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Growth and Mortality of the Brown Trout (*Salmo trutta* L.) Population from Upper Aksu Stream, Northeastern Anatolia, Turkey

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Abstract: Age, sex, mortality, and growth characteristics of brown trout (*Salmo trutta*) from the upper Aksu Stream were investigated. Females and males comprised 52.13% and 47.87% of the population, respectively. Age ranged from 1 to 8. The fork length (L) and total weight (W) were 5.7-22.8 cm and 2.9-142.6 g, respectively. Length-weight relationships were $W = 0.015 \times L^{2.939}$, $W = 0.015 \times L^{2.928}$, and $W = 0.015 \times L^{2.932}$ for females, males, and overall, respectively. The estimated von Bertalanffy growth parameters were $L_\infty = 33.27$ cm, $K = 0.107$ y^{-1}, and $t_0 = -1.046$ y for females; $L_\infty = 29.50$ cm, $K = 0.143$ y^{-1}, and $t_0 = -0.562$ y for males; and $L_\infty = 32.13$ cm, $K = 0.124$ y^{-1}, and $t_0 = -0.724$ y for overall. Phi prime (Φ`) was 2.09 for females, males, and overall. Instantaneous total mortality rate (Z) was 0.58 y^{-1}.

Key Words: *Salmo trutta*, northeastern Anatolia, Çoruh River, age, growth, mortality

Kuzey Doğu Anadolu Yukarı Aksu Çayı Alabalık, *Salmo trutta* L. Populasyonunda Büyüme ve Ölüm Oranları

Özet: Yukarı Aksu Çayı'nda yaşayan alabalıkların (*Salmo trutta*) yaş, boy, cinsiyet, büyüme ve ölüm oranları incelenmiştir. Dişi ve erkekler populasyonun sırasıyla % 52,13 ve % 47,87'sini olusturmuştur. Yaş 1-8 arasında tespit edilmiştir. Çatal boy (L) ve toplam ağırlık (W) 5,7-22,8 cm ve 2,9-142,6 g arasında değişim göstermiştir. Boy-ağırlık ilişkisi dişi, erkek ve tüm populasyon için sırasıyla $W = 0{,}015 \times L^{2{,}939}$, $W = 0{,}015 \times L^{2{,}928}$ ve $W = 0{,}015 \times L^{2{,}932}$ olarak hesaplanmıştır. Von Bertalanffy büyüme parametreleri dişiler için; $L_\infty = 33{,}27$ cm, $K = 0{,}107$ $yıl^{-1}$, $t_0 = -1{,}046$ yıl, erkeler için; $L_\infty = 29{,}50$ cm, $K = 0{,}143$ $yıl^{-1}$, $t_0 = -0{,}562$ yıl ve tüm populasyon için; $L_\infty = 32{,}13$ cm, $K = 0{,}124$ $yıl^{-1}$, $t_0 = -0{,}724$ yıl olarak tespit edilmiştir. Fi Üssü (Φ`) dişiler, erkeler ve tüm bireyler için 2,09 olarak hesaplanmıştır. Anlık toplam ölüm oranı 0,58 $yıl^{-1}$ olarak tespit edilmiştir.

Anahtar Sözcükler: *Salmo trutta*, Doğuanadolu, Çoruh Nehri, yaş, büyüme, ölüm oranı

Introduction

The brown trout, *Salmo trutta* L., which is distributed naturally across Europe including Turkish fresh waters (Geldiay and Balık, 1996), was introduced successfully into at least 24 countries outside Europe over a span of less than 90 years (1852-1938), and the status of brown trout changed from that of a European species to that of a global species (Elliot, 1994). This species is exploited wherever it is distributed, and as a renewable resource it has importance for sport and commercial fishing, and aquaculture at the international level (Baglinière and Maisse, 1999).

Although many factors can affect the growth of brown trout, it is generally agreed that water temperature, fish size, and level of food intake are the 3 most important variables. It is well known that brown trout, which can be described as opportunistic feeders, demonstrate considerable variation in growth and size between individuals and among populations, depending on the above factors (Klemetsen et al., 2003). Reproduction has more priority than growth in brown trout as well as the other Salmonids, which seems to be a weakness of their life cycle (Elliot, 1994).

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Structure, growth (Tabak et al., 2001; Arslan, 2003; Alp et al., 2005), reproduction (Alp et al., 2003; Arslan, 2003), and mortality (Alp et al., 2003; Arslan, 2003) of brown trout from different parts of Turkish fresh waters have been disclosed recently. Arslan (2003), using exploitation rate as the determining factor, described brown trout from the Anuri and Cenker streams as a highly exploited fish. A number of other authors have also documented the decline in brown trout populations in Turkey, blaming heavy fishing pressure including illegal destructive methods, water pollution, and the degradation of spawning areas (Karatas, 1999; Alp et al., 2003; Arslan, 2003).

The current investigation focuses on the brown trout of Aksu Stream, northeastern Anatolia. Age class structure, sex ratio, growth, and mortality rate were determined in the upper part of the stream.

