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Density, Biomass and Length-Weight Relationship of Brown Trout (*Salmo trutta* Linnaeus, 1758) Population in the Çoruh River Basin, North-Eastern Anatolia, Turkey

Özge Zencir TANIR [1*], Özden FAKIOĞLU[2]

[1] Erzincan University, Kemah Vocational School, 24000 Erzincan-Turkey
[2] Atatürk University, Faculty of Fisheries, 25240 Erzurum-Turkey

A B S T R A C T

This study was conducted to determine density, biomass and length-weight relationship for brown trout (*Salmo trutta* Linnaeus, 1758) caught from removal method based on single-pass electro fishing. A total area of 2.176 ha was sampled and 167 fishes were caught using electro fishing between May 2012 and June 2013 in Tortumkale Stream of Çoruh River, Turkey. Mean density and biomass of brown trout were found to vary between 106-167 fish ha^{-1} and 4.76-10.64 kg ha^{-1}, respectively. The length-weight relationship exponent b values ranged from 3.0672 to 3.3158 and indicated positive allometric growth. Length-weight relationship in between stations were statistically significant (r^2>0.9917, p<0.05). Our results revealed that the density of the brown trout population in Tortumkale Stream is at a level indicating a risk of extinction of this species. Density of brown trout occuring in restricted habitats was reduced in Tortumkale Stream; especially it causes reduction of their population overfishing on adult individuals in reproduction season and lower of recruitment to the population. Also, biotic and abiotic effects of rainbow trout (*Oncorhynchus mykiss*), aquacultures activities, recreational fisheries, barriers of dam construction and irrigation canals, pollution from domestic, industrial and agricultural waste contribute to the destruction of the habitat of brown trout.

Keywords: Brown trout, growth, density, biomass, Turkey

A R T I C L E I N F O

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*** CORRESPONDING AUTHOR**

zencir06@hotmail.com
Tel : +90 446 226 66 66

Kuzeydoğu Anadolu Çoruh Nehri Havzası'ndaki Kırmızı Benekli Alabalık (*Salmo trutta* Linnaeus, 1758) Populasyonunun Yoğunluk, Biyokütle ve Boy-Ağırlık İlişkisi

Öz: Bu çalışma, tek avlı ayrılmaya dayalı metot uygulanarak avlanan kırmızı benekli alabalığın (*Salmo trutta* Linnaeus, 1758) yoğunluk, biyokütle ve boy-ağırlık ilişkisini belirlemek için yürütülmüştür. Toplam 2,1760 ha alan, Kuzey Doğu Anadolu Çoruh Nehri Havzası'nın Tortumkale Çayı'nda; Mayıs 2012-Haziran 2013 tarihleri arasında elektroşokla 167 adet balık avlanmıştır. Ortalama yoğunluk ve biyomas değerleri sırasıyla 106-167 adet/ha ve 4,76-10,64 kg/ha arasında değişmiştir. Boy-ağırlık ilişkisinin b değerleri 3.0672-3.3158 arasında değişmiş ve pozitif allometrik büyüme gözlemlenmiştir. İstasyonlar arasındaki boy-ağırlık ilişkisi istatistikî olarak önemlidir (r^2>0,9917, p<0,05). Elde edilen sonuçlar doğrultusunda kırmızı benekli alabalık türünün, yok olma riski altında olduğunu tespit edilmiştir. Tortumkale Çayı'nda sınırlı habitatlarda yaşayan kırmızı benekli alabalığın yoğunluğu; özellikle populasyona yeni birey katılımının azalması ve üreme döneminde yetişkin bireyler üzerine aşırı av baskısı nedeniyle azalmıştır. Aynı zamanda, gökkuşağı alabalığı akuakültür aktivitelerinin biyotik ve abiyotik etkileri, rekreasyonel balıkçılık, baraj yapılar ve sulama kanalları bariyerleri ile evsel, endüstriyel ve tarımsal atıklardan kaynaklanan pollusyon kırmızı benekli alabalığın habitatlarını tahribine katkı sunmaktadır.

