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Length-weight and length-length relationships of the European bitterling, *Rhodeus amarus* (Bloch, 1782) inhabiting inland waters of Samsun Province

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Abstract

In this study, length-weight relationships (LWRs) and length-length relationships (LLRs) for Rhodeus amarus sampled from the Terme and Terice Streams were calculated in April-November 2016. A total of 117 fish specimens (from Terme = 57, from Terice= 60) were examined. Total, fork and standard length were measured (±0.1 cm) and weighted (±0.01 g) for all captured fish. Total length varies between 4.5 and 8.9 cm, weight varies between 0.730-9.940 g for all populations. Length-weight equations were calculated as $W=0.005TL^{3.479}$ *and* $W=0.004TL^{3.586}$ *for Terme and Terice, respectively. According to analyses bitterling has positive allometric growths for two localities. Length-length relationships equations show that total, fork and standard length values are very strong between each other (P<0.001, coefficient of determination >0.95).*

Keywords: *Rhodeus amarus*, length-weight relationships, length-length relationships, fisheries, Samsun.

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Samsun bölgesi iç sularında yaşayan acı balık, *Rhodeus amarus* (Bloch, 1782)'un boy-ağırlık ve boy-boy ilişkileri

Özet

Bu çalışmada, Nisan-Kasım 2016 tarihleri arasında Terme ve Terice akarsularından örneklenen Rhodeus amarus türünün boy-ağırlık ilişkisi (LWRs) ve boy-boy ilişkileri (LLRs) hesaplanmıştır. Toplam 117 balık örneği (Terme'den=57, Terice'den=60) incelenmiştir. Tüm balıkların total, çatal ve standart boyları ölçülmüş (±0.1 cm) ve ağırlıkları tartılmıştır (±0.01 g). Tüm populasyonlar için total boylar 4.5 ve 8.9 cm arasında, ağırlıklar 0.730-0.940 g arasında değişmiştir. Boy-ağırlık ilişkisi denklemleri Terme ve Terice için sırası ile $W=0.005TL^{3.479}$, $W=0.004TL^{3.586}$ *olarak hesaplanmıştır. Analiz sonuçlarına göre her iki habitatta da acı balık pozitif allometrik büyüme özelliğine sahiptir. Boy-boy ilişki denklemleri total, çatal ve standart boylar arasında birbirleri ile çok güçlü ilişki olduğunu gösterir (P<0.001, belirtme katsayısı >0.95).*

Anahtar kelimeler: *Rhodeus amarus, boy-ağırlık ilişkisi, boy-boy ilişkisi, balıkçılık, Samsun.*

1. Introduction

Length-weight relationship has been widely used to predict body weight from length measurements. Since weighting of fish is difficult due to both temporal and technical reasons in the study area [1]. The length-weight relationships (LWRs) and length-length relationships (LLRs) are useful for estimating the biomass of fish stocks, transformation of different body length types, respectively [2-7]. The length-weight relationship and length-length relationship are often used to calculate the condition indices, standing stock biomass, in the determination of ontogenetic changes, compare the life history characteristics and morphology of populations from different regions, several other aspects of fish population dinamics [5, 8-12]. Length-weight relationships (LWRs) are important in assessing the well-being of individuals within a particular species or separate stocks of the same species [13].

Rhodeus amarus is a small, short lived fish. The bitterling lives in central, eastern Europe and northern Asia [14]. Studies on this species are concentrated on behavioural aspect of reproduction, feeding, population genetic structure, systematics and morphology [15-19]. However, there are limited studies about bitterling population dinamics [20-25]. In this context, length-weight and length-length relationships are very important for fisheries researchs. Length-weight related parameters provide predicting the weight of the fish from its length, a comparison of the morphology and life cycle of the populations from different habitats. The aim of this study is to determine the length-weight and length-length relationships of *Rhodeus amarus* in Terme and Terice Stream.