Materials and Methods

This study was carried out at the upper part of Aksu Stream, Çoruh River, in northeastern Turkey (Figure 1). The stream originates from the Seven Lakes system of the Kaçkar Mountains at an elevation of 3000 m and drains 40 km into the Çoruh River at an elevation of 900 m. The sampling site was a 1.5-km-long part of the upper stream with an elevation of 2800-2900 m. In the study area, the stream is characterized by a high velocity (2 m s^{-1}), abundant oxygen (12.5 mg l^{-1}), and low temperature (13 °C max. in summer). The water stays frozen from November through March. The narrow stream bed is composed of large boulders, which form water falls, rapids, and small ponds. Stream width is 2 m and depth is 30 cm. There is no woody vegetation. The stream is fed from a lake.

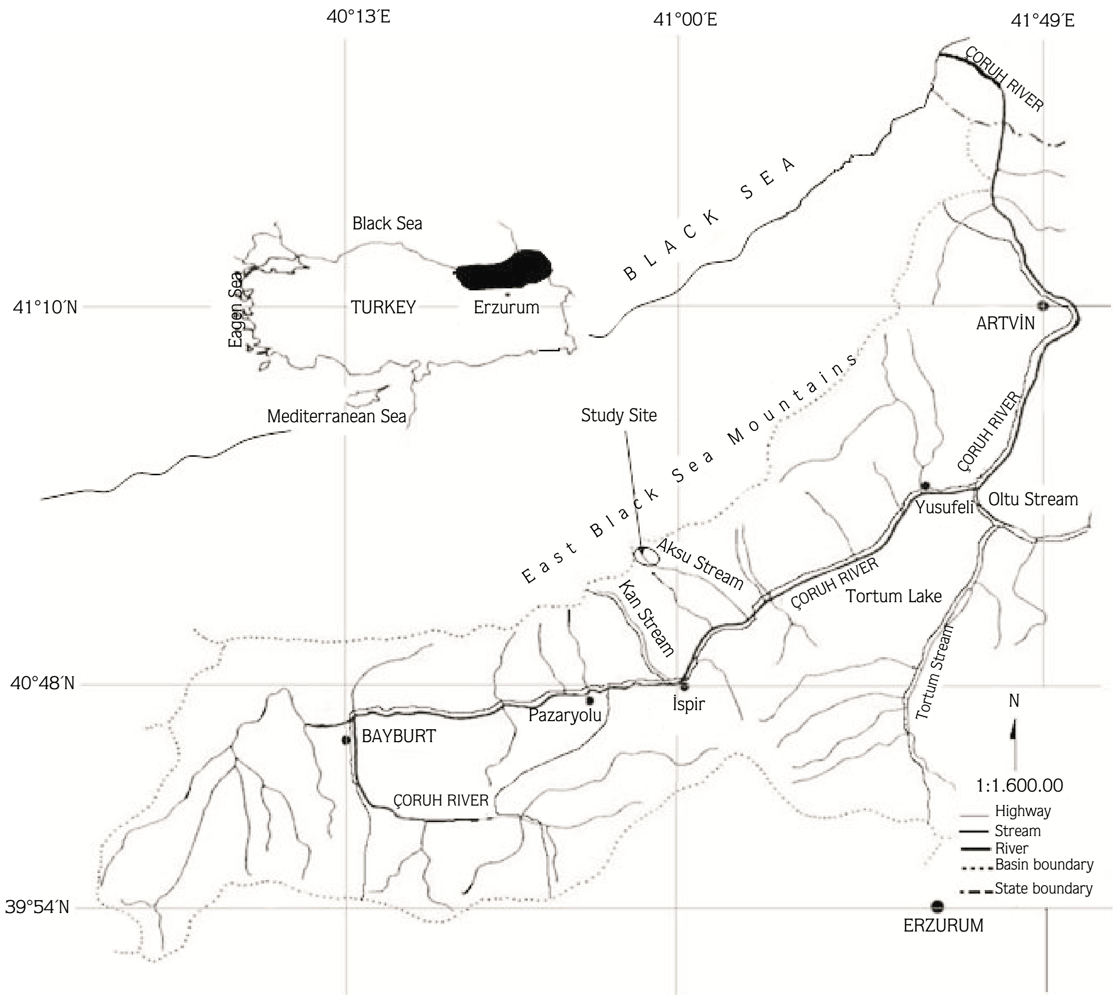

Figure 1. The study area.

A total of 163 fish were collected during summer (June-August) 2002 from Aksu Stream using electroshock equipment (ENDRESS ES 650, 220 V AC, 12 V DC). After sampling, the fish were placed on ice and transferred to the laboratory. All samples were thawed, rinsed, and blotted dry. They were then measured to the nearest millimeter and weighed to the nearest gram prior to dissection. Fork length was considered length of the fish in all cases.

Sex was determined by examining the gonads under the microscope. Age was determined using otoliths (Dervies and Frie, 1996).

The length-weight relationship, $W = aL^b$ was transformed into its logarithmic expression: LogW = Loga + bLogL. The parameters *a* and *b* were calculated by least-squares regression for males, females, and the overall population (Ricker, 1975).