Anahtar kelimeler: Kırmızı benekli alabalık, büyüme, yoğunluk, biyomas, Türkiye

How to Cite
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Introduction

Brown trout, also known as redpoints trout (*Salmo trutta* Linnaeus, 1758), is a species of the Salmonidae family and is widespread throughout the world including the freshwaters of Turkey. This species has also been registered in Europe, North

Africa, the Middle East and the western regions of Asia (Alp et al. 2005). Therefore, in addition to being a global species, brown trout has a significant place in sports fishing, commercial fishing and aquaculture (Özvarol et al. 2010). From an ecological and economic perspective, *S trutta* is considered the most important native fish species found in the freshwaters of Turkey. They live in clear, clean, cool and oxygen-rich rivers with waterfalls at 50 to 2300 m altitude and a maximum temperature of 20°C (Duman et al. 2011).

In Turkey, the stocks and population of brown trout have been gradually reduced and the species is at the risk of extinction due to environmental factors such as pollution, construction, destruction of stream beds and spawning areas; attempts to restock with other fish species such as rainbow trout (*O. mykiss*); and fishing activities using illegal and prohibited equipment (Arıman and Kocaman 2003; Kocabaş et al. 2013). However, there is a lack of both direct and indirect data concerning the population of brown trout in rivers in Turkey and their preservation status that would allow an accurate assessment regarding their risk of the extinction of the subspecies (Smith and Darwall 2006; Tarkan et al. 2008). Therefore, brown trout is listed as DD = Data Deficient in the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (Smith and Darwall 2006).

The fluctuation of the fish population is really important for stock assessment and management. In this way, a major decline and rise in the population density or the population biomass can be detected, and appropriate management strategies can be adopted (Chen et al. 2004). A relatively simple and inexpensive method to assess the welfare of lentic systems is to monitor the density and biomass of fish population (Platts and Mchenry 1988; Bohlin et al. 1989).

Length-weight relationship (LWR) are important and have many applications in fish stock assessments, biomass estimations, ecological studies and modeling aquatic ecosystems (Froese 2006). In addition, the LWR is important in terms of providing for the estimation of weight from the length and the calculation of condition indices as well as providing general information about the morphology of populations in different habitats and their life cycles (Petrakis and Stergiou 1995; Froese et al. 2011).

Many scientists in various regions of the world have been studied the density and biomass of trout populations per surface unit in rivers (Almodovar and Nicola 1998; Maia and Valente 1999; Dikov and Zivkov 2004; Vlach et al. 2005; Zanetti et al. 2010; Kolev 2010, 2012). There are some studies for the LWR regarding brown trout in freshwater of different geographic regions of Turkey (Ölmez et al. 1998; Kocaman et al. 2004; Alp and Kara 2004; Arslan et al. 2004; Alp et al. 2005; Arslan et al. 2007; Gülle et al. 2007; Özvarol et al. 2010; Kocabaş et al. 2011; Kocabaş et al. 2012; Yıldırım et al. 2012; Başusta et al. 2013) although little work has been done in Turkey on brown trout populations parameters (i.e. density and biomass) (Korkmaz et al. 1998; Korkmaz 2005). But still there is no detailed information about the density and biomass of brown trout. With this respect it is needed to establish the status of fish density and biomass in a number of localities and stream profiles in North-eastern Anatolia, Turkey.

In addition, there were no studies and data about density, biomass and the LWR of brown trout in Tortumkale Stream. This study investigated density, biomass and LWR of brown trout living in Tortumkale stream in Çoruh River, Turkey to provide a basis for future studies on this population.

Material and Methods

Tortumkale Stream is one of the most important tributaries of Tortum Stream (Figure 1). Tortum Stream, which arise from Dumlu Mountain of the eastern Mescit Mountains is in Erzurum province. It has an average of 50 km length and fast-flowing river systems. The Tortum Stream is the most important resource landslides which feeds the lake and regarded as one of the world's largest waterfall. There are four trout farm, four stone quarries, two concrete plants as well as use of irrigation water and three Hydroelectric Dams Project are not completed on the Tortum Stream and its tributaries (Köktürk and Atamanalp 2015).

