Turk J Zool
31 (2007) 185-192

Structure and Reproductive Characteristics of Two Brown Trout (*Salmo trutta*) Populations in the Çoruh River Basin, North-eastern Anatolia, Turkey

Murat ARSLAN[1]*,•, N. Mevlüt ARAS[2]

[1]Department of Fisheries and Aquaculture, İspir H. Polat Vocational School, Atatürk University, 25900 İspir, Erzurum - TURKEY

[2]Department of Fisheries and Aquaculture, Faculty of Agriculture, Atatürk University, 25640 Erzurum - TURKEY

Received: 28.02.2006

Abstract: The reproductive characteristics of 2 brown trout (*Salmo trutta*) populations were examined in 2 tributaries, the Anuri and Cenker streams, of the Çoruh River, north-eastern Turkey. Sampling was carried out by electrofishing monthly from November 2000 to October 2002. Age varied from 0 to 6 in the Anuri Stream, and from 0 to 7 in the Cenker Stream. Fork length (L) ranges were 4.29-29.9 cm and 3.7-34.4 cm for the Anuri and Cenker streams, respectively. The majority of individuals from both populations were smaller than 20 cm. While age and length at first maturity in males and females were 1.99 and 3.19 years, and 14.1 and 17.2 cm for the Anuri Stream, they were 1.99 and 3.22 years, and 14.0 and 17.3 cm for the Cenker Stream, respectively. Fecundity (F) was higher ($P < 0.05$) in the Cenker Stream (392 ± 46) than in the Anuri Stream (308 ± 27). Significant relationships were found between fecundity and length and weight for both populations ($P < 0.05$). Spawning took place in September and October in both populations.

Key Words: Brown trout (*Salmo trutta*), north-eastern Anatolia, reproductive characteristics

Kuzeydoğu Anadolu Çoruh Nehri Havzasındaki İki Alabalık (*Salmo trutta*) Populasyonunun Yapısı ve Üreme Özellikleri

Özet: Çoruh Havzasının iki önemli kolu olan Anuri ve Cenker çaylarında yaşayan kahverengi alabalıkların, *Salmo trutta*, yaş, boy, eşey ve üreme özellikleri incelenmiştir. Balıklar Kasım 2000-Ekim 2002 tarihleri arasında aylık olarak elektroşok yöntemi ile toplanmıştır. Anuri Çayı'nda yaş 0-6 arasında değişirken, Cenker Çayı'nda 0-7 arasında olduğu, çatal boy dağılımının (L) Anuri Çayı'nda 4,29-29,9 cm, Cenker Çayı'nda ise 3,7-34,4 cm arasında gerçekleştiği tespit edilmiştir. Her iki populasyonun çoğunluğunu 20 cm'den küçük bireyler oluşturmuştur. İlk eşeysel olgunluk yaşı ve boyu Anuri ve Cenker çaylarında dişi ve erkekler için sırasıyla 1,99; 3,19 yıl ve 14,1; 17,2 cm, 1,99; 3,22 yıl ve 14,0; 17,3 cm olarak hesaplanmıştır. Her iki populasyonda da fekondite (F) ile boy ve ağırlık arasında önemli ilişkiler tespit edilmiştir ($P < 0,05$). Fekondite Cenker Çayı'nda (392 ± 46) Anuri Çayı'ndan (308 ± 27) daha yüksek bulunmuştur ($P < 0,05$). Üreme her iki populasyonda da Eylül-Ekim aylarında gerçekleşmistir.

Anahtar Sözcükler: Kahverengi alabalık (*Salmo trutta*), Kuzeydoğu Anadolu, üreme özellikleri

Introduction

The brown trout (*Salmo trutta*) is a native salmonid species of Eurasia and North Africa (Elliot, 1994). It is very well accepted that the brown trout is the only species among salmonid fishes in Turkish waters (Kuru, 1975; Geldiay and Balık, 1996). Brown trout populations inhabiting Turkish waters have been depleted because of water pollution, land use practices, introduction of non-native fishes and overexploitation (Karataş, 1999). The studies on this species are still limited in Turkey and they are mostly concentrated on morphometric characteristics and population structure (Geldiay, 1968; Aras, 1974; Yanar et al., 1987; Bardakçı et al., 1994; Çetinkaya, 1999) with a few recent studies about reproduction characteristics (Karataş, 1997, 1999; Tabak et al., 2001; Alp et al., 2003).