Growth in length was expressed by the von Bertalanffy equation, $L_t = L_\infty (1 - e^{-K(t-t_0)})$, where L_∞ is the asymptotic length (cm), L_t is the length at age *t*, *K* is the growth coefficient determining how fast the fish approaches the asymptotic length, and t_o is the theoretical age when the length of the fish is zero (Ricker, 1975). The specific growth rate was calculated by the formula: $Log_eL_n - Log_eL_{n-1}$, where L_n is the average length (cm) at age n and L_{n-1} is the average length (cm) at age *n – 1* (Ricker, 1975). Phi prime *(Φ`)* was calculated by the formula: $\Phi` = LogK + 2LogL_\infty$, where *K* is the growth coefficient and L_∞ is the asymptotic length (cm) (Pauly and Munro, 1984).

Estimates of the instantaneous rate of total mortality *(Z)* were obtained using the age-based catch-curve method (Ricker, 1975).

Analysis of covariance (ANCOVA) was used to determine the effects of sex on the weight-length relationship. The chi-square test was used to compare sex ratios. The t test was performed to evaluate the difference of the *b* slope of length-weight relationship from 3 (Erkoyuncu, 1995). Statistically significant differences were considered at $P < 0.05$.

Results

The age and length distributions of brown trout from Aksu Stream were determined from a sample taken in 2002 of 163 fish: 78 males and 85 females (Table 1). The overall ratio of males to females was 1:1.09 with no significant differences between the sexes in terms of fish numbers according to the chi-square test ($P > 0.05$). The size of the fish ranged from 5.7 to 22.8 cm, and the dominant length class was 11.0 cm. This comprised 14.7% of the sample. Moreover, of the fish sampled 97.5% were shorter than 20 cm (Table 1). Age varied from 1 to 8, and the dominant age group was determined to be 3 years old, comprising 34.4% of the fish. The majority of the samples (90.2%) were composed of individuals ranging in age from 1 to 5. The mass of the fish varied from 2.9 to 142.6 g and weights at the various ages are provided in Table 1.

The relationship between fork length and total weight for females, males, and overall were $W = 0.015 \times L^{2.939}$, $W = 0.015 \times L^{2.928}$, and $W = 0.015 \times L^{2.932}$, respectively (Figure 2). There was no statistically significant difference between the weight-length relationships of males and females (ANCOVA, $P > 0.05$), with negative allometric growth indicated by a *b* value significantly lower than 3 (t test, $P < 0.05$).

The longest and heaviest male was 21.8 cm and 138.0 g, and the longest and heaviest female fish was 22.8 cm and 142.6 g, respectively. The highest specific growth rate was determined to be 0.48 and 0.33 for males and females, respectively, between the ages of 1 and 2. Specific growth rates decreased with increasing age (Table 1).

The von Bertalanffy growth parameters were L_∞ = 33.27 cm, K = 0.11 y^{-1}, and t_o = –1.046 y for females; L_∞ = 29.50 cm, K = 0.14 y^{-1}, and t_o = –0.562 y for males; and L_∞ = 32.13 cm, K = 0.12 y^{-1}, and t_o = –0.724 y for overall. Φ` was 2.09 for males, females, and pooled data (chi-square test, $P > 0.05$).

The relationships between lengths at age data (observed lengths) and von Bertalanffy growth curves (expected lengths) are plotted in Figure 3. Observed and expected values were not significantly different from each other for males, females, or the overall samples.

The instantaneous total mortality *(Z)* was calculated as 0.58 for the brown trout sampled from Aksu Stream (Figure 4).

Table 1. Age-length frequency data for males, females and all individuals (L: length; W: weight; SE: standard error).

Length classes (cm)	Age classes (year)								Total
	1	2	3	4	5	6	7	8	
male									
5	1								1
6									
7		1							1
8		7							7
9		10	1						11
10		2	6						8
11		1	11	1					13
12			5	1					6
13			2	2					4
14			1	8					9
15				1	3	1			5
16				1	3		2		6
17					1	2			3
18					1	1			2
19									
20					1				1
21							1		1
22									
N	1	21	26	14	9	4	3		78
$\bar{L} \pm$ SE (cm)	5.70	9.18 ± 0.18	11.57 ± 0.21	14.12 ± 0.33	16.84 ± 0.49	17.15 ± 0.75	18.03 ± 1.89		
Specific growth (G)		0.48	0.23	0.20	0.18	0.02	0.05		
$\bar{W} \pm$ SE (g)	2.90	10.52 ± 0.68	20.09 ± 1.20	37.52 ± 2.53	63.54 ± 6.43	64.64 ± 7.32	83.67 ± 27.17		
female									
5									
6	1								1
7	2								2
8		5	1						6
9		9							9
10		5	6						11
11			11						11
12			8	1					9
13			2	6					8
14			1	3					4
15			1	3	1	1			6
16				2	2				4
17				1	3	1			5
18				1	1	1			3
19									
20						1	1	1	3
21							1	1	2
22								1	1
N	3	19	30	17	7	4	2	3	85
$\bar{L} \pm$ SE (cm)	6.97 ± 0.28	9.36 ± 0.17	11.76 ± 0.24	14.79 ± 0.41	16.94 ± 0.35	18.23 ± 1.02	20.70 ± 0.30	21.73 ± 0.61	
Specific growth (G)		0.33	0.23	0.22	0.15	0.05	0.08		
$\bar{W} \pm$ SE (g)	4.24 ± 0.33	10.6 ± 0.59	21.14 ± 1.16	41.67 ± 3.45	62.45 ± 4.31	73.36 ± 12.65	80.20 ± 8.60	122.07 ± 15.89	

Table 1. (Contunued).