The stream substratum is constituted of rocks, boulders of various size, pebbles and sand in the lower section. The bottom of site 1 was covered with partially-large stony and rocky structures, and the banks were stony riverbeds; the bottom of site 2 was covered with large stony and rocky and typically fast flowing soft-water, and the banks were un-wooded and rocky; the bottom of site 3 was covered with large stony and big rocky, and the banks were occasionally tree roots and typically fast flowing soft-water.

This study was carried out in Tortumkale Stream. Three sampling sites were assigned on Tortumkale Stream for fish sampling, water samples and measuring water characteristics. These sampling sites in Tortumkale Stream were selected according to habitat structure, depth, water velocity, size and structure of substratum (Hankin 1984). Some physical and chemical characteristics of sampling sites were shown in Table 1.

Table 1. Some physical and chemical characteristics of sampling sites (±SD).

Sampling times and sites		pH	Water Temperature (˚C)	Dissolved Oxygen (mg L^{-1})	Water Velocity (m sec^{-1})	Conductivity (µmhos/cm)	Depth (m)	Width (m)	Area (ha)
May 2012	1	7.6±0.14	6.9±0.29	9.4±0.08	1.25±0.02	829±89.60	0.55±7.74	6.0±2.78	0.120
	2	7.4±0.45	7.10±0.40	9.5±0.33	1.30±0.14	724±87.26	0.60±7.87	6.5±2.64	0.130
	3	8.0±0.30	7.80±0.25	9.7±0.22	0.60±0.15	526±96.25	0.65±7.83	9.0±1.89	0.180
August 2012	1	7.1±0.47	15.4±0.60	7.5±0.57	1.10±0.18	811±76.02	0.44±6.46	6.0±1.75	0.120
	2	7.8±0.40	16.7±0.39	7.3±0.53	1.20±0.21	688±72.43	0.50±6.07	8.0±1.32	0.160
	3	7.4±0.60	17.1±0.49	8.2±0.42	0.50±0.18	547±69.04	0.55±7.26	7.5±1.00	0.150
November 2012	1	7.5±0.27	12.2±0.29	7.7±0.39	1.20±0.29	823±67.67	0.40±5.27	7.7±2.25	0.154
	2	7.6±0.27	13.4±0.40	7.8±0.33	1.30±0.18	726±76.29	0.45±6.29	6.7±1.89	0.134
	3	7.1±0.43	11.6±0.41	8.0±0.37	0.60±0.18	644±89.15	0.40±6.18	8.7±1.25	0.174
March 2013	1	8.2±0.47	5.40±0.55	9.9±0.29	1.20±0.35	786±50.77	0.62±6.07	6.0±1.80	0.120
	2	7.7±0.25	4.90±0.46	9.8±0.36	1.30±0.21	665±65.85	0.55±6.74	6.5±2.00	0.130
	3	7.5±0.66	6.10±0.39	9.5±0.49	0.70±0.18	595±84.72	0.50±6.18	9.0±1.32	0.180
June 2013	1	7.4±0.43	12.4±0.33	7.8±0.43	1.30±0.29	791±81.66	0.70±5.52	6.0±1.50	0.120
	2	7.3±0.37	14.8±0.40	6.7±0.21	1.20±0.35	711±99.30	0.65±5.64	7.1±1.50	0.142
	3	7.8±0.63	15.7±0.52	7.1±0.18	0.70±0.29	575±89.08	0.60±5.18	8.1±1.04	0.162
Total Sampling Area (ha)									2.176

