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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Length-weight and length-length relationships of chub (*Squalius cephalus,* L., 1758) inhabiting a few inland waters of the Middle Black Sea Region

Orta Karadeniz Bölgesi'ndeki bazı akarsularda yaşayan tatlısu kefali (*Squalius cephalus,* L.1758)'nin boy-ağırlık ve boy-boy ilişkileri

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Abstract: In this study, the length-weight and length-length relationships of chub (*Squalius cephalus,* L.1758) sampled from a few inland waters of the middle Black Sea were investigated. A total of 218 (Abdal (N=44), Akçay (N=57), Terme (N= 55), Yedikır (N=62)) chub individuals were sampled from different localities. All captured individuals were measured to the nearest 0.1 cm for total, fork and standard lengths. The weight of each sample (W) was recorded (0.01 g). According to results of analyses, there were no statistically significant differences between sexes in terms of length and weight (P>0.05). So, entire populations (female+male) were evaluated together for analyses. The average total lengths of chub sampled from the Abdal Stream, Akçay Stream, Terme Stream and Yedikır Dam Lake varies between 11.49±0.792, 10.31±0.518, 10.33±0.289 and 11.11±0.327 cm, respectively. The length-weight relationships (LWRs) were found highly significant ($P < 0.001$, $r^2 > 0.990$) for all localities. The value of 'b' of LWR was significantly different from 3.0 in chub and the growth type is possitive allometric for all localities. The equations of length-weight relationship were calculated as $W=0.007TL^{3.224}$, $W=0.006TL^{3.285}$, $W=0.005TL^{3.298}$, $W=0.007TL^{3.210}$ for Abdal, Akçay, Terme and Yedikır, respectively. Length-length relationship was also highly significant (P<0.001) with coefficient of determination (r^2) ranging from 0.916 to 0.999.

Keywords: *Chub, length-weight relationship, length-length relationship, Black Sea, Turkey*

Öz: Bu çalışmada orta Karadeniz Bölgesi'ndeki bazı içsularda yaşayan tatlısu kefalinin (*Squalius cephalus,* L.1758) boy-ağırlık ve boy-boy ilişkileri incelenmiştir. Toplamda 218 (Abdal (N=44), Akçay (N=57), Terme (N= 55), Yedikır (N=62)) örnek farklı lokalitelerden örneklenmiştir. Yakalanan tüm örneklerin total, çatal ve standart boyları (0.1 cm) ölçülmüştür. Her bir örneğin ağırlığı (W) kaydedilmiştir (0.01 g). Analiz sonuçlarına göre cinsiyetler arasında boy ve ağırlık bakımından istatistiksel olarak önemli bir farklılık yoktur (P>0.05). Bu sebeple tüm populasyon (dişi+erkek) analizlerde birlikte değerlendirilmiştir. Abdal Çayı, Akçay Çayı, Terme Çayı ve Yedikır Baraj Gölü'nden örneklenen tatlısu kefalinin ortalama total boyları sırasıyla 11.49±0.792, 10.31±0.518, 10.33±0.289 ve 11.11±0.327 cm arasında değişmektedir. Boy-ağırlık ilişkileri tüm lokaliteler için önemli bulunmuştur ($P < 0.001$, $r^2 > 0.990$). Boy-ağırlık ilişkisinin "b" değeri istatistiksel anlamda 3'ten faklıdır ve tüm lokaliteler için büyüme tipi pozitif allometriktir. Boy-ağırlık ilişkilerinin denklemleri sırası ile Abdal, Akçay, Terme ve Yedikır için $W=0.007TL^{3.224}$, $W=0.006TL^{3.285}$, $W=0.005TL^{3.298}$, $W=0.007TL^{3.210}$ olarak hesaplanmıştır. Boy-boy ilişkilerinin regresyon katsayıları 0.916 ile 0.999 arasında değişim göstermektedir ve istatistiksel anlamda önemlidir (P<0.001).

Anahtar kelimeler: *Tatlısu kefali, boy-ağırlık ilişkisi, boy-boy ilişkisi, Karadeniz, Türkiye*

INTRODUCTION

Squalius cephalus (chub) (L., 1758) is a freshwater fish species widely distrubuted all around the world. The chub is widespread in the whole of Europe, the Black Sea, the Azov Sea, the Caspian Sea, and most of the inland waters in Anatolia. This fish species is economically important and there are lots of studies about genetic, biological characteristic, population parameters and systematics of chub from different localities (Laroche et al., 1999; Arlinghaus and Wolter, 2003; Turan et al., 2007; Dehais et al., 2010; Bulut et al., 2012; Cejko and Krejszeff, 2016; Gouskov, 2016; Özcan et al., 2017). The conservation status of chub is "LC" according to IUCN (The IUCN Red List of Threatened Species, Version 2017-3).

