

Research article

Length-weight and length-length relationships of *Squalius* sp. populations living in freshwaters of Samsun (Türkiye)Canan İMAMOĞLU^{*}, Nazmi POLAT, Semra SAYGIN, Melek ÖZPİÇAK, Savaş YILMAZ

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Abstract: This study aims to determine the length-weight and length-length relationships of *Squalius* sp. populations living in some freshwater resources (10 different localities) within the borders of Samsun province, Türkiye. A total of 500 fish samples were captured in this water resources. The total length and weight of the *Squalius* sp. individuals were ranged from 6.50-36.80 (13.53±0.148) cm and 2.90-696.17 (37.84±1.976) g, respectively. The parameters a and b of the equation $W = aTL^b$ were estimated for *Squalius* sp. inhabiting each location. The b value of *Squalius* sp. populations ranged from between 2.985 and 3.332. Isometric growth was observed in populations Akçay Stream, Mert River, Taşkelik Stream, Terme Stream, and Yeşilpınar Stream and positive allometric growth was observed in populations Abdal Stream, Engiz Stream, Istavloz Stream, Kaynatma Stream, and Tersakan Stream. Length-length relationships with a coefficient of determination ranging from 0.975 to 0.998 for *Squalius* sp. populations. There are no previous studies available on length-weight and length-length relationships of the *Squalius* sp. in the Engiz Stream, Istavloz Stream, Kaynatma Stream, Mert River, Taşkelik Stream, Tersakan Stream, and Yeşilpınar Stream. It is thought that all the data obtained as a result of the research will contribute to the current literature.

Keywords: *Squalius*, length-weight relationship, length-length relationship, Samsun

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Introduction

In recent years, taxonomic revision studies have been carried out to eliminate the systematic confusion of species belonging to the genus *Squalius*. In Türkiye, 22 species of the genus *Squalius* have been recorded up to now, and 14 of them have been reported as endemic (Çiçek et al., 2015, 2018, 2020a, 2023; Bayçelebi, 2019; van der Laan, 2021; Froese & Pauly, 2023). Chub of the genus *Squalius* (Bonaparte, 1837), a member of the Leuciscidae family, has a wide distribution area in the Black Sea, Caspian Sea and Azov Sea basins and the Caucasus in all of Europe (Durand et al., 2000; Sanjur et al., 2003; Geldiay & Balık, 2009; Stout et al., 2016). While the chub is distributed to all inland waters in Anatolia, it has spread all over Türkiye except for the vicinity of Van Lake (Geldiay & Balık, 2009). Because of having high

environmental tolerance, chub has a wide distribution in aquatic systems (Arlinghaus & Wolter, 2003).

Freshwater fish biodiversity has been widely threatened by the influence of human impact and global environmental changes (Arthington et al., 2016; Costa et al., 2021). In fisheries management, length-weight (LWRs) and length-length relationships (LLRs) provide valuable information such as population structure, body shape variations, and growth for fish biologists (Moutopoulos & Stergiou, 2002; Jellyman et al., 2013). It is possible to identify the pattern of fish growth by analyzing the relationship between length and weight. In particular, LWR can be used to assess fish biomass as a practical indicator of fish body health and to compare species-specific growth across habitats and regions (Petraakis & Stergiou, 1995; Koutrakis & Tsikliras, 2003). LLRs are used to study taxonomic differences, including

the influence of different environmental factors (Bhakat et al., 2019). Different types of fish length measurements are used in ichthyological studies (Karachle & Stergiou, 2012; Johnson & Friesen, 2013; Jiang et al., 2022; Özpiçak et al., 2022). For instance, standard length (SL) is used in systematic studies, whereas total length (TL) and fork (FL) length are commonly used to estimate fish growth (Moutopoulos & Stergiou, 2002). Thus, LLRs are needed to transform length from different fish body length measurements.

There are many studies dealing with the LWRs and LLRs of species belonging to the economically important *Squalius* genus (Özpiçak et al., 2018; Aydemir et al., 2019; Saç & Özuluğ, 2021; Çiçek et al., 2022; Yedier, 2022; Yazıcıoğlu et al., 2023). In this study, it was aimed to determine the length-weight and length-length relationships of *Squalius* sp. populations living in some freshwater resources (10 different localities) within the borders of Samsun.