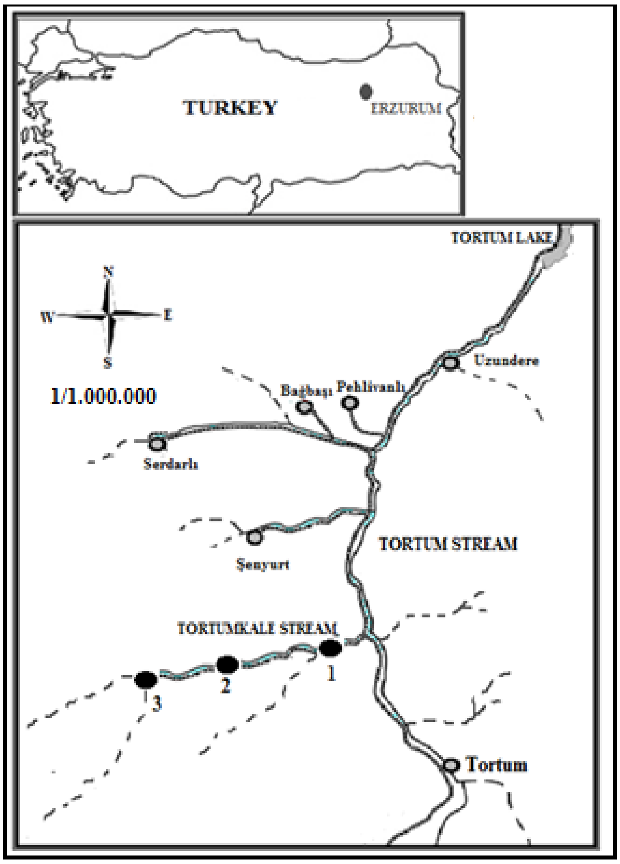

Figure 1. Study area and sampling sites.

Fish samples in Tortumkale Stream were collected approximately every 3 months between May 2012 and June 2013 by electro fishing. A pulsed DC current of 2 amperes at 500-750 volts was used in electro fishing, the current being supplied by a generator. The electro fishing team consisted of three experienced crew members with one using the anode and the other two using dip nets to capture the fish. Each sampling site was closed at both ends with 8-10 mm mesh size nets (Lacroix 1989) and the fishing was carried out in an upstream direction. Then, we took the measurement per 10-20 m to determine the mean stream depth (m) and width (m) (Neves and Pardue 1983).

Due to the rocky and stony of stream bed could be made only single-pass electro fishing in selected sampling sites (Seber 1973). Fish caught in each sample site were anesthetized with MS 222 and mortality was not observed. Fish caught were placed into different plastic buckets for 40 liters. Then, fish were numbered, measured and weighted to the nearest 1 mm (total length) and 1gr, respectively. To conserve as live the fish, fresh brook water was added into plastic buckets from time to time until experimental treatments were finished. Fish caught were returned to the water as alive in accordance with permission. This procedure was repeated in all sampling dates. In order to determine fish density (population size) and biomass in each sampling site, it was used removal method based on single-pass electro fishing (Seber 1973). Removal method based on single-pass electro fishing is described as:

$$\widehat{N}_i = \frac{C_i}{\hat{p}}$$

$\widehat{N}_i$ is population density; $\hat{p}$ is the catch efficiency ($\hat{p} = 1 - \hat{q}$) ; C_i is total catch. $i = 1, \ldots, n$. Catch efficiency value (0.63) has been used that calculated for brown trout in the Hatila Creek having similar bottom structure and habitat (Korkmaz et al. 1998). Catch efficiency may also vary as a function of fish size, operator skill, electrofisher settings, habitat, temperature and fish abundance (Van Dishoeck 2009). The sampling variance and an approximate 95 percent confidence interval of $\widehat{N}_i$ were estimated from the following equations, respectively.

$$S^2_{\widehat{N}_i} = \widehat{N}^2 . \hat{q} . \frac{(1+\hat{q})}{n} . \hat{p}^3 + \widehat{N} . \frac{\hat{q}}{\hat{p}} + \widehat{N} . \hat{q}^2 . \frac{(5+\hat{q})}{n} . \hat{p}^4 \text{ and } \widehat{N}_i \pm S_{\widehat{N}_i}$$

The biomass or standing crop ($\hat{B}$) was estimated by $\hat{B} = B . \left(\frac{\widehat{N}_i}{N}\right)$.Where, B is the total weight of fish caught and N is the total number of fish caught. Values of density and biomass of fish per unit area where catches were estimated by $\widehat{N}/A$ and $\hat{B}/A$, respectively. Where A is area of sampling sites (ha) (Bohlin et al. 1989).