Length-weight (LWRs) and length-length relationships (LLRs) are very important for fisheries researches. Length-weight-related parameters provide predicting the weight of the fish from its length and life cycle of the populations from different habitats. Also, LWRs allow the transformations of growth-in-length equations to growth in-weight, for use in stock

assessment models; an estimate of the condition of fish; useful for region comparisons of life histories of fish species (Petrakis and Stergiou, 1995; Gonçalves et al., 1997; Binohlan and Pauly, 1998). LLRs are important in comparing growth studies using different length types for fisheries management (Moutopoulos and Stregiou, 2002).

In fisheries biology, LWRs and LLRs are base studies and allow for comparisons of species growth between different regions. Therefore, these studies are also prefered for stock analyses. In this study, we aimed to determine the LWRs and LLRs of chub which sampled from the four different localities (Abdal Stream, Akçay Stream, Terme Stream and Yedikır Dam Lake) along inland waters of the Middle Black Sea Region.

MATERIALS AND METHODS

Sampling

Chub samples obtained from Abdal Stream (N=44), Akçay Stream (N=57), Terme Stream (N=55) and Yedikır Dam Lake (N=62). The coordinates of sampling locations and date were recorded using GARMIN GPS (Table 1-Figure 1). Samples were collected with SAMUS 725 MP electroshocker.

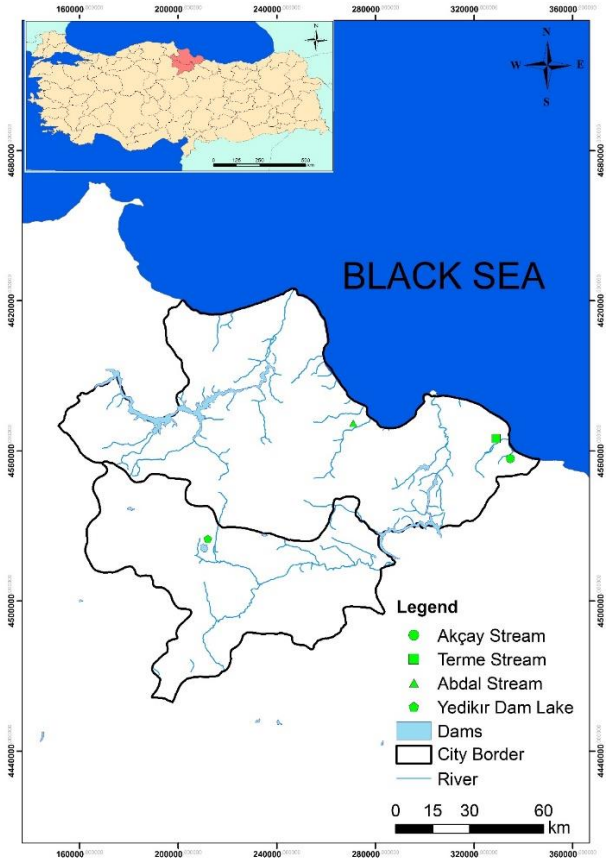

Figure 1. Sampling area

Table 1. Coordinates of sampling localities

Locality	Sampling Date	Coordinates	N
Abdal Stream	April 2017	41°09'22.38 "N 36°44'21.54" E	44
Akçay Stream	October 2015	41°05'30.99 "N 37°07'20.89" E	57
Terme Stream	February 2016	41°09'34.03 "N 36°53'28.48" E	55
Yedikır Dam Lake	July 2016	40°47.5'5.38 "N 35°33'10.16" E	62

Biological studies and statistical analysis

Fish samples were measured for total length (TL), fork length (FL) and standard length (SL) (0.1 cm.) The weight of each fish (W) was recorded (0.01 g). Sex was determined by macroscopic examination of the gonads.

Length–weight relations were calculated using the equation $W = aL^b$, where W is the total weight of the fish (g), L is the total length (cm), a and b are the parameters of the equation (Bagenal and Tesch, 1978). The t-test employed to test whether the slopes (b) were significantly different from 3, indicating the growth type: isometric (b=3), positive allometric (b>3) or negative allometric (b<3). Analysis of variance (ANOVA) was used to test differences of the b values of length-weight relationship between sexes (Zar, 1999).