Length classes (cm)	Age classes (year)								Total
	1	2	3	4	5	6	7	8	
overall									
5	1								1
6	1								1
7	2	1							3
8		12	1						13
9		19	1						20
10		7	12						19
11		1	22	1					24
12			13	2					15
13			4	8					12
14			2	11					13
15			1	4	4	2			11
16				3	5		2		10
17				1	4	3			8
18				1	2	2			5
19									0
20					1	1	1	1	4
21							2	1	3
22								1	1
N	4	40	56	31	16	8	5	3	163
± SE (cm)	6.65 ± 0.38	9.26 ± 0.13	11.67 ± 0.16	14.49 ± 0.27	16.89 ± 0.31	17.69 ± 0.62	19.10 ± 1.23	21.73 ± 0.61	
Specific growth (G)		0.30	0.25	0.23	0.14	0.07	0.13		
± SE (g)	3.91 ± 0.41	10.56 ± 0.45	20.65 ± 0.83	39.80 ± 2.21	63.06 ± 3.96	69.00 ± 6.97	82.28 ± 15.15	122.07 ± 15.89	

Discussion

The occurrences of male and female brown trout from Aksu Stream were not significantly different ($P > 0.05$) as in some other populations (Jonsson and Sanlund, 1979; Lobon-Cervia et al., 1986; Haugen and Rygg, 1996; Alp et al., 2003; Arslan, 2003). This situation is normally expected for most fish populations (Nikolsky, 1963).

Individuals sampled from Aksu Stream ranged from 1 to 8 in terms of age. At 6 years and up, there were 7 males and 9 females. Age-class ranges for brown trout from different studies have been reported to be 0-4 (McFadden and Cooper, 1962), 0-5 (Lobon-Cervia et al., 1986; Crisp and Beaumont, 1996), 0-6 (Aras, 1974; Hesthagen et al., 2004), 0-7 (Jonsson and Sandlund, 1979; Arslan, 2003), 0-10 (Hesthagen et al., 1999; Alp et al., 2003) and 0-12 (Haugen and Rygg, 1996). However, Svalastog (1991) reported a 38-year-old brown trout from Norway. Maximum longevity and age in fish are affected by their genetics, food intake, water temperature, floodplain, and fishing activities (Elliott, 1994; Crisp, 2000). Although one fish from Cenker Stream, Coruh Basin, where the present study was conducted, was reported in our early studies to be 10 years old (Arslan et al., 2000), Aksu Stream seems to support a proportionally longer lifespan than other populations in the same basin. This may result from non-commercial fishing activity in Aksu Stream and rugged geography, which makes the area difficult to access. On the other hand, because of the connection to the lake, older fish may move into the lake for feeding after staying for a certain period of their lives in Aksu Stream.

Lengths varied from 5.7 to 22.8 cm. Size of brown trout in terms of their age in Aksu Stream are contrasted with other habitats. In general, size distribution in the present study is lower than those

Table 2. Average length at age and b values in length-weight relationship for brown trout from different habitats.

Author (s)	Study area	Mean lengths of age classes										b values
		0	1	2	3	4	5	6	7	8	9	
Campbell, 1971	Loch Lanish	8.7	21.2	36.1	43.1	50.2	57.1	63				
	L. Carn a Chuillin	4.5	13	25.8	34.4	40	44					
	Loch Rannoch	5.7	12.6	19.8	24.8	28.8	31.8	37.8	46	58.8	62.1	
	Loch Einich	3.6	9.2	14.6	18.7	20.9	24.2	28	31.0	36.5		
	Dubh Lochainn of Beinn A`Bhuird, Scotland	3.5	7.1	9.4	11.1	13.1	14.5	14.8				
Papageorgou et al., 1983/1984	Aspropotamos Stream, Greece	7.6	11.7	14.8	17	18.7	20.5	21.2	22.6			2.95
Jonsson, 1985	Voss River, Norway	6.7	14	18.1	22	24						2.688
			14.8	21	23.1	25						
Lobon-Cervia et al., 1986	River Ucero		11	20.1	27.8	34.2	39.5					
	River Avion-Milanos, Spain		9.3	18.7	25.3	31.8						
Swales, 1986	Upland Reservoir, England	6.8	10.1	20.4	27.5							2.696
Yanar et al., 1987	Hodacu Stream, Turkey											2.996
Yıldırım, 1991	Barhal Stream, Turkey											3.00
Bembo et al., 1993	Grwne Tributary		6.5	12.6	18.6							
	Main River		6.2	11.9	18.9							
	Menascin Tributary		6.4	11.8	18.2							
	Main River		6.4	12.2	21.3							
	Senni Tributary		6.7	11.7	18.1							
	Main River, UK		6.3	11.8	20.7							
Crisp and Beaumont, 1996	Wye, England	2.8	7.9	11.2	14.7	17	18.6					
Hesthagen et al., 1999	Sub-Alpine Reservoir, Norway			13.7	18.5	21.6	25.1	28.1	31.1			
Çetinkaya, 1999	Çatak Stream, Turkey		9.3	11.9	14.4	16.7	18.8		33.5	39		3.07
Tabak et al., 2001	East Black Sea streams, Turkey	11.6	14.6	20.2	27.7	36.2						3.035
Arslan, 2003	Anuri Stream	6.8	10.3	13.7	16.2	18.8	23.7	27.1				3.037
	Cenker Stream, Turkey	6.2	10.1	13.3	16.1	18.9	22.2	24.9	30.3			3.000
Hesthagen et al., 2004	Sulbalpine Norwegian River -Section-1	3.5	7.6	12.4	15.3	19.5	22.2	22.9				
	Section-2, Norway	4.3	7.8	11.1	14.3	16.9			27.8			
Present study	Aksu Stream, Turkey	6.7	9.3	11.7	14.5	16.9	17.7	19.1	21.7			2.932