2. Material and methods

Rhodeus amarus (Figure 1) samples were collected between April and November 2016 from the two different localities (Terme and Terice Streams) in Samsun, Turkey (Figure 2).

Figure 1: *Rhodeus amarus* (original foto).

All captured fish were measured (±0.1 cm) for total length (TL), fork length (FL), standart length (SL) and weighted (±0.01 g) using electronic balance. Fish identification was confirmed using the FishBase [26].

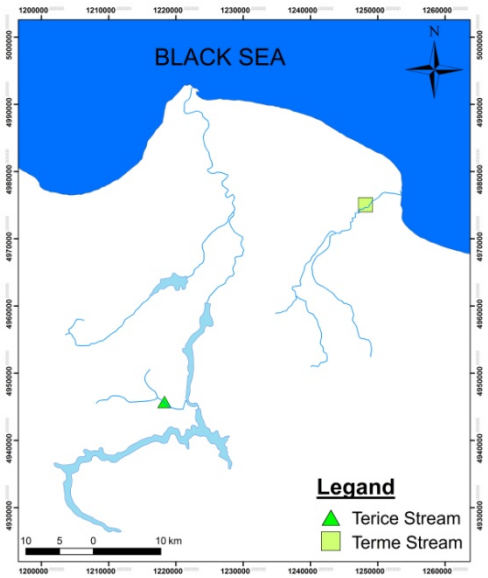

Figure 2: Study area.

LWR equation is indicated in;

$$W = aL^b \quad (1)$$

where W is fish weight (in grams), L is total length (in cm), a is a constant and b is the slope. Length-weight were log-transformed and estimated by linear regression equation of the log-transformed data:

$$\log_{10} W = \log_{10} a + b \log_{10} TL \quad (2)$$

where a is the intercept and b is the allometric coefficient [27]. The t-test (confidence level of 95%) is applied to confirm whether b value is different from 3 (isometric growth value) [28]. This equation is sometimes also referred as the length-weight key [29].

Length-length relationships (LLR) are calculated using linear regression model for TL, FL and SL [30]. Length-weight and length-length relationships were determined for two localities separately. Analyses were conducted using SPSS 20, Minitab 17.0 and the Excel software, and results were considered as significant for $P<0.05$.

3. Results

The average total lengths and weights of the individuals sampled from the Terme and Terice Streams were determinated as 6.809±0.108, 5.463± 0.102 cm and 4.454±0.248, 1.828±0.164 g, respectively. The descriptive statistics calculated separately for two different habitats were offered in Table 1.

Table 1. Values of length and weight for *Rhodeus amarus* (N: number of specimens, Se: standard error, Sd: standard deviation, Min.: minimum, Max.: maximum; all TL in cm W in g).

Localities	Variable	N	Mean	Se	Sd	Min.	Max.
Terme	TL	57	6.81	0.11	0.82	4.60	8.90
Stream	W	57	4.46	0.25	1.87	1.12	9.94
Terice	TL	60	5.46	0.10	0.79	4.50	8.00
Stream	W	60	1.83	0.16	1.27	0.73	7.24

According to the statistical analyses there are differences in terms of total length and weight between localities ($P<0.001$). Overall, there is a strong correlation between length and weight relationship for two localities (R^2 >0.921). These values are suggesting that the total length and weight are in a harmony with each other. Length-weight equations were calculated as $W=0.005TL^{3.479}$ and $W=0.004TL^{3.586}$ for Terme and Terice, respectively. (Table 2).

Table 2: Parameters of length-weight relationships for *R. amarus*. (CI: Confidence intervals, r^2: correlation coefficient, P; P-value).

	Regression parameters				
Localities	**a**	**b**	**95% CI of b**	**R^2**	**P**
Terme Stream	0.005	3.479	3.242-3.717	0.921	<0.001
Terice Stream	0.004	3.586	3.370-3.802	0.952	<0.001

As seen in Table 2, the b values varies between 3.479 and 3.586. Analyses showed that bitterling has positive allometric growths for two localities (Figure 3, 4).