* E-mail: muratars@atauni.edu.tr
• Current address: School of Environment and Natural Resources, The Ohio State University, Columbus, OH 43210, USA. E-mail: arslan.7@osu.edu

It has been well established that fish should be allowed to reproduce at least once in their life span. A fish must allocate time and resources to reproduction to be present genetically in the next generation (Wootton, 1998). These facts make the determination of age and length at first maturity for fish very important for the regulation and maintenance of fish populations.

The aims of this study were (1) to investigate the current population structure such as age, sex and length distribution, and (2) to determine the reproductive biology of the brown trout, using spawning time, fecundity, and length and age at first maturity in the Anuri and Cenker streams, 2 tributaries of the Çoruh River, north-eastern Turkey.

Materials and Methods

This study was carried out in the Anuri and Cenker streams, 2 important tributaries of the Çoruh River, located in north-eastern Turkey (Figure 1). Both streams originate in the Kaçkar Mountains. The Cenker Stream, with a high altitude reaching 2700 m above sea level, runs throughout a sharp and narrow valley, and forms a high waterfall downstream. The stream bed is composed of boulders. The width and depth varied from 2 to 4.5 m and from 10 to 60 cm, respectively. Water temperature fluctuated between 1 and 20 °C and water flow changed between 0.3 and 2 $m^3 s^{-1}$ during the study period. In summer, water is used permanently for agriculture in remote villages. Water continues to flow although the pools favourable for trout become limited.

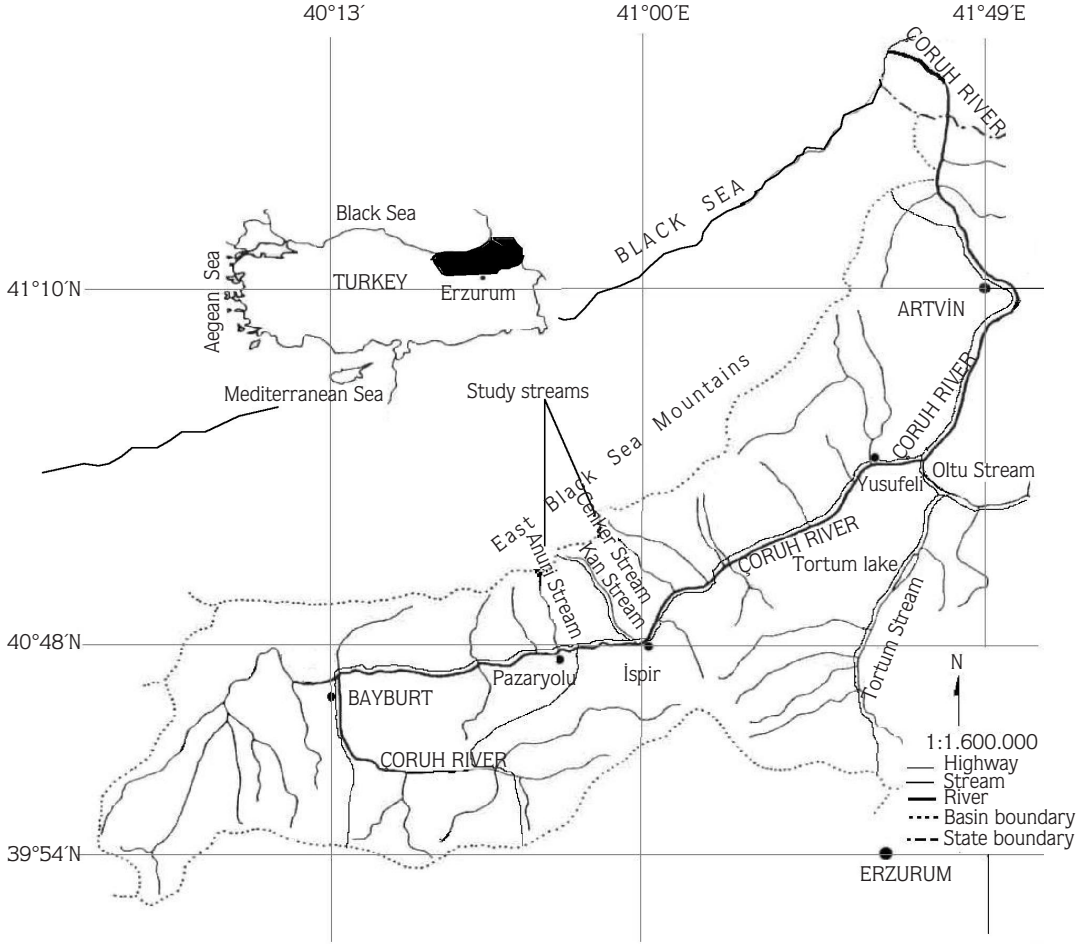

Figure 1. The study area.

