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Length-weight and length-length relationships of three endemic freshwater fish species from Anatolia, Turkey

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Abstract

This study aims to investigate the length-weight (LWRs) and length-length relationships (LLRs) of three endemic freshwater fish species (*Squalius recurvirostris*, *Squalius carinus* and *Capoeta turani*) living in Turkey. Fish samples were captured with backpack electro-shocker from June 2006 to October 2010. The calculated values of parameter *b* in the LWRs were 3.363 and 3.045 for *S. recurvirostris* (Eber and Ilgın Lake populations, respectively), 3.275 for *S. carinus* and 3.111 for *C. turani*. The coefficients of correlation (r) for all the LLR equations were greater than 0.95. The growth parameters of *S. recurvirostris* is provided for the first time in this study.

Introduction

Endemism that is the ecological classification of a species having a range restriction is one of the most conspicuous notions in biogeography and has a central role in conservation biology (Fattorini, 2007). Anatolia located in the region where three (Mediterranean, Caucasus and Irano-Anatolian hotspots) of the world's 35 biodiversity hotspots cross and interact has notable endemism habitats that reflect the richness of biodiversity (Myers et al., 2000; Gür, 2016). According to Çiçek et al. (2020), a total of 208 freshwater fish species is endemic to Turkey's inland waters.

Until 2000's most of the short-snouted chubs, within the 'Euro-Asiatic' lineage, were identified as chub *Squalius cephalus* and known from almost all water bodies of Anatolia (Doadrio & Carmona, 2006; Özuluğ & Freyhof, 2011). Based on the molecular and morphological studies (Durand et al., 2000; Kottelat & Freyhof, 2007; Turan et al., 2009; Özuluğ & Freyhof, 2011; Turan

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et al., 2013; Turan et al., 2017a), numerous species of chubs existed in Anatolia as valid and most of these species were endemic to restricted water bodies. One of these endemic chubs, Akşehir chub *Squalius recurvirostris* Özuluğ & Freyhof, 2011 is known from Lake Eber, Ilgın and Akşehir basins in the Central Anatolia and was listed as Vulnerable (VU) in IUCN Red List (IUCN 2021). The other endemic chub, Chocolate chub *Squalius carinus* Özuluğ & Freyhof, 2011 has existed in the Lake Işıklı basin in upper Büyük Menderes drainage (Özuluğ & Freyhof, 2011). According to IUCN (2021), *S. carinus* was listed as Endangered (EN) due to its limited distribution range.

The genus *Capoeta* is the other species-rich fish group that existed in Turkey and it shows high endemism with 13 species recently recognized from Anatolia (Turan et al., 2006a,b; Turan et al., 2008; Özuluğ & Freyhof, 2008; Küçük et al., 2009; Schöter et al., 2009; Turan et al., 2017b; Elp et al., 2018). One of them, Seyhan scraper *Capoeta turani* Özuluğ & Freyhof, 2008 is known from the tributaries of the River Seyhan in southern Anatolia. According to IUCN (2021), *C. turani* was listed as Near Threatened (NT) due to qualify for a threatened category in the near future with the threats of natural system modifications, pollution, and climate change.

The relationship between length and weight of a fish has importance in fisheries management and it provides information about the growth of the fish, its general well-being, condition and fatness (Froese, 2006; Jisr et al., 2018). When the literature was examined, it was observed that there is a very limited number of studies on the growth features estimated for *S. carinus* and *C. turani* (Balık et al., 2004; Mazlum et al., 2015; Ergüden & Giannetto, 2016). However, no studies have been found on the LWR of *S. recurvirostris*. The current study aims to estimate the length-weight (LWRs) and length-length (LLRs) relationships of these endemic fish species for Turkey.

Materials and Method

Fish samples were captured by electro-fishing (DEKA 3000 portable electro-shocker) between June 2006 and October 2010. The data of the sampling sites and the sampling dates were specified in Table 1. After anaesthesia (clove oil) fishes were fixed in 5% formaldehyde solution. The fixed samples were measured for standard length (SL), fork length (FL) and total length (TL) to the nearest 0.1 cm (Kottelat & Freyhof, 2007). Total body weight (W) was weighed on a digital balance with a 0.01 g accuracy.

Table 1. The data of the sampling areas and sampling dates of three endemic freshwater fish species living in Anatolia.

Species	Sampling Areas

	Basin	Sub-basin	Locality No	Locality	Coordinate	Sampling Date
Squalius recurvirostris	Akarçay Basin	Eber Lake	1	Aksu Stream	38.81012°N 30.25601°E	24.10.2010
	Konya Closed Basin	Ilgın Lake	2	Ali Stream	38.13555°N 31.66737°E	25.10.2010
			3	Battal Stream	38.2356333°N 31.8802667°E	26.06.2008
Squalius carinus	Büyük Menderes River	Işıklı Lake	4	Işıklı Spring	38.32144°N 29.85121°E	13.06.2006 26.10.2010
			5	Yeşilhüyük Stream	38.154433°N 30.064750°E	27.06.2008
Capoeta turani	Seyhan River Basin	Seyhan Reservoir	6	Çatkıt Stream	37.10259°N 35.10954°E	30.09.2009
			7	Ecemiş Stream	37.13897°N 35.14235°E	30.09.2009

The LWRs were calculated by the following equation: $W=aL^b$, where W is the total weight (g), L is the total length (cm), a is the regression intercept and, b is the slope (Le Cren, 1951; Froese, 2006). The logarithmic transformation of this equation was performed as $\ln W=\ln a+b\ln L$ and parameters a and b were computed by the regression analysis (King, 2007). 95% confidence intervals (CI) of parameters a and b were calculated to determine the growth type (isometric or allometric) by the equation: $95\%CI=x\pm(t_{0.05}\times SE)$ (x: b; t: table value of t (t-test at 95% confidence); SE: standard error value of b) (King, 2007). The calculations were made by combining the data of the same populations collected from the different sampling points in the same sub-basins. The LLRs in the fish were calculated using linear regression analysis for being comparable to the results of different studies, which will use different length measures.