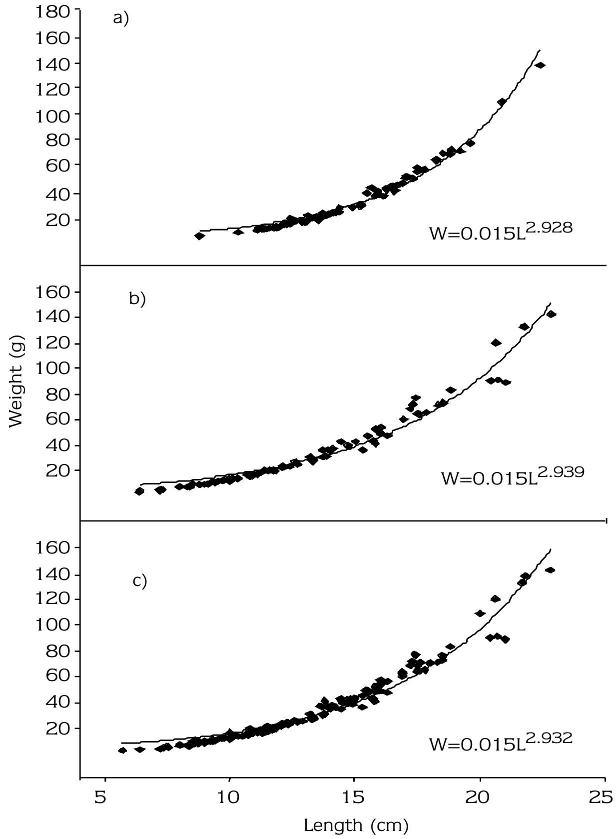

Figure 2. Length-weight relationships for male (a), female (b), and overall (c).

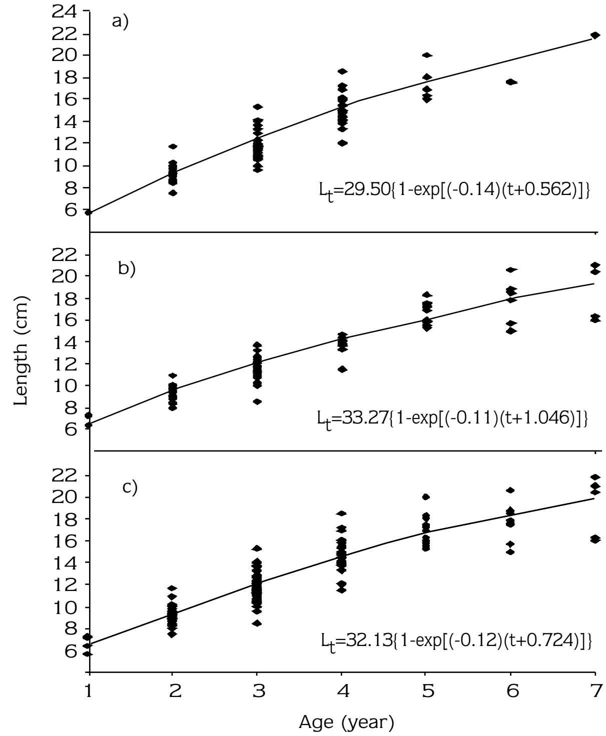

Figure 3. Length at age data (von Bertalanffy growth slopes) for male (a), female (b), and overall (c).

Table 3. Von Bertalanffy growth parameters and phi prime for brown trout from different habitats.

Author	Study area	L_∞ (cm)	K (year^{-1})	Φ`
Crisp and Beaumont, 1995	Afon Dyfi, UK	21.6	0.34	2.20
Crisp et al., 1974	Cow Green Stream, England	39.0	0.15	2.36
Crisp et al., 1975	Trout Beck, England	21.5	0.20	1.97
Crisp and Beaumont, 1996	Wye and Severn Rivers, UK	21.5	0.34	2.20
Crisp and Cubby, 1978	Knock Ore Gill, England	30.8	0.22	2.32
Arslan et al., 2000	Cenker Stream, Turkey	36.88	0.15	2.31
Tabak et al., 2001	East Black Sea Streams, Turkey	40.52	0.27	2.65
Hesthagen et al., 1999	Sub-Alpine Reservoir, Norway	39.1	0.21	2.51
Haugen and Rygg, 1996	Norwegian Reservoir, Norway	42.8	0.29	2.73
Crisp and Beaumont, 1996	Wye, UK	21.4	0.34	2.19
Lobon-Cervia et al., 1986	River Ucero	65.94	0.18	2.89
	River Avion-Milanos, Spain	64.04	0.18	2.87
Arslan, 2003	Anuri Stream, Turkey	36.94	0.13	2.25
	Cenker Stream, Turkey	38.41	0.13	2.28
Present study	Aksu Stream, Turkey	32.13	0.12	2.09