The LWR $W = a \times L^b$, was transformed into its logarithmic expression: $LogW = loga + b \times logL$. The parameters a and b were calculated by least-squares regression for sampling sites. The LWR curves were compared between all sampling sites. The significance of the regression was assessed by analysis of variance (ANOVA), and the variation in b values from 3 were controlled by the t-test for evaluating growth curve. When the b value in the LWR was equal to or did not show statistically significant deviation from 3, the growth was isometric, whereas the positive or negative allometric growth occurred when the b value deviated significantly from 3 (Ricker 1975).

Results

A total area of 2.176 ha was sampled by single pass electro fishing and 167 brown trout were caught from the Tortumkale Stream between May 2012 and June 2013. The results of single pass electro fishing together with estimates of brown trout density and biomass at the three sampling sites and sampling periods are presented in Table 2.

Table 2. Stock density and biomass obtained from sampling sites in the Tortumkale Stream.

Sampling times and sites		C_i	B	$\widehat{N}_i$ (fish)	$\widehat{N}_i \pm S_{\widehat{N}_i}$	$\hat{B}$ (g)	$\widehat{N}_i$ (fish ha^{-1})	$\hat{B}$ (kg ha^{-1})
May 2012	1	21	1414.03	34	34±11	2289.38	283	19.08
	2	11	428.14	18	18±8	700.59	127	4.93
	3	4	103.45	7	7±6	181.04	43	1.12
	Mean	12	648.54	19.67		1057.00	151	8.38
August 2012	1	10	578.65	16	16±8	925.84	133	7.72
	2	8	653.45	13	13±7	1061.86	100	8.17
	3	9	352.94	15	15±8	588.23	83	3.27
	Mean	9	528.35	14.67		858.64	106	6.38
November 2012	1	15	1416.52	25	25±10	2360.87	162	15.33
	2	11	302.02	18	18±8	494.21	134	3.69
	3	6	346.15	10	10±6	576.92	57	3.32
	Mean	11	688.23	17.67		1144.00	118	7.44
March 2013	1	19	1267.95	31	31±11	2068.76	258	17.24
	2	14	1062.77	23	23±9	1745.98	144	10.91
	3	9	340.22	15	15±8	567.03	100	3.78
	Mean	14	890.31	23.00		1460.59	167	10.64
June 2013	1	14	552.21	23	23±9	907.20	192	7.56
	2	10	411.11	16	16±8	657.78	123	5.06
	3	6	179.83	10	10±6	299.72	56	1.67
	Mean	10	381.05	16.33		621.57	123	4.76

According to these results, mean density and biomass of brown trout were found to vary between 106-167 fish ha^{-1} and 4.76-10.64 kg ha^{-1}, respectively. Mean density was as follows: 151 fish ha^{-1} at the May 2012; 106 fish ha^{-1} at the August 2012; 118 fish ha^{-1} at the November 2012; 167 fish ha^{-1} at the March 2013; 123 fish ha^{-1} at the June 2013. Mean biomass was as follows: 8.38 kg ha^{-1} at the May 2012; 6.38 kg ha^{-1} at the August 2012; 7.44 kg ha^{-1} at the November 2012; 10.64 kg ha^{-1} at the March 2013; 4.76 kg ha^{-1} at the June 2013.The lowest and the highest density and biomass values were observed during May 2013 in 3rd sampling site and 1st sampling site.

The sample size (n), ranges of total length and total weight, parameters a and b of the LWR, 95% confidence intervals of a and b, the determination coefficient (r^2), and growth type are given in Table 3. According to sampling sites, captured fish were measured as 16.0 ± 0.50 cm, 66.19 ± 6.34 g; 14.6 ± 0.63 cm, 52.91 ± 6.73 g; 13.2 ± 0.76 cm, 38.89 ± 6.21 g (S.D.), respectively (Table 3).