All length-length relationships of chub samples were computed using linear regression analysis (Zar, 1999). Relationships between TL & FL, FL & SL, and SL & TL were estimated separately according to all localities.

Statistical analyses were tested by at the 0.05 significance level. SPSS 20, Minitab 15.0 and the Excel software were utilized in the evaluation of data.

RESULTS

The average total length of the individuals sampled from the Abdal Stream, Akçay, Terme and Yedikır Dam Lake varies between 11.49±0.792, 10.31±0.518, 10.33±0.289 and 11.11±0.327 cm. The descriptive statistics of chub samples from four locality indicated in Table 2. There are no differences in terms of TL or W between localities according to sex ($P>0.05$). So, entire populations (female+male) were evaluated together for analyses.

LWRs were calculated for all localities. The LWRs were significantly important ($P < 0.001$, $r^2 > 0.990$, Table 3). The value of 'b' of LWR was found to be significantly different from 3.0 in chub and the growth type were possitive allometric for all localities according to results of this study (Table 3).

Table 2. Descriptive statistics of *S. cephalus* samples from different localities

Locality	Parameters TL (cm)/ W (g)	N	Mean	Min.	Max.	SD.	SE.
Abdal Stream	TL	44	11.49	5.60	29.40	5.255	0.792
	W		33.59	1.82	328.1	64.36	9.700
Akçay Stream	TL	57	10.31	5.80	18.00	3.911	0.518
	W		18.81	1.79	67.57	19.37	2.570
Terme Stream	TL	55	10.33	6.40	15.60	2.146	0.289
	W		13.18	2.39	46.99	8.61	1.160
Yedikır Dam Lake	TL	62	11.11	6.70	17.70	2.575	0.327
	W		20.18	3.39	71.30	16.75	2.130

TL: total length; W: weight; SD: standard deviation, Min: minimum; Max: maximum; SE: standard error

Table 3. Parameters of the LWR and growth types for *S. cephalus* according to localities

Locality	a	b	r^2	95% Confidence Interval	Growth Type
Abdal Stream	0.007	3.224	0.995	3.156-3.292	(+) Allometry
Akçay Stream	0.006	3.285	0.997	3.245-3.356	(+) Allometry
Terme Stream	0.005	3.298	0.993	3.194-3.402	(+) Allometry
Yedikır Dam Lake	0.007	3.210	0.992	3.104-3.316	(+) Allometry

Table 4. LLRs between TL, FL and SL of chub inhabiting a few inland waters of Middle Black Sea Region of Turkey

Localities	Equations	a	b	r^2	P
Abdal Stream	TL=a+bFL	0.279	1.04	0.999	<0.001
	FL=a+bSL	-0.019	1.15	0.999	<0.001
	SL=a+bTL	-0.201	0.84	0.999	<0.001
Akçay Stream	TL=a+bFL	0.110	1.06	0.998	<0.001
	FL=a+bSL	0.929	0.99	0.922	<0.001
	SL=a+bTL	-0.239	0.87	0.916	<0.001
Terme Stream	TL=a+bFL	-0.048	1.08	0.981	<0.001
	FL=a+bSL	0.297	1.09	0.985	<0.001
	SL=a+bTL	-0.016	0.83	0.984	<0.001
Yedikır Dam Lake	TL=a+bFL	0.267	1.03	0.991	<0.001
	FL=a+bSL	0.011	1.11	0.996	<0.001
	SL=a+bTL	-0.125	0.86	0.989	<0.001

LLRs were calculated by using the linear regression model. LLRs were also highly significant (P<0.001) with coefficient of determination (r^2) ranging from 0.916 to 0.999 (Table 4).

DISCUSSION

The LWRs parameters are extremely important for fish biology and fisheries management (Garcia et al., 1989). Also, length-length associations have a great importance in the comparison of studies using different lengths types (Moutopoulos and Stergiou, 2002; Hossain et al., 2006; Singh and Serajuddin, 2017).

In this study, maximum total lengths of *S. cephalus* were found as 29.40 cm (Abdal Stream), 18.00 cm (Akçay Stream), 15.60 cm (Terme Stream) and 17.70 cm (Yedikır Dam Lake), respectively. Variations in fish growth in terms of length and weight can be explained as an adaptive response to different ecological conditions (Nikolsky, 1963). Le Cren's concept hypothetically stated that the value of 'b' in ideal fish to be 3, indicating an isometric growth, which is widely used as a scale in length–weight relationship study (Singh and Serajuddin, 2017). The values of 'b' in the present study indicated positive allometric growth for all localities. Many studies have been found when the literature examined about LWR and growth type of *S. cephalus* (Table 5).