Results

The estimated LWRs of three species were summarized in Table 2. The calculated values of parameter b in the LWRs were 3.363 and 3.045 for *S. recurvirostris* (Eber and Ilgın Lake populations, respectively), 3.275 for *S. carinus* (Işıklı Lake population) and 3.111 for *C. turani* (Seyhan Reservoir population). The coefficients of correlation between length and weight (r) varied between 0.995 for *S. recurvirostris* (Eber Lake population) and 0.997 for *S. carinus*.

The estimated LLRs of three endemic species were summarized in Table 3. The coefficients of correlation (r) for all the LLR equations were greater than 0.95 and significantly linear.

Table 2. The descriptive statistics and estimated parameters of LWRs of three endemic freshwater fish species in Anatolia (n: number of individuals, TL: total length (cm), W: body weight (g), Min:

minimum, Max: maximum, *a*: intercept, *b*: slope, 95% CI: 95% confidence intervals, r: the coefficient of correlation, A+: positive allometric, I: isometric).

Species	Locality No	n	TL	W	Regression Parameters		95% CL of *a*	95% CL of *b*	r	Type of Growth
			Min.-Max.	Min.-Max.	*a*	*b*				
Squalius recurvirostris	1	20	10.6 – 22.3	11.17– 141.62	0.004	3.363	0.002 – 0.007	3.163 – 3.562	0.995	A+
	2, 3	32	7.9 – 23.4	5.64 – 161.18	0.010	3.045	0.007- 0.014	2.921 – 3.170	0.996	I
Squalius carinus	4, 5	26	4.6 – 16.9	0.78 – 52.06	0.006	3.275	0.004 – 0.007	3.170 – 3.379	0.997	A+
Capoeta turani	6, 7	37	4.5 – 15.4	0.80 – 38.92	0.008	3.111	0.006 – 0.010	3.009 – 3.214	0.996	A+

Table 3. Relationships between total, fork and standard length for three endemic fish species inhabited in Anatolia (n: sample size, TL: Total length, FL: Fork length, SL: Standard length, *a* and *b* are the parameters of linear regression analysis).

Species	Locality No	n	FL = *a* + *b*TL	SL = *a* + *b*TL
Squalius recurvirostris	1	20	FL=0.965×TL–0.388 (r=0.999)	SL=0.888×TL–0.622 (r=0.999)
	2, 3	32	FL=0.949×TL–0.116 (r=0.999)	SL=0.811×TL–0.038 (r=0.999)
Squalius carinus	4, 5	26	FL=0.953×TL–0.194 (r=0.999)	SL=0.839×TL–0.341 (r=0.999)
Capoeta turani	6, 7	37	FL=0.884×TL–0.014 (r=0.999)	SL=0.796×TL–0.295 (r=0.999)

Discussion

The estimation of LWRs for fish populations is an important and useful component in the field of fisheries science and management and the range of the *b* value usually estimated in fishes was within the range of 2.5–3.5 (Froese, 2006; Froese et al., 2011). The *b* values of the LWRs for these three endemic fishes presented in this study are in this expected range (Table 2). The "*b*" value for *C. turani* population living in the Üçürgene Stream (Seyhan River basin) has been reported as 2.8942 (isometric growth) by Mazlum et al. (2015). In the present study, type of growth show positive allometry. Similarly, the type of growth has reported as positive allometric with a value of 3.168 for the same fish species that existed in the tributaries of the Seyhan River by Ergüden & Giannetto (2016). These differences or similarities may depend on the number or size of individuals, gender, gonad or stomach fullness, disease, sampling period, different habitat types and food availability (Froese, 2006; Nadaf et al., 2013).

The *b* value for *S. carinus* population living in the Işıklı Lake has been reported as 3.04 (isometric growth) by Balık et al. (2004), whereas positive allometry was found in this study. The higher *b* value may be attributed to the number and size of fish specimens, the sampling period and the sampling method used in the present study (n: 26; 4.6-16.9 cm TL; June 2006, 2008 and October 2010; electro-shocker) compared with those reported by Balık et al. (2004) (n: 528; 13.5-23.1 cm FL; from February 1998 to January 1999; trammel nets).

One of the most important phenomena for the conservation of an endemic species is the understanding of the biological characteristics of that species. With the present study, it is concluded that this basic information on the length-weight relationships calculated for *S. recurvirostris*, *S. carinus* and *C. turani* populations would contribute to the most models of stock management and conservation of these endemic fish in Turkey. The growth parameters (*a* and *b*) calculated for *S. recurvirostris* populations will provide the first information on LWRs of this fish. However, the present data prove the presence of spatial variability of LWRs of *S. recurvirostris* in the Eber and Ilgın Lake populations. Length–weight relationships for these three fish species are not yet available under their valid species names (Froese & Pauly, 2019), therefore the results can be used as useful information for the FishBase database. Additionally, the values for the coefficient of correlation (*r*) for all the LLR equations of the three species were greater than 0.95 and these results would be useful for comparative growth studies of the same species.

Author Contributions

All author contributions are equal for the preparation research in the manuscript.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

Conflict of Interest

The authors declare that they have no conflict of interest.

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