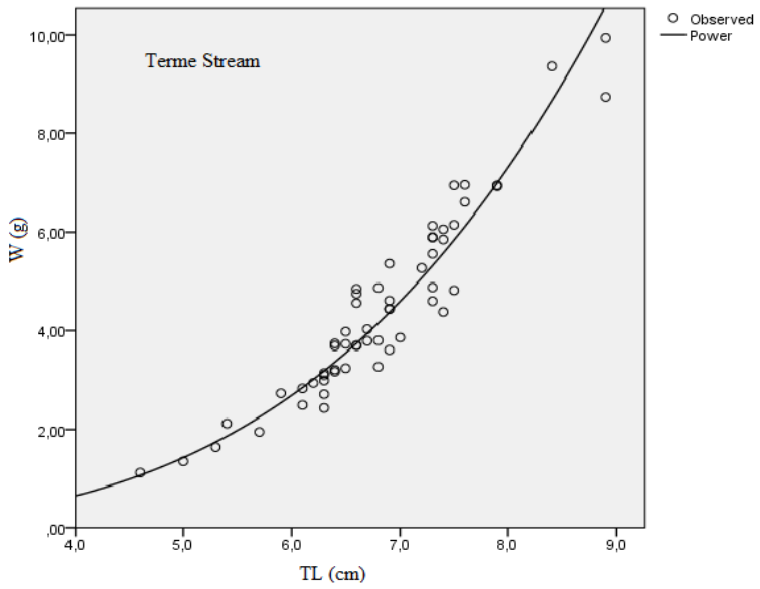

Figure 3: LWR for *Rhodeus amarus* in Terme Stream.

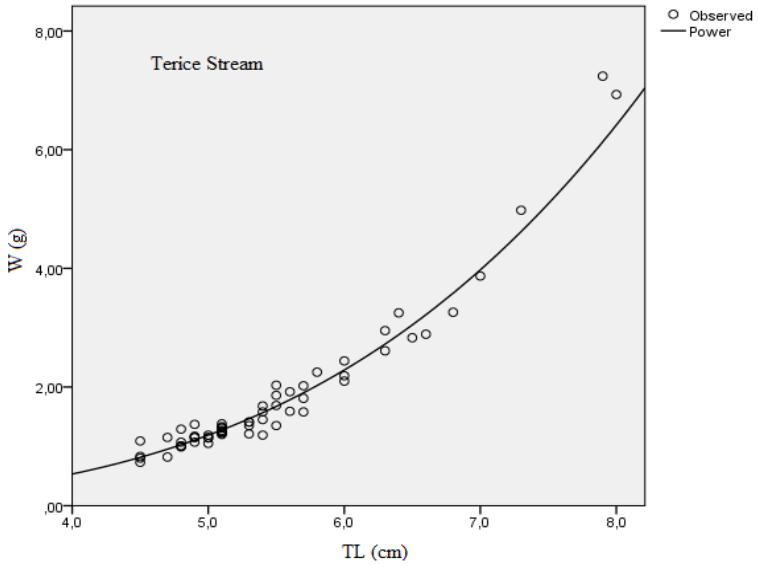

Figure 4: LWR for *Rhodeus amarus* in Terice Stream.

Length-length relationships reveal that all length values are very strong between each other (P<0.001) (Table 3).

Table 3: Parameters of length-length relationships for *Rhodeus amarus*.