The LWR were found as W = 0.0092*$L^{3.1158}$ (r^2=0.9931) at 1st sampling site, W = 0.0105*$L^{3.0734}$ (r^2=0.9927) at 2nd sampling site and W = 0.0104*$L^{3.0672}$ (r^2=0.9917) at 3rd sampling site (Figure 2-4). The LWR exponent *b* values ranged from 3.06 to 3.31.The *b* values of the LWR from Tortumkale Stream were significantly different from 3.0 ($p<0.05$) and indicated positive allometric growth. All values of the coefficient of determination (r^2) varied between 0.9917 and 0.9931 (Table 3).

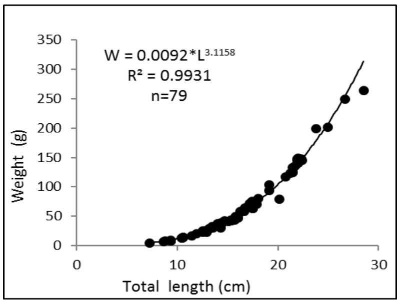

Figure 2. The LWR in brown trout (1st sampling site).

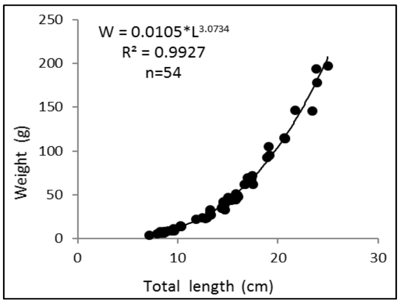

Figure 3. The LWR in brown trout (2nd sampling site).

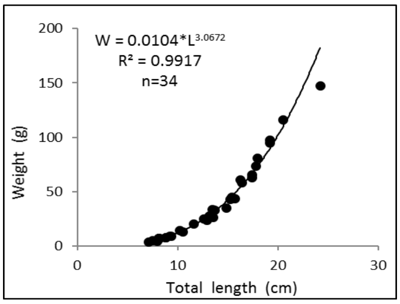

Figure 4. The LWR in brown trout (3rd sampling site).

Table 3. Descriptive statistics and estimated parameters of the LWR for brown trout according to the sampling sites.

Sampling sites	N	L±SD (cm) Min. Max.	W±SD (g) Min. Max.	Regression parameters a	b	95% Cl of a	95% Cl of b	r^2	t-test	GT
1	79	7.2-28.5 (16.0±0.50)	5.02-264.31 (66.19±6.3)	0.0092	3.3158	-2.107 to 1.967	3.057 to 3.175	0.9931	$p<0.05$	A+
2	54	7.1-25.0 (14.6±0.63)	4.02-197.34 (52.91±6.7)	0.0105	3.0734	-2.064 to -1.895	2.999 to 3.146	0.9927	$p<0.05$	A+
3	34	7.1-24.2 (13.2±0.76)	4.02-197.34 (38.89±6.2)	0.0104	3.0672	-2.094 to -1.871	2.966 to 3.168	0.9917	$p<0.05$	A+
Overall	167	7.1-28.5 (14.99±0.3)	4.02-264.31 (56.34±3.9)	0.0090	3.115	-2.107 to -1.966	3.057 to 3.174	0.993	$p<0.05$	A+

N=sample size, *L*=total length (cm), *W*=total weight (g), *a*=intercept, *b*=slope, *Cl*=confidence intervals, r^2=coefficient of determination, *GT*=growth type, *A+*=positive allometric

Discussion

This study reveals density, biomass and LWR of brown trout in the Tortumkale Stream. The LWR were studied to give information on the growth condition of fish and to find out whether the fish grows isometrically or allometrically (Tesch 1971). According to sampling period, the lowest mean density and biomass values were observed during August 2012 with 106 fish ha^{-1} and 6.38 kg ha^{-1} whilst the highest mean density and biomass values were observed during March 2013 with 167 fish ha^{-1} and 10.64 kg ha^{-1}. Water temperature is the most important factor that influences on population parameters ($\widehat{N}_i$ and $\widehat{B}$). The reason for the decrease in total fish density and biomass during the sampling period can be explained by seasonal changes occurred in the water temperature.

