakarya River										
Seydi Stream	26	85.70-176.77	5.49-49.68	0.0081	3.0574	2.645-3.459	0.264	ns	0.9082	0.94
Porsuk Stream	25	51.89-195.00	1.34-84.68	0.0097	3.0501	2.964-3.102	0.927	ns	0.9966	1.09
Emet Stream	39	89.46-136.07	7.93-30.05	0.0131	2.9347	2.618-3.263	0.373	ns	0.9027	1.13
Göynük Stream	16	106.82-163.51	13.75-50.00	0.0162	2.8769	2.504-3.254	0.690	ns	0.9516	1.19
<i>B. oligolepis</i> (endemic, LC)										
Susurluk River										
Simav Stream	81	64.93-329.75* ¹	3.37-438.44	0.0127	2.9769	2.872-3.081	0.436	ns	0.9758	1.21
Zeytinli Creek	31	67.88-172.19	3.98-71.96	0.0089	3.1360	2.974-3.296	1.728	ns	0.9853	1.22
Tuzla Stream	20	91.41-238.53	9.24-173.77	0.0111	3.0371	2.917-3.161	0.671	ns	0.9939	1.23
Gönen Stream	31	66.00-128.07	3.17-23.37	0.0366	2.4495	2.206-2.702	4.547	<0.001	0.9338	1.07

IUCN assessments. Endemic freshwater fish species are the most sensitive because they are often distributed over a small area and they are the most exposed to human impacts (İnnal et al. 2019). The length-weight relationship data of fish species is an important parameter in estimating the length and age structure of its dynamic population, playing a key role in fisheries assessments (EAGDERİ et al. 2020).

Small individuals appear to be abundant in five *Barbus* spp. NIKOLSKY (1980) suggested that the situation in wide range of length distribution in a population is to be accepted as an indication of enough level in the food of water system. The decrease of individuals in old age groups in the population will

cause increase of individuals in young length groups and decreasing the food competition. The examined material comprised 914 specimens of five *Barbus* spp. ranging in size between 39.35 to 245.83 mm (*B. xanthos*), 42.50 to 208.49 mm (*B. pergamonensis*), 85.66 to 173.81 mm (*B. niluferensis*), 51.89 to 195.00 mm (*B. escherichii*) and 64.93 to 329.75 mm (*B. oligolepis*) (Fig. 2). In the study, new maximum length are provided for two species (Susurluk River–Simav Stream, *B. oligolepis*, 329.75 mm; Susurluk River–Nilüfer Stream, *B. niluferensis*, 173.81 mm). New maximum weight are provided for two species (Eşen Stream, *B. xanthos*, 196.58 g; Gediz River, *B. pergamonensis*, 95.07 g) (Table 2).