Localities	Equation	a	b	r^2	P
Terme Stream	TL= a+b FL	0.414	0.998	0.97	<0.001
	FL= a+b SL	0.304	1.070	0.97	<0.001
	SL= a+b TL	-0.408	0.900	0.98	<0.001
Terice Stream	TL= a+b FL	0.284	1.020	0.95	<0.001
	FL= a+b SL	0.253	1.100	0.95	<0.001
	SL= a+b TL	-0.194	0.841	0.98	<0.001

4. Discussion

The regression coefficient values obtained from both LWRs and LLRs are high (R^2 > 0.92). This means that the our results of both relationships can be reliably used. The range of b is normally between 2.5 and 3.5 [28]. However, the b values in fish differ according to species, sex, age, seasons and feeding [31]. In this study b values of LWR was 3.479, 3.586 for Terme Stream and Terice Stream, respectively. The b value of LWR ranged 2.288-3.400 in different studies [20-25, 32-35] (Table 4).

Table 4: The LWRs parameters of the *Rhodeus amarus* species at different localities (TL: total length; FL: fork length; SL; standard lenght, I: Isometric, A(+): positive allometry, A(-): negative allometry, tg: type of growth).

References	Locality	Measured Length	Min-Max. (cm)	a	b	R^2	tg
Ustaoğlu et al. [32]	Göksu Springs (Turkey)	FL	3.1-6.4	0.0170	3.200	0.970	-
Tarkan et al. [20]	Ömerli Dam Lake (Turkey)	TL	5.0-8.7	0.0132	3.010	-	I
Battes and Stoica [21]	Bistriţa River (Romania)	SL	3.68-7.11	0.0568	2.288	-	A(-)
Tarkan et al. [22]	Ömerli Dam Lake (Turkey)	TL	5.6-9.0	0.0124	3.040	0.900	A(+)
Tarkan et al. [22]	Büyükçekmece Dam Lake (Turkey)	TL	5.7-7.0	0.0065	3.400	0.815	A(+)
Koutrakis et al. [33]	Rihios Estuary (Greece)	TL	1.2-8.3	0.0097	3.035	0.949	-
Verreycken et al. [34]	Yser, Scheldt and Meuse Rivers (Belgium)	TL	1.8-11.2	0.0079	3.266	0.920	-
İlhan et al. [23]	Western Black Sea (Turkey)	TL	5.4-7.1	0.0083	3.374	0.964	I
İlhan et al. [23]	Gediz Basin (Turkey)	TL	2.2-8.3	0.0197	2.865	0.969	A(-)
İlhan et al. [23]	Small Meander Basin (Turkey)	TL	2.3-6.1	0.0218	2.886	0.973	A(-)
İlhan et al. [23]	Northern Eagean Basin (Turkey)	TL	2.20-7.30	0.0178	2.978	0.978	I
İlhan et al. [23]	Marmara Basin (Turkey)	TL	1.6-8.1	0.0168	2.998	0.973	I
İlhan et al. [23]	Meriç Basin (Turkey)	TL	2.8-7.8	0.0151	3.058	0.974	I
İlhan et al. [23]	Sakarya Basin (Turkey)	TL	1.6-6.9	0.0169	2.948	0.984	A(-)
İlhan et al. [23]	Susurluk Basin (Turkey)	TL	1.9-7.9	0.0174	2.924	0.923	A(-)
İlhan et al. [23]	Yeşilırmak Basin (Turkey)	TL	5.5-6.9	0.0183	2.884	0.959	I
İlhan et al. [24]	Lake Marmara (Turkey)	TL	2.8-6.5	0.0089	3.328	0.972	A(+)
Stavrescu-Bedivan et al. [25]	Timiş River (Romania)	SL	2.3-6.6	0.0204	3.044	0.914	A(+)
Saç and Okgerman [35]	Büyükçekmece Reservoir (Turkey)	TL	5.3-8.2	0.0170	2.837	0.710	A(-)
This Study	Terme Stream	TL	4.6-8.9	0.0050	3.479	0.921	A(+)
This Study	Terice Stream	TL	4.5-8.0	0.0040	3.586	0.952	A(+)