Material and Methods

Sampling and Laboratory Examinations

Fish samples were caught using an electroshocker (SAMUS 725MP) between May and November 2022. A total of 50 samples (totally 500) from each location were obtained. Sampling was made from locations determined from Abdal Stream, Akçay Stream, Engiz Stream, Istavloz Stream, Kaynatma Stream, Mert River, Taşkelik Stream, Terme Stream, Tersakan Stream, Yeşilpınar Stream located within the borders of Samsun province. The coordinates of the sampling locations are given in Table 1.

The samples were brought to the laboratory in iced storage containers. In the laboratory, the systematic positions of the collected fishes were determined according to literature keys (Kottelat & Freyhof, 2007; Geldiay & Balık, 2009; Polat & Uğurlu, 2011; Bayçelebi, 2019).

Total length (TL), fork length (FL) and standard length (SL) were measured (± 0.1 cm) and all samples were weighted (± 0.01 g).

Table 1. Locations where fish samples were caught and their coordinates.

Basin	Locality	Coordinate	Sampling time	Number of samples
Kızılrınmak Basin	Engiz Stream	41°28'17.5"N 36°01'56.3"E	August 2022	50
	Istavloz Stream	41°09'39.5"N 35°30'58.9"E	September 2022	50
	Kaynatma Stream	41°28'29.2"N 35°49'54.7"E	August 2022	50
Yeşilrınmak Basin	Taşkelik Stream	41°34'58.0"N 35°42'17.9"E	May 2022	50
	Abdal Stream	41°09'01.5"N 36°39'32.9"E	August 2022	50
	Akçay Stream	41°06'10.3"N 37°07'51.3"E	August 2022	50
	Mert River	41°14'29.7"N 36°16'26.4"E	August 2022	50
	Terme Stream	41°08'56.4"N 36°53'17.9"E	May 2022	50
	Tersakan Stream	40°57'05.4"N 35°57'53.9"E	November 2022	50
	Yeşilpınar Stream	41°04'43.0"N 36°40'45.2"E	August 2022	50

Length-Weight and Length-Length Relationships

Length-weight relations (LWRs) were calculated according to the equation: $W = aTL^b$ in which W is body weight (g) and TL is total length (cm), a is the intercept and b is the regression coefficient of the LWRs (Froese, 2006). The 95% confidence interval (CI) of the b value was calculated and the r^2 was determined (Zar, 1999). The parameters a and b were calculated according to linear regression analysis based on natural logarithm: $\ln(W) = \ln(a) + b \times \ln(TL)$. The difference of b value from 3 in the length-weight relationship was analyzed with the t-test to determine the growth type of the fish (b=3 isometric growth, b<3 negative allometric growth, b>3 positive allometric growth).

Length-length relationships (LLRs) such as TL vs FL, TL vs SL, and FL vs SL were calculated using linear

regression analysis of formula: $y=a+bx$ (Zar, 1999) and the coefficient of determination (r^2) was determined. All analyses were performed by using Minitab 21.1, SPSS 20.0 and Excel software package programs.

Results

Totally, 500 individuals were examined in this study. The total length and weight of the *Squalius* sp. individuals were ranged from 6.50-36.80 (13.53 ± 0.148) cm and 2.90-696.17 (37.84 ± 1.976) g, respectively. The individual with the minimum total length was observed in the Engiz Stream, and the individual with the maximum total length was observed in the Abdal Stream. The highest mean total length (16.05 cm) was recorded in Tersakan Stream. The descriptive statistics of length and weight data of *Squalius* sp. individuals are presented in Table 2.

Table 2. Descriptive statistics of *Squalius* sp. samples from different localities (Min: minimum; Max: maximum; SE: standard error, SD: standard deviation).