The LWR exponent b values for all the species were within the limits (2-4) reported by (Tesch 1971; Bagenal and Tesch 1978) for most fishes. The LWR exponent *b* values ranged from 3.06 to 3.31. Exponent *b* was very close to values cited in the literature, 2.828 to 3.027 in Ceyhan, Seyhan and Euphrates Basins by Alp and Kara (2004), 2.89 to 3.04 in Kan Stream, Çoruh Basin by Arslan et al. (2004), 2.971 to 3.009 in Fırnız Stream by Alp et al. (2005), 2.997 to 3.106 in West Karadeniz Basin by Gülle et al. (2007), 3.008 to 3.166 in Coruh Basin by Özvarol et al. (2010) and 2.93 to 3.07 in Upper Coruh River by Yıldırım et al. (2012). However, quite different estimations were also noted. Kocaman et al. (2004) calculated the exponent for brown trout as 2.590 in Teke Stream (Erzurum). In Hatila Brook by Ölmez et al. (1998), in Aksu Stream by Arslan et al. (2007), in Uzungöl Stream by Kocabaş et al. (2011; 2012) and Munzur River by Başusta et al. (2013) reported values of 2.9056, 2.932, 2.788 to 2.949, 2.919 and 2.87 for brown trout which are much closer to the result obtained in the current study.

The *b* value has been shown to vary according to season, habitat, gonad development, sex, diet, feeding, stomach fullness, and spawning period

(Bagenal and Tesch 1978). In addition, changes in the *b* value result from several other factors such as sampling time and method, differences in length between the caught species, weight distribution and the ecological status of their habitat (Moutopoulos and Stergiou 2002).

The brown trout density and biomass in the Tortumkale Stream are > 19 to 612 fish ha^{-1} and 0.52 to 56.23 kg. ha^{-1} in Hatila Brook by Korkmaz et al. (1998), 1000 to 2000 fish ha^{-1} and 23.04 to 27.04 kg. ha^{-1} in Lima River by Maia and Valente (1999), 914.8 fish ha^{-1} and 61.258 kg. ha^{-1} in Veleka River by Dikov and Zikov (2004), 28 fish ha^{-1} and 2.55 kg. ha^{-1} in Kadıncık Brook by Korkmaz (2005), 108 to 608 fish ha^{-1} and 2.77 to 26.77 kg. ha^{-1} in some Bulgarian Rivers by Kolev (2010) and 630 fish ha^{-1} and 21.73 kg. ha^{-1} in Bunayska River by Kolev (2012). However, values of the brown trout density and biomass range from 1163.48 to 3135.08 fish ha^{-1} and 67.26 to 208.22 kg. ha^{-1} in Gallo River by Almodovar and Nicola (1998), 6076 fish ha^{-1} and 278.6 kg. ha^{-1} in Úpoř Brook by Vlach et.al. (2005) and 2580 fish ha^{-1} and 100.15 kg. ha^{-1} in river basins of Cagliari province by Zanetti et.al. (2010) were higher than our results.

These differences can be said to be caused by the fact that selective fishing or catch efficiency. The variable catch efficiency is not only dependent on the characteristics and habits of fish populations but also on factors related to the design and implementation of the sampling and on the physical, chemical and environmental characteristics of the habitat (Bravo et al. 1999).

The results of this study concerning the density, biomass and length-weight relationship of the brown trout population will not only assist fishery biologists in the sustainable management of this species, but also contribute to the introduction preventive measures for the preservation of stocks, and provide a baseline for future studies.

This study found that the density of the brown trout population in Tortumkale Stream is at a level indicating a risk of extinction of this species. The main causes were the wastewater from the surrounding trout farms, rainbow trouts escaping from farm and overfishing. Other factors contributing to the destruction of the habitat of brown trout are considered to be the destruction of breeding areas due to the ongoing construction of a dam in the area; contamination from domestic, industrial and agricultural waste; and changes in the water regime throughout the year. Native brown trout is an ecological and economic asset and is among the significant gene sources of Turkey. We believe that relevant institutions and organizations should implement strict regulations to preserve this species.

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