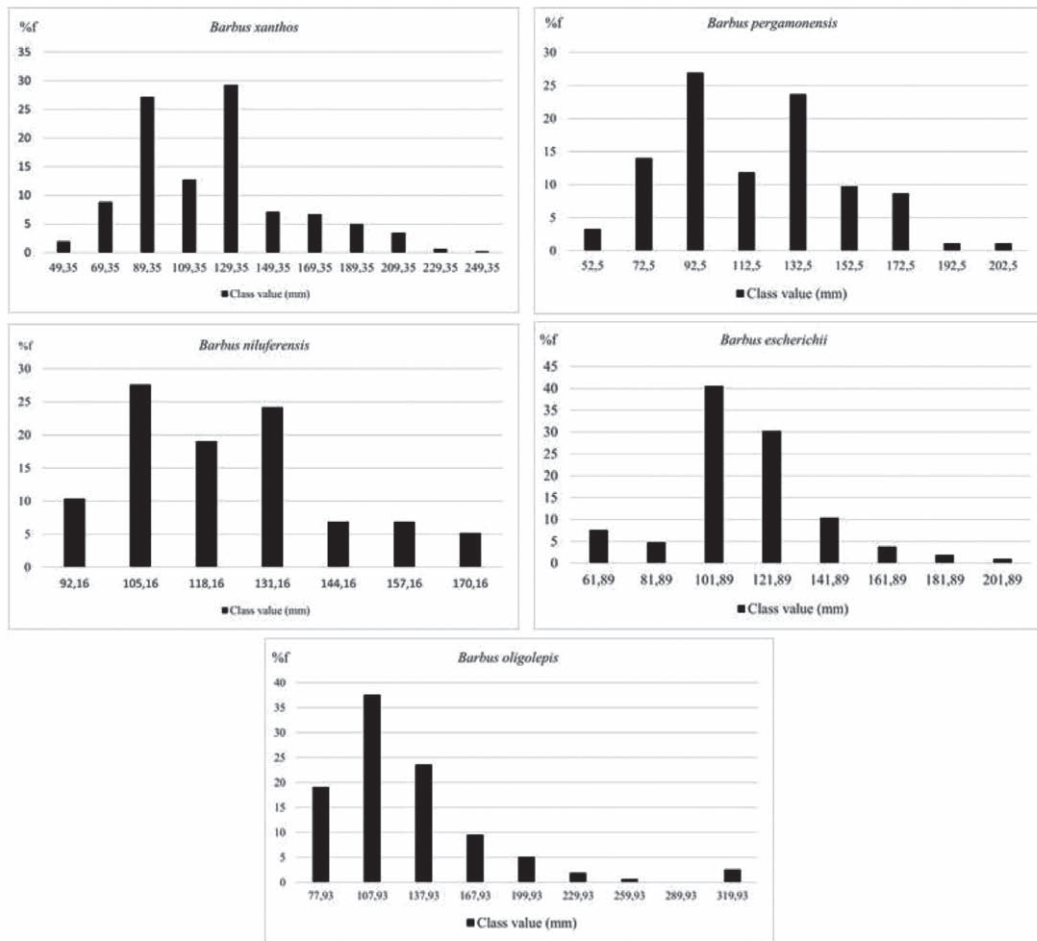


Fig. 2. Total length in frequency distributions for five *Barbus* spp. (all specimens) in Western Anatolia

Table 3. Comparison of length–weight relationships parameters in *Barbus* spp. in Western Anatolia reported by different studies

Species	Locality	Ref.	n	TL range* ²	W range	a	b	R ²
<i>B. escherichii</i>	Kirmir Stream	1	750	3.4-31.3	-	0.0080	3.1340	0.9730
<i>B. oligolepis</i>	Biga Peninsula	2	595	2.1-27.6	-	0.0102	3.0880	0.9910
<i>B. pergamonensis</i> * ¹	Western Anatolia	3	107	4.8-20.9	1.3-105.5	0.0090	3.0950	0.9910
<i>B. pergamonensis</i>	Küçük Menderes River basin	4	14	6.0-13.0	2.4-27.7	0.0101	3.0700	0.9900
<i>B. pergamonensis</i> * ¹	Muğla province (Western Anatolia)	5	229	2.7-22.9	0.1-143.2	0.009	3.1290	0.9890
<i>B. niluferensis</i>	Nilüfer Stream+Kocaçay Stream	6	119	6.4-16.4	-	0.0126	2.9776	0.9767

*¹ Currently named as *B. xanthos*; *² cm; Ref: References; 1. ZENCİR & KORKMAZ (2016); 2. İLHAN et al. (2012); 3. GAYGUSUZ et al. (2013); 4. YERLİ et al. (2016); 5. GIANNETTO et al. (2015); 6. MAZLUM et al. (2015).

The length–weight relationships data of two endemic species (*B. xanthos* and *B. pergamonensis*) are given for the first time. The expected range of $2.5 < b < 3.5$ was confirmed for all species (FROESE 2006). Positive or negative allometry indicates a rounder or slimmer body, respectively, whereas isometric growth shows that the body grows in the same proportion in all dimensions (JOBLING 2008). The values of parameter b varied from 2.4495 to (*B. oligolepis*, Gönen Stream) to 3.3881 (*B. xanthos*, Büyük Menderes River-Şirindere Stream). The correlation coefficient

between length and weight (R^2) varied between 0.9027 to for *B. escherichii* (Sakarya River-Emet Stream) and 0.9966 for *B. escherichii* (Sakarya River-Porsuk River). The condition factor values varied between 0.94 to for *B. escherichii* (Sakarya River-Seydi Stream) and 1.52 for *B. xanthos* (Eşen Stream). According to TESCH (1971), the values b varies between 2 and 4, and mostly remained within the expected range of 2.5-3.5. Length–weight relationship parameters are affected by various factors such as season, number of individuals surveyed, habitat, gonad maturity, gender

and diet (BAGENAL & TESCH 1978). The comparison of the values obtained in the study with other studies conducted in the basin is shown in Table 3 (ZENCİR & KORKMAZ 2016, İlhan et al. 2012, GAYGUSUZ et al. 2013, YERLİ et al. 2016, GIANNETTO et al. 2015, MAZLUM et al. 2015). The difference in b value is at an important place in *B.xanthos* (Aksu Stream, Şirindere Stream, Dalaman River Eustary, Yuvarlakçay Stream, Kargı Stream), *B. pergamonensis* (Küçükler Reservoir), *B. niluferensis* (Nilüfer River) and *B. oligolepis* (Gönen Stream), according to Pauly's t-test. Populations in these localities show allometric growth. Other populations show isometric growth (Table 2). This agreed with other studies involving fish species from different localities (Table 3). Differences in b values obtained with other studies may be due to factors affecting fish growth, such as water quality and nutrient availability (SPARRE et al. 1989). The differences with other studies in the basin may be due to the number of samples, sampling time and different sampling methods of the species.

More specific and long-term studies of the sampled areas will also help to identify local conditions that may affect the biological characteristics of endemic species. The results of the study provide useful information for the management and protection of endemic species that are particularly threatened by water pollution, habitat loss, river regulation, water extraction and invasive-alien fish inflows.