The Anuri Stream, rising 2500 m above sea level, has 3 small villages along its course. During the study period, the water flow fluctuated between 0.5 and 3 $m^3 s^{-1}$. Depth and width varied from 2.5 to 5 m and from 10 to 70 cm, respectively. Water temperature was similar to that in the Cenker Stream (1-20 °C). While woody vegetations are rare in the Cenker Stream, they are abundant in this stream basin. Moreover, in comparison to the Cenker Stream, there were more pools and riffles here. The water of the stream is used for agricultural production near the stream.

Both streams are characterised by large seasonal fluctuations in discharge, level and temperature of water, and food supply. The streams are covered with ice in winter and so sampling was not possible during this season (December, January, and February). Because of the heavy rain and melting glacier, short-term turbidity occurred in spring in 2001 and 2002. *S. trutta* is the only species present in both streams.

Over the study period, from November 2000 to October 2002, 713 brown trout in the Cenker Stream and 956 in the Anuri Stream were examined. Fish were sampled monthly by electrofishing (ENDRESS ES 650, 240 V AC and 12 V DC) from November 2000 to October 2002. Fish were transferred to the laboratory in a chilled container, then measured (fork length) to the nearest millimetre and weighed to the nearest gram. Age was determined using the otoliths. Sex was determined by examining the gonads under a microscope. Gonads from mature fish were removed and weighed to the nearest 0.1 g. The ovaries were fixed in Gilson solution before to determine fecundity (Avşar, 1998). The number of eggs per female (fecundity, F) was determined by counting the eggs from the mature fish not spawned just before the spawning period. Relationships between fecundity and fork length and total weight were determined from the equations: $F = aL^b$; $F = a + bW$, where F is the number of eggs as fecundity, L is the fork length (cm), W is the total weight (g), and a and b are the constant parameters in the regression analysis (Wootton, 1998).

Gonadosomatic index (GSI) was calculated monthly to investigate the reproductive cycle by the formula GSI = 100 Gw/W, where G_W is the gonad weight (g) and W is the total weight (g) (Wootton, 1998).

Age and length at first maturity were determined according to the logistic regression model using the following formulas; $P=1/(1+e^{[-r(t-t_m)]})$ and $P=1/(1+e^{[-r(L-L_m)]})$ where P is the rate (%) of the mature fish in each age and length group, L is the mean value (cm) of each length group, Lm is the smallest length (cm) of the mature fish comprising at least 50% of total fish in this length, t is the age group, tm is the earliest age (year) of the mature fish comprising at least 50% of the total fish in this age, and r is the curve of the logistic function (King, 1996).

A chi-squared test was used to compare the sex ratio. An independent t test was used to compare fecundities of the 2 populations. Seasonal variation in the GSI was tested by one-way ANOVA and Duncan's multiple comparison test. Percentage data were subjected to arc sinus transformation prior to the statistical analyses (Yıldız and Bircan, 1994). Statistically significance was set at $P < 0.05$.

Results

Age ranged between 0 and 6 in the Anuri Stream while it varied between 0 and 7 in the Cenker Stream. The group of age 1 was dominant in both populations (49.58% and 33.24% in the Anuri and Cenker streams, respectively). Of the 713 individuals examined in the Cenker Stream, 341 were males and 352 were females. The ratio of males to females was 0.97:1. In Anuri, the numbers of males and females were 448 and 477, respectively, in 956 samples, and the ratio of males to females was 0.94:1 (Figure 2). The numbers of males and females were not significantly different in the Anuri and Cenker streams ($P > 0.05$). The fork length of the fish ranged from 4.9 to 29.9 cm in the Anuri Stream and from 3.7 to 34.4 cm in Cenker (Figure 3). Of the fish from the Anuri Stream, 94.97% were composed of individuals smaller than 20 cm. In the Cenker Stream, this proportion was 87.80%.

Age and length at first maturity were 1.99 and 3.19 years, and 14.1 and 17.2 cm for the Anuri Stream, while they were 1.99 and 3.22 years, and 14.0 and 17.3 cm for the Cenker Stream in males and females, respectively. Maturity rate showed logistic regression with age and length in all cases (Figure 4).

Monthly changes in the GSI values of the brown trout for each sex in the Anuri and Cenker streams are shown in Figure 5. The GSI in female brown trout ranged