According to this study bitterling has positive allometric growth for Terme and Terice Streams. The results were determined similar, except for those by [22, 24, 25]. There

are a few studies showing different growth type from *R. amarus* inhabiting Terme and Terice Stream (isometric or negative allometry) [20, 21, 23]. Data on the lengths and weights of fish have commonly been analysed to yield biological information. Value of b can be affected by geographic difference and enviromental conditions such as stomach fullness, time and date of catching fish, area, disease. A number of factors influence the LWRs in fish, such as growth phase, season, gonad maturity, sex, size ranges, the measured lenght [36]. In the present study, these factors were not considered. The aim of this study was only to analyse length-length and length-weight relationship for *R. amarus* in Terme and Terice Stream. That will be helpful for sustainable fishery management, conservation programs and comparative growth studies [37]. The coefficient of correlation ranged between 0.815 and 0.984 for *R. amarus* in literature. In this study, coefficient of correlation (LWR) was >0.92 (P<0.001).

Most of the researches used total length while the others use fork and standard length. For *R. amarus* most researches measured total length [20, 23, 24, 33, 34] while some researches used fork length [32] and standard length [21, 25]. In this study, coefficient of correlation (LLR) was estimated as >0.95 (P<0.001). When the literature is examined, it is observed that the regression coefficient of length-length relationships for *R. amarus* is >0.92 (Table 5). Length-length relationships in fish are useful for comparative studies using different length measures. Length-length relationships provides important baseline data to facilitate future fish monitoring and researches. As no study currently exists on the length-weight relationship and length-length relationship of *R. amarus* from the Terme and Terice Stream, the aim of this study was to investigate the LWRs and LLRs in Terme and Terice Stream for *R. amarus*. Morever, to the best of author's knowledge, this study provides the first findings on the length-length relationship parameters for *R. amarus.*

Table 5: The LLRs parameters of the *Rhodeus amarus* species at different localities (N: individuals).

References	Locality	N	Equation	a	b	r^2
Gaygusuz et al. [38]	Büyükçekmece Dam Lake	41		0.0323	1.2024	0.928
Gaygusuz et al. [38]	Ömerli Dam Lake	266	TL=a+b SL	0.1737	1.924	0.975
Gaygusuz et al. [38]	Terkos Dam Lake	46		0.4962	1.1020	0.963
Gaygusuz et al. [38]	Büyükçekmece Dam Lake	41	FL=a+b SL	0.2578	1.0552	0.914
Gaygusuz et al. [38]	Ömerli Dam Lake	266		-0.0792	1.1361	0.979
Gaygusuz et al. [38]	Terkos Dam Lake	46		0.0796	1.0791	0.969
Gaygusuz et al. [38]	Büyükçekmece Dam Lake	41		-0.0299	1.0980	0.943
Gaygusuz et al. [38]	Ömerli Dam Lake	266	TL=a+b FL	0.3033	1.0419	0.982
Gaygusuz et al. [38]	Terkos Dam Lake	46		0.4481	1.0156	0.983
Saç and Okgerman [35]	Büyükçekmece Reservoir	1477	FL=aTL+ b	0.9110	0.0280	0.975
Saç and Okgerman [35]	Büyükçekmece Reservoir	1477	SL= aTL- b	0.7740	-0.0580	0.931
			TL= a+b FL	0.414	0.998	0.970
This Study	Terme Stream	57	FL= a+b SL	0.304	1.070	0.970
			SL= a+b TL	-0.408	0.900	0.980
			TL= a+b FL	0.284	1.020	0.950
This Study	Terice Stream	60	FL= a+b SL	0.253	1.100	0.950
			SL= a+b TL	-0.194	0.841	0.980

This study is the first study that examined the relationships between total length-weight and length-length relationships of *R. amarus* sampled from Terme and Terice Streams. This paper will be a useful reference for fishery biologists in future studies on the

population assessment of the species inhabiting the Terme and Terice Streams freshwater ecosystem.

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