		Locality									
		Abdal Stream	Akçay Stream	Engiz Stream	Istavloz Stream	Kaynatma Stream	Mert Stream	Taşkelik Stream	Terme Stream	Tersakan Stream	Yeşilpınar Stream
Total Length	Min	9.30	10.10	6.50	7.40	9.70	9.30	7.30	7.20	12.50	10.90
	Max	36.80	22.30	24.80	22.20	21.50	21.00	27.70	22.50	19.60	17.60
	Mean	15.20	13.20	13.46	13.10	13.29	13.23	13.16	11.58	16.05	13.62
	SE	0.67	0.33	0.54	0.53	0.35	0.39	0.53	0.37	0.23	0.19
	SD	4.75	2.36	3.79	3.72	2.51	2.74	3.77	2.58	1.62	1.35
Fork Length	Min	8.70	9.20	6.20	6.90	9.00	8.90	6.70	7.00	11.70	10.10
	Max	34.80	21.00	23.80	21.00	20.40	19.10	26.40	21.10	18.70	16.30
	Mean	14.38	12.32	12.77	12.30	12.50	12.52	12.39	10.99	15.17	12.67
	SE	0.64	0.32	0.52	0.49	0.35	0.37	0.51	0.35	0.23	0.18
	SD	4.56	2.26	3.69	3.48	2.46	2.58	3.63	2.48	1.60	1.24
Standard Length	Min	7.70	8.10	5.20	6.00	8.00	7.70	5.90	5.90	10.30	8.90
	Max	30.80	18.60	21.20	18.30	18.30	16.80	23.30	19.10	16.60	14.40
	Mean	12.62	10.78	11.14	10.80	11.06	11.01	10.73	9.59	13.22	11.28
	SE	0.56	0.28	0.46	0.44	0.31	0.32	0.45	0.32	0.20	0.15
	SD	3.98	1.99	3.28	3.13	2.17	2.26	3.20	2.28	1.43	1.09
Weight	Min	8.81	11.11	2.90	4.56	10.25	10.82	4.58	4.51	21.56	14.41
	Max	696.17	129.35	264.36	158.24	131.13	89.86	292.09	139.38	108.88	59.44
	Mean	63.17	29.92	42.82	36.51	32.15	32.30	35.30	21.33	56.30	28.68
	SE	14.34	2.98	7.21	4.51	3.22	2.99	6.63	2.89	2.69	1.29
	SD	101.39	21.09	51.00	31.92	22.76	21.16	46.90	20.44	19.02	9.14

Table 3. Length-length relationships between total length (TL), fork length (FL) and standard length (SL) of different *Squalius* sp. populations.

Localities	Equations	a	b	r ²	P
Abdal Stream	TL= a+b FL	0.2144	1.04197	0.998	<0.001
	TL= a+b SL	0.162	1.19125	0.997	<0.001
	FL= a+b SL	-0.0476	1.14303	0.998	<0.001
Akçay Stream	TL= a+b FL	0.416	1.0378	0.989	<0.001
	TL= a+b SL	0.493	1.1783	0.988	<0.001
	FL= a+b SL	0.141	1.1292	0.987	<0.001
Engiz Stream	TL= a+b FL	0.3643	1.02559	0.998	<0.001
	TL= a+b SL	0.6174	1.15293	0.997	<0.001
	FL= a+b SL	0.2566	1.12328	0.997	<0.001
Istavloz Stream	TL= a+b FL	-0.0342	1.06750	0.998	<0.001
	TL= a+b SL	0.2537	1.18866	0.997	<0.001
	FL= a+b SL	0.2801	1.11255	0.998	<0.001
Kaynatma Stream	TL= a+b FL	0.5683	1.01725	0.997	<0.001
	TL= a+b SL	0.498	1.1560	0.996	<0.001
	FL= a+b SL	-0.0598	1.13558	0.997	<0.001
Mert River	TL= a+b FL	0.012	1.0558	0.995	<0.001
	TL= a+b SL	-0.066	1.2074	0.992	<0.001
	FL= a+b SL	-0.056	1.1420	0.994	<0.001
Taşkelik Stream	TL= a+b FL	0.2888	1.03908	0.998	<0.001
	TL= a+b SL	0.541	1.1760	0.995	<0.001
	FL= a+b SL	0.250	1.1310	0.996	<0.001
Terme Stream	TL= a+b FL	0.158	1.0386	0.990	<0.001
	TL= a+b SL	0.769	1.1274	0.992	<0.001
	FL= a+b SL	0.616	1.0824	0.995	<0.001
Tersakan Stream	TL= a+b FL	0.770	1.0078	0.981	<0.001
	TL= a+b SL	1.165	1.1264	0.986	<0.001
	FL= a+b SL	0.606	1.1016	0.975	<0.001
Yeşilpınar Stream	TL= a+b FL	-0.089	1.0821	0.983	<0.001
	TL= a+b SL	-0.215	1.2269	0.978	<0.001
	FL= a+b SL	-0.042	1.1272	0.982	<0.001

The LLRs between total length (TL), fork length (FL), and standard length (SL) of different *Squalius* sp. populations were summarized in Table 3. In this study, it was determined that there were strong relationships between different length types in all populations. It was observed that the regression coefficient values obtained from LLRs were high in all localities ($p < 0.001$, $r^2 > 0.97$).