from some others (Papageorgou et al., 1983/1984; Jonsson, 1985; Lobon-Cervia et al., 1986; Swales, 1986; Crisp and Beaumont, 1996; Hesthagen et al., 1999; Çetinkaya, 1999; Tabak et al., 2001; Arslan, 2003; Hesthagen et al., 2004). Age group 1 brown trout from the River Usk (Bembo et al., 1993) and from Aksu Stream have similar length values. From the literature reviewed, Dubh Lochainn of Beinn A`Bhuird (Campbell, 1971) is the only location whose brown trout has a similar size distribution within all age classes (Table 2). This variation, which depends primarily on water temperature and food availability, may be considered a characteristic of brown trout (Klemetsen et al., 2003). The proportionally lower size of brown trout in the present study can be attributed to the low temperature at the study site, which is characterized by its high elevation and snow cover, and, therefore, to low feeding activity. Comparison of the parameters of the von Bertalanffy growth equation to the literature (Table 3) shows that in Aksu Stream the brown trout has moderate L_∞ and lower K, indicating a slower growth rate. Females had higher L_∞ than males but lower K, indicating that males grow faster and reach a smaller size. This may be attributed to the genetic differences related to the duration of attaining sexual maturity between the sexes.

Considering both L_∞ and K, growth can also be judged by Φ`, which in the present study is intermediate among the other data reported in the literature (Table 3).

The *b* values of length-weight relationships were calculated as 2.939, 2.928, and 2.932 for males, females, and overall, respectively. While there was no significant difference between the sexes in terms of the length-weight relationships, *b* values significantly lower than 3 ($P < 0.05$) indicated negative allometric growth. In comparison to the literature, brown trout from Aksu Stream had an intermediate *b* value (Table 2). Geographic location and associated environmental conditions, such as water temperature, which is the determining factor of feeding capacity, seasonality (date and time of capture), stomach fullness, disease, and parasite loads, can affect the value of *b* (Bagenal and Tesch, 1978).

The instantaneous rate of total mortality was determined to be 0.58 for brown trout from Aksu Stream. This value is much lower than those obtained from other sites in the same basin (Arslan, 2003). This may be attributed to the lower fishing activity in comparison to the other locations in the same basin. The Z values of the Aksu brown trout were lower than those reported by Jonsson and Sandlund (1979), Lobon-Cervia et al. (1986), Hesthagen et al. (1999), and Hesthagen et al. (2004), but similar to those by Papageorgou et al. (1983/84), Crisp and Beaumont (1996), and Alp et al. (2003). In comparison with the other populations, the Aksu brown trout has a proportionally lower Z value than average (Table 4).

Consequently, the brown trout from the upper part of the Aksu Stream may not be considered under high fishing pressure, which may be inferred from the low mortality rate in comparison to the other populations in the same basin. Fish over 22 cm, which are not recorded in this study, seem to move to the connected lake to have a better habitat. Regarding the same age classes, fish from Aksu Stream are smaller than those from the other streams in the same basin. Proportionally, the growth rate is lower in Aksu brown trout. These factors and the low *b* value (negative allometry) in the length-weight relationship may be attributed to the habitat features, characterized by low temperature, high water velocity, low pond structure along the stream bed, and low vegetation, resulting in low habitat complexity and food availability as well as a short feeding season.

Acknowledgments

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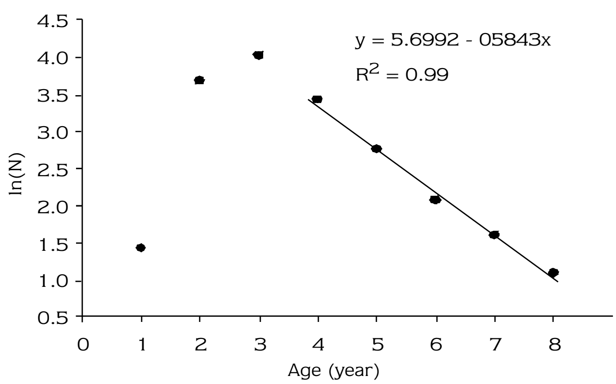

Figure 4. Instantaneous mortality of brown trout from Aksu Stream.

Table 4. Age range and instantaneous rate of total mortality for brown trout from different habitats.