In this study, the growth type of chub was found as possitive allometric. "b" values of Abdal Stream, Akçay Stream, Terme Stream and Yedikır Dam Lake are 3.224, 3.285, 3.298 and 3.210, respectively. Some factors such as genetic isolation and specific environmental conditions (e.g. temperature, eutrophication levels, food supply and diseases) are responsible for intraspecific differences in growth parameters (Stefanova et al., 2008). Therefore, "b" values of most of the studies could be different from each other between regions.

Length-weight and length-length relationships provides important baseline data to facilitate future fish monitoring and researches. In this study, both LWRs and LLRs were found significantly important (P<0.001). "r^2" values of LWRs were between 0.992 and 0.997. Various studies indicated that LWRs are very strong in chub (Table 5).

LLRs are also useful for conversion purposes when comparisons are made with literature values, information on growth patterns and consequently to estimate fish biomass (Ault et al., 2005; Aburto-Oropeza et al., 2011). There are different studies used total, fork and standard lengths. This differences causes confusion in some of the studies carried out. At that point, LLRs plays a key role in comparision of studies. Özcan et al. (2017) investigated LLRs of chub from Karasu River and found highly significant relationships (r^2 >0.95, P<0.001). In this study, LLRs were significantly important for all localities (P<0.001) and coefficient of determination (r^2) ranged from 0.916 to 0.999.

Table 5. Length-weight relationships of chub from different areas

Study area	N	b	Growth Type	Literature
Northern Aegean Eustuarine (Greece)	627	3.856	A(+)	Kautrakis and Tsigliras (2003)
Topçam Dam Lake (Turkey)	332	3.12	A(+)	Şaşı and Balık (2003)
Işıklı Lake (Turkey)	528	3.04	I	Balık et al. (2004)
Sır Dam Lake (Turkey)	422	3.214 (for males) 3.174 (for females)	A(+) A(+)	Kara and Solak (2004)
Almus Dam Lake (Turkey)	305	3.359	A(+)	Karataş and Can (2005)
Karakaya Dam Lake (Turkey)	527	2.820	A(-)	Kalkan et al. (2005)
Gelingülü Dam Lake (Turkey)	267	2.870	I	Kırankaya and Ekmekçi (2007)
İkizcetepeler Dam Lake (Turkey)	414	2.96 (for males) 2.86 (for females)	A(-) A(-)	Koç et al. (2007)
Hafik Lake (Turkey)	242	2.828	I	Ünver and Kekilli (2010)
Çamkoru Pond (Turkey)	374	3.012	A(+)	İnnal (2010)
Tödürge Lake (Turkey)	466	3.088	I	Ünver and Erk'akan (2012)
Gamasiab River (Iran)	60	3.97	A(+)	Sedaghat et al. (2012)
Apa Dam Lake (Turkey)	474	2.43	A(-)	Mert et al. (2015)
Uzunçayır Dam Lake (Turkey)	334	3.136	A(+)	Demirol et al. (2016)
Yeniağa Lake (Turkey)	729	3.109	A(+)	Kılıç and Becer (2016)
Devres Stream (Turkey)	329	2.97 (for males)-3.11 (for females)	-	Benzer and Gül (2017)
Karasu Stream (Turkey)	254	3.24	A(+)	Özcan et al. (2017)
Akçay River (Büyük Menderes Basin) (Turkey)	366	2.72 (for) males) 2.75 (for females)	A(-) A(-)	Şaşı and Özay (2017)
Abdal Stream (Turkey)	44	3.224	A(+)	This study
Akçay Stream (Turkey)	57	3.285	A(+)	This study
Terme Stream (Turkey)	55	3.298	A(+)	This study
Yedikır Dam Lake (Turkey)	62	3.210	A(+)	This study

(M: Male, F: Female, A(+): Possitive Allometry, I: Isometric, A(-): Negative Allometry)

Length-weight and length-length relationships are important in effective management of fisheries. This is the first study that examined the relationships between total length-weight and length-length relationships of *S. cephalus* sampled from Abdal Steram, Akçay Stream, Terme Stream and Yedikır Dam Lake. The authors hope that this study will support investigators in future for ecological studies and reliable growth estimations.

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