The total length-weight relationship parameters of *Squalius* sp. were calculated separately for 10 different populations in Table 4. Among the length-weight relationship parameters of *Squalius* sp. populations from different habitats, the "a" value varies between 0.005 and 0.012, the slope "b" value varies between 2.985 and 3.332,

and the correlation coefficient (r^2) varies between 0.959 and 0.994. Based on the coefficient of determination, it can be seen that the length and weight of the fish have a strong relationship. The length-weight relationships (LWRs) were found to be significant for all localities ($r^2 > 0.959$, $p < 0.001$). In this research, isometric growth ($b=3$, t test, $p > 0.05$) was determined at Akçay Stream, Mert River, Taşkelik Stream, Terme Stream, and Yeşilpınar Stream locations. Positive allometric growth ($b > 3$, t test, $p < 0.05$) was observed in Abdal Stream, Engiz Stream, Istavloz Stream, Kaynatma Stream, and Tersakan Stream locations. The length-weight relationships of the *Squalius* sp. samples are given in Figure 1.

Table 4. Parameters of the LWR and growth types for *Squalius* sp. according to localities.

Locality	a	b	3%95 Confidence Interval	r ²	P	Growth Types
Abdal Stream	0.008	3.176	3.0836; 3.2684	0.990	p<0.05	(+) Allometry
Akçay Stream	0.008	3.125	2.9644; 3.2856	0.969	p>0.05	Isometry
Engiz Stream	0.005	3.332	3.2155; 3.4485	0.985	p<0.05	(+) Allometry
Istavloz Stream	0.009	3.145	3.0768; 3.2132	0.994	p<0.05	(+) Allometry
Kaynatma Stream	0.008	3.148	3.0556; 3.2404	0.990	p<0.05	(+) Allometry
Mert Stream	0.012	3.001	2.9027; 3.0993	0.987	p>0.05	Isometry
Taşkelik Stream	0.010	3.074	2.9575; 3.1905	0.983	p>0.05	Isometry
Terme Stream	0.011	3.023	2.9005; 3.1455	0.981	p>0.05	Isometry
Tersakan Stream	0.007	3.214	3.0253; 3.4027	0.959	p<0.05	(+) Allometry
Yeşilpınar Stream	0.011	2.985	2.8224; 3.1476	0.965	p>0.05	Isometry

Discussion

In the current study, it was determined that the total length, fork length, and standard length distributions of all samples varied between 6.50-36.80 cm, 6.20-34.80 cm, 5.20-30.80 cm, and weights varied between 2.90-696.17 g, respectively. When the studies on the *Squalius* genus in Türkiye are examined, it is observed that the total length varies between 2.50 cm (Ilhan et al., 2012; Biga Peninsula) and 53.2 cm (Dedeoğlu et al., 2020; Borçka Dam Lake) and the weights varies between 0.43-2307.88 g (Çiçek et al., 2020b; Sarı & Becer, 2021). When the literature is examined, it is thought these differences in the length and weight of *Squalius* may result from sampling time and method, gender differences, and ecological characteristics of the studied areas (Nikolsky, 1963; Froese, 2006).

Most of studies on *Squalius* genus were used total length data (Koutrakis & Tsikliras, 2003; Ilhan et al., 2012; Sedaghat et al., 2012; Mazlum et al., 2015; Yerli et al., 2016; Çiçek et al., 2022; Holubová et al., 2022) and fork length data (Şaşı & Balık, 2003; Balık et al., 2004; Sen & Saygin, 2008; Yiğit et al., 2008; Kılıç & Becer, 2016; Sarı & Becer, 2021) in their evaluations, while the

others were used standard length data (Stefanova et al., 2008; Saç et al., 2019). It is possible to compare and interpret the results obtained from different studies with length-length conversions. There are several studies dealing with the relationships between different types of length measurements related to the *Squalius* genus (Birecikligil et al., 2016; Yerli et al., 2016; Özcan et al., 2017; Özpiçak et al., 2018; Seçer et al., 2020; Saç & Özuluğ, 2021; Yedier, 2022).