Literature cited	Location	Age Range	Total Mortality
	Cedar Run	0-4	0.36[2]
	Spring Creek	0-4	0.71[2]
McFadden and Cooper, 1962	Spruce Creek	0-7	0.47[2]
	Young Woman's Creek	0-4	0.26[2]
	Kettle Creek	0-4	0.72[2]
	Shaver Creek, United States	0-8	0.362[2]
Aras, 1974	Different streams in Çoruh and Aras River, Turkey	1-6	
	Sqre in Sqre Osa River system	1-6	0.9507[1]
Jonsson and Sandlund, 1979	Qestre	1-6	1.1255[1]
	Vestra, Norway	1-6	1.9251[1]
Papageorgou et al., 1983/84	Aspropotamos Stream, Greece	0-8	0.5933[1]
Lobon-Cervia et al., 1986	River Ucero	1-5	1.5413[1]
	River Avion-Milanos, Spain	1-4	0.9076[1]
Crisp and Beaumont, 1996	Wye River, England	0-5	0.5861[1]
Haugen and Rygg, 1996	Norwegian Reservoir, Norway	1-12	
Hesthagen et al., 1999	Sub-Alpine Reservoir, Norway	1-8	0.8267[1]
Arslan et al., 2000	Cenker Stream, Turkey	1-10	
Alp et al., 2003	A Tributary of Ceyhan River, Turkey	1-9	0.5698[1]
Hesthagen et al., 2004	Sulbalpine River Section-1	0-6	0.6544[1]
	Sulbalpine River Section-2, Norway	0-7	0.9326[1]
Arslan, 2003	Anuri Stream, Turkey	0-6	0.9559
	Cenker Stream, Turkey	0-7	0.7395
Present study	Aksu Stream, Turkey	0-8	0.5834

[1] Authors calculated values of total mortality using age-frequency values.
[2] Authors calculated values of instantaneous rate of total mortality using annual rates of survival values.

References

Aras, M.S. 1974. Çoruh ve Aras Havzası Alabalıkları Üzerine Biyo-Ekolojik Araştırmalar. Doktora tezi. Atatürk Üniversitesi, Erzurum, 81 pp.

Arslan, M. Aras, N.M. and Yıldırım, A. 2000. Cenker Çayı (Çoruh Havzası)'nda yaşayan *Salmo trutta labrax* (Pallas, 1811)'ın populasyon yapısı ve büyüme özellikleri. Su Ürünleri Sempozyumu 20-22 Eylül 2000 Sinop, pp. 266-278.

Arslan, M. 2003. Çoruh Havzası Anuri ve Cenker çaylarında yaşayan alabalık, *Salmo trutta* Linneaus 1766, populasyonları üzerine araştırmalar. Doktora tezi, Atatürk Universitesi, Erzurum, 141 pp.

Alp, A., Kara, C. and Büyükçapar, M. 2003. Reproductive biology of brown trout, *Salmo trutta macrostigma* Dumeril 1858, in a tributary of the Ceyhan River which flows into the eastern Mediterranean Sea. Journal of Applied Ichthyology 19: 346-351.

Alp, A., Kara, C. and Büyükçapar, H.M. 2005. Age, growth and diet composition of the resident brown trout, *Salmo trutta macrostigma* Dumeril 1858, in Fırnız Stream of the River Ceyhan, Turkey. Turk. J. Vet. Anim. Sci. 29: 285-295.

Baglinière, J.C. and Maisse, G. 1999. Biology and Ecology of the Brown and Sea Trout. Springer-Praxis Series in Aquaculture and Fisheries, Heidelberg.

Bagenal, T.B. and Tesch, F.W. 1978. Age and growth. In: Methods for Assessment of Fish Population in Fresh Waters (ed. T.B. Bagenel), Blackwell Scientific, London, pp 101-136.

Bembo, D.G., Beverton, R.J.H., Weightman A.J. and Cresswell, R.C. 1993. Distribution, growth and movement of River Usk brown trout (*Salmo trutta*). Journal of Fish Biology 43: 45-52.

Campbell, R.N. 1971. The growth of brown trout *Salmo trutta* L. in northern Scottish lochs with special reference to the improvement of fisheries. Journal of Biology 3: 1-28.

Crisp, D.T., Mann, R.H.K. and McCormark, J.C. 1974. The poulations of fish at Cow Green, upper Teesdale, before impoundment. Journal of Applied Ecology 11: 969-996.

Crisp, D.T., Mann, R.H.K. and McCormark, J.C. 1975. The population of fish in the River Tee system on the Moor House National Nature Reserve, Westmorland. J. Fish Biology 7: 573-593.

Crisp, D.T. and Cubby, P.R. 1978. The population of fish in tributaries of the River Eden on the Moor House National Nature Reserve, Northern England. Hydrobiologia 57: 85-93.

Crisp, D.T. and Beaumont, W.R.C. 1995. Trout (*Salmo trutta*) population of the Afon Cwm, a small tributary of the Afon Dyfi, Mid-Wales. J. Fish Biology 46: 703-716.

Crisp, D.T. and Beamount, W.R.C. 1996. The trout (*Salmo trutta* L.) populations of the Rivers Severn and Wye, mid-Wales, UK. The Science of the Total Environment 177: 113-123.

Crisp, D.T. 2000. Trout and Salmon Ecology, Conservation and Rehabilitation, Blackwell Science, Oxford.

Çetinkaya, O. 1999. Çatak Çayı (Dicle Nehri) Dağ Alabalıklarının (*Salmo trutta macrostigma*, Dum., 1858) bazı biyolojik özelliklerinin incelenmesi. Istanbul Üniversitesi, Su Ürünleri Fakültesi Dergisi 9: 111-122.