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References

- BAGENAL T. B. 1978. Methods for assessment of fish production in fresh waters. Third edition. Oxford: Blackwell Scientific Publications, pp. 101–136.
- EAGDERİ S., MOULUDI-SALEH A. & ÇİÇEK E. 2020. Length–weight relationship of ten species of Leuciscinae subfamily (Cyprinidae) from Iranian inland waters. *International Aquatic Research* 12:133–136.
- FROESE R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal Applied Ichthyology* 22: 241–253.
- FROESE R., TSIKLIRAS A.C. & STERGIU K.I. 2011. Editorial note on weight–length relations of fishes. *Acta Ichthyologica et Piscatoria* 41 (4): 261–263.
- GAYGUSUZ Ö., AYDIN H., EMİROĞLU Ö., TOP N., DORAK Z., GAYGUSUZ Ç. G., BAŞKURT S. & TARKAN A. S. 2013. Length–weight relationships of freshwater fishes from the western part of Anatolia. Turkey. *Journal Applied Ichthyology* 29: 285–287.
- GIANNETTO D., TARKAN A. S., AKBAŞ F., TOP N., AĞDAMAR S., KARAKUŞ U., POMPEI L. & LORENZONI M. 2015. Length–weight and length–length relationships for three endemic cyprinid species of the Aegean region (Turkey) with proposed standard weight equations. *Turkish Journal of Zoology* 39: 925–932.
- GÜÇLÜ S. S., KALAYCI G., KÜÇÜK F. & TURAN D. 2020. *Barbus xanthos*, a new barbel from the Southern Aegean basin (Teleostei: Cyprinidae). *Journal of Fish Biology* 96: 1309–1319.
- İLHAN A., SARI H. M., SAYGI H. & USTAĞLU M. R. 2012. Length–weight relationships of freshwater fishes in the Biga Peninsula (northwestern Anatolia, Turkey). *Journal Applied Ichthyology* 28: 857–858.
- İNNAL D., GÜÇLÜ S. S., ÜNAL M. C., DOĞANGİL B. & GIANNETTO D. 2019. Age structure and length–weight relationship for four species of *Aphanius* Nardo, 1827 (Actinopterygii: Aphaniidae) endemic to the Lake District, Central Anatolia, Turkey. *Acta Zoologica Bulgarica* 71 (2): 211–217.
- JOBLING M. 2008. Environmental factors and rates of development and growth. In: HART P.J. & REYNOLDS J. D. (Eds.): *Handbook of fish biology and fisheries*, Vol. 1.: Fish biology. Oxford: Blackwell Publishing Ltd., pp. 97–122.
- KOTTELAT M. & FREYHOF J. 2007. *Handbook of European freshwater fishes*. xiv+646 p. Berlin: Kottelat, Cornol: Freyhof.
- LECREN E. D. 1951. The length–weight relationship and seasonal cycle in gonad development and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology* 20 (2): 201–219.
- MAZLUM R. E., TURAN D. & BILGIN S. 2015. Length–weight relationships of nine cyprinid species from inland waters of Turkey. *Turkish Journal of Fisheries and Aquatic Sciences* 15: 375–378.
- NIKOLSKY G.V. 1980. Theory of fish population dynamics as the biological background for rational exploitation and management of fishery resources. Koenigstein: Otto Koeltz Science Publishers, 317 p.
- PAULY D. 1984. Fish population dynamics in tropical water: a manual for use with programmable calculators. *ICLARM Studies and Reviews* 8.
- PITCHER T. J. & HART P. J. 1982. *Fisheries ecology*. London: Chapman and Hall.
- RICKER W. E. 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada* 191: 1–382.
- SPARRE P., URSIN E. & VENEMA S.C. 1989. Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper No: 306 p.
- TESCH F. W. 1971. Age and growth. In: RICKER W. E. (Ed): *Methods for assessment of fish production in fresh waters*. Oxford: Blackwell Scientific Publications. pp. 99–130.
- TSOUMANI M., LIASKO R., MOUTSAKI P., KAGALOU I. & LEONARDOS I. 2006. Length–weight relationships of an invasive cyprinid fish (*Carassius gibelio*) from 12 Greek lakes in relation to their trophic status. *Journal Applied Ichthyology* 22: 281–284.
- TURAN D., KAYA C., GEIGER M. F. & FREYHOF J. 2018. *Barbus anatolicus*, a new barbel from the Kızılırmak and Yeşilirmak River drainages in northern Anatolia (Teleostei: Cyprinidae). *Zootaxa* 4461: 539–557.
- YERLİ S. V., KORKMAZ M. & MANGIT F. 2015. Length–length and length–weight relationships for four endemic cyprinid species in Küçük Menderes River Basin, Turkey. *Journal of Applied Ichthyology* 32: 991–993.
- ZAR J. H. 1999. *Biostatistical analysis*. 4th Edn. NJ, USA: Prentice Hall, Upper Saddle River.
- ZENCİR Ö. & KORKMAZ A. Ş. 2016. Length–weight and length–length relationships of fish species in Kirmir Stream and its tributaries (Suveri and İlhan Stream) of Sakarya River, Turkey. *Journal of Applied Biological Sciences* 10 (1): 55–60.

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