The parameter b values of length-weight relationships (LWRs) in fishes are usually found within the expected range of 2–4 (Tecsh, 1971; Bagenal & Tesch, 1978) or 2.5–3.5 (Froese, 2006). According to the result of this study, the b value of LWR ranged from 2.985-3.332, while this value varied between 2.694 (Çiçek et al., 2022; *Squalius berak*) to 3.363 (Saç & Özuluğ, 2021; *Squalius recurvirostris*) in different studies. When the LWRs of the *Squalius* genus in the literature were examined, it was determined that the species showed isometric growth, positive allometric growth and negative allometric growth (Table 5).

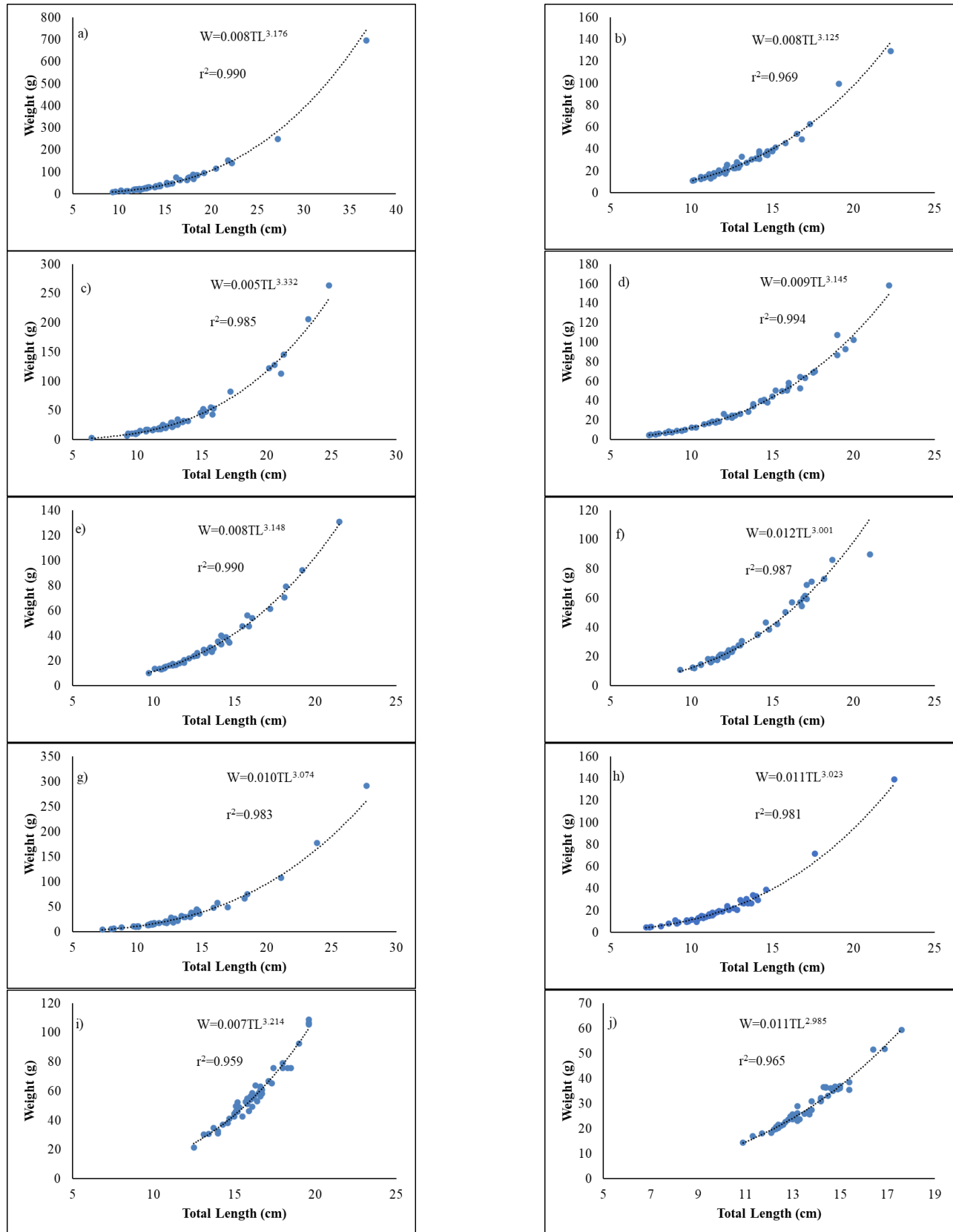


Figure 1. Total length-weight relationships in ten different locations a) Abdal Stream, b) Akçay Stream, c) Engiz Stream, d) Istavloz Stream, e) Kaynatma Stream, f) Mert River, g) Taşkelik Stream, h) Terme Stream, i) Tersakan Stream, j) Yeşilpınar Stream.