Dervies, D.R and Frie, R.V. 1996. Determination of age and growth. In: Fisheries Techniques. (ed. B.R. Murphy and D.W. Willis), American Fisheries Society, Bethesda, Maryland, pp 483-508.

Elliott, J.M. 1975. The growth rate of brown trout (*Salmo trutta* L.) fed on reduced rations. J. Animal Ecology 44: 823-842.

Elliot, J.M. 1994. Quantitative Ecology and the Brown Trout, Oxford University Press, Oxford.

Erkoyuncu, I. 1995. Balıkçılık Biyolojisi ve Populasyon Dinamiği, Ondokuz Mayıs Üniversitesi Yayınları No. 95, Sinop.

Geldiay, R. and Balık, S. 1996. Türkiye Tatlısu Balıkları, Ege Üniversitesi Basımevi, İzmir.

Haugen, T.O. and Rygg, T.A. 1996. Intra- and interspecific life history differences in sympatric grayling and brown trout in a Norwegian reservoir. Journal of Fish Biology 48: 964-978.

Hesthagen, T., Fløystad, L., Hegge, O., Staurnes, M. and Skurdal, J. 1999. Comparative life-history characteristics of native and hatchery-reared brown trout, *Salmo trutta,* in a sub-Alpine reservoir. Fisheries Management and Ecology 6: 47-61.

Hesthagen, T., Forseth, T., Hegge, O., Saksgård, R. and Skurdal, J. 2004. Annual variability in the life-history characteristics of brown trout (*Salmo trutta* L.) in a subalpine Norwegian lake. Hydrobiologia 521: 177-186.

Jonsson, B. and Sandlund, O.T. 1979. Environmental factors and life histories of isolated river stocks of brown trout (*Salmo trutta* m. *fario*) Søre river system, Norway. Env. Biol. Fish 4: 43-54.

Jonsson, B. 1985. Life history patterns of freshwater resident and sea-run migrant brown trout in Norway. Tr. Am. Fish. Soc. 114: 182-194.

Karataş, M. 1999. Age at sexual maturity, spawning time, sex ratio, fecundity of population of trouts (*Salmo trutta* L.) inhabiting in the Tifi brook (Tokat-Turkey). Symposium Development and Growth of Fishes. 5-8 July, 1999, St. Andrews, Scotland.

Klemetsen, A., Amundsen, P.-A., Dempson, J.B., Jonsson, B., Jonsson, N., O'Connell, M.F. and Mortensen, E. 2003. Atlantic salmon *Salmo salar* L., brown trout *Salmo trutta* L., and Arctic charr *Salvelinus alpinus* (L.): a review of aspects of their life histories. Ecology of Freshwater Fish 12: 1-59.

Lobon-Cervia, J., Montañés, C.M. and Sostoa, A. 1986. Reproductive ecology and growth of a population of brown trout (*Salmo trutta* L.) in an aquifer-fed stream of Castile (Spain). Hydrobiologia 135: 81-94.

McFadden, J.T. and Cooper, E.L. 1962. An ecological comparison of six populations of brown trout (*Salmo trutta*). Tr. Am. Fish. Soc. 91: 53-62.

Nikolsky, G.W. 1963. The Ecology of Fishes (Translated by L. Birkett). Academic Press, London and New York.

Papageorgiou, N., Neophitou, C.N. and Vlachos, C.G. 1983/84. The age, growth and reproduction of brown trout (*Salmo trutta fario*) in the Aspropotamos stream. Acta Hydrobiol. 25/2: 451-467.

Pauly, D. and Munro, J.L. 1984. Once more on the comparison of growth in fish and invertebrates. ICLARM, Fishbyte, 2: pp 21.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board.

Svalastog, D. 1991. A note on maximum age of brown trout, *Salmo trutta* L. Journal of Fish Biology 38: 967-968.

Swales, S. 1986. Population dynamics, production and angling catch of brown trout, *Salmo trutta*, in a mature upland reservoir in mid-Wales. Environ. Biol. Fish. 16:279-293.

Tabak, İ., Aksungur, M., Zengin, M., Yılmaz, C., Aksungur, N., Alkan, A., Zengin, B. and Mısır, S. 2001. Karadeniz Alabalığı (*Salmo trutta labrax* Pallas, 1811)'nın Biyoekolojik Özelliklerinin Tespiti ve Kültüre Alınabilirliğinin Araştırılması. Proje sonuc raporu. Su Ürünleri Merkez Araştırma Enstitüsü, Trabzon.

Yanar, M., Akyurt, İ. and Bircan, R. 1987. *Salmo trutta* L.'nın gonada gelişimi, yumurta verimliliği, büyüme durumu ve et verim özellikleri üzerine bir araştırma. Et ve Balık Endüstrisi Dergisi 8: 3-12.

Yıldırım, A. 1991. Barhal Havzası alabalıklarının (*Salmo trutta labrax*, Pallas 1811) biyo-ekolojisi üzerine araştırmalar. Y. Lisans tezi, Atatürk Üniversitesi, Erzurum, 45 pp.