In this study, isometric and positive allometric growth were also determined. When the literature was examined, it was determined that there were similarities and differences in both b values and growth types. These differences or similarities in b values in the LWRs can be attributed to many factors such as seasonal, type of habitat, length range, sex, gonad maturity, spawning period, diet, feeding, growth phase, ontogenetic change, stomach fullness of the fish (Tesch, 1971; Bagenal & Tesch, 1978; Froese, 2006). In additionally, the number of samples used in the study, length-weight distributions, sampling time, size type, the measured length and geographic location used may have caused these differences (Tesch, 1971; Froese, 2006; Sasi & Ozay, 2017; Saygın et al., 2018). The

details of the length-weight relationship obtained for *Squalius* genus are shown in Table 5.

Conclusion

To the authors' knowledge, no previous studies on LWRs and LLRs of the *Squalius* sp. in the Engiz Stream, Istavloz Stream, Kaynatma Stream, Mert River, Taşkelik Stream, Tersakan Stream, and Yeşilpınar Stream. It is thought that all the data obtained as a result of the research will contribute to the current literature. It is hoped that the results of this study will contribute to future fisheries management and conservation plans for *Squalius* sp. populations in this region.

Table 5. Parameters of the length-weight relationship of some species of *Squalius* genus in different regions (TL: total length; FL: fork length; SL: standard length; I: Isometric, A(+): positive allometry, A(-): negative allometry).

Species	Locality	N	Length	Min.-Max. (cm)	b	Growth Type	References
<i>S. anatolicus</i>	Oymapınar Dam Lake	422	FL	20.00-55.1	3.195	A(+)	Sarı & Becer, 2021
<i>S. aristotelis</i>	Biga Peninsula	263	TL	2.5-15.7	3.243	-	Ilhan et al., 2012
<i>S. berak</i>	Fırat Basin	96	TL	7.1-22.1	2.694	-	Çiçek et al., 2022
<i>S. cappadocicus</i>	Melendiz River	357	TL	2.6-24.5	2.988	I	Seçer et al., 2020
<i>S. carinus</i>	Büyük Menderes River	26	TL	4.6-16.9	3.275	A(+)	Saç & Özuluğ, 2021
	Abdal Stream	44	TL	5.60-9.40	3.224		
	Akçay Stream	57	TL	5.80-18.00	3.285	A(+)	Özpiçak et al., 2018
<i>S. cephalus</i>	Terme Stream	55	TL	6.40-15.60	3.298		
	Yedikır Dam Lake	62	TL	6.70-17.70	3.210		
	Tabakhane Stream	326	TL	3.50-14.50	3.065	A(+)	Yedier, 2022
<i>S. cii</i>	Karamenderes Stream	77	TL	7.8-33.8	3.201	A(+)	Yalcin Ozdilek & Partal, 2022
<i>S. fellowesii</i>	Eşen Stream	404	TL	3.6-20.2	3.258	A(+)	Çiçek et al., 2020b
<i>S. kosswigi</i>	Küçük Menderes River Basin	136	TL	3.5-22.2	3.10	-	Yerli et al., 2016
<i>S. kottelati</i>	Ceyhan River	18	TL	18.0-28.5	3.055	I	Mazlum et al., 2015
<i>S. orientalis</i>	Borçka Dam Lake	392	TL	14.1-53.2	3.306	A(+)	Dedeoğlu et al., 2020
<i>S. orpheus</i>	Meriç-Ergene River	65	SL	6.0-17.3	3.131	-	Saç et al., 2019
	Bayındır Stream	46	TL	9.0-13.8	2.936	A(-)	Aydemir et al., 2019
<i>S. pursakensis</i>	Kızılırmak Basin	45	TL	4.0-13.0	3.145	-	Çiçek et al., 2022
	Akarçay Basin	20	TL	10.6-22.3	3.363	A(+)	
<i>S. recurvirostris</i>	Konya Closed Basin	32	TL	7.9-23.4	3.045	I	Saç & Özuluğ, 2021
<i>S. seyhanensis</i>	Seyhan Basin	61	TL	7.1-45.3	3.078	-	
<i>S. turcicus</i>	Aras Basin	320	TL	4.9-37.3	3.179	-	Çiçek et al., 2022

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Ethical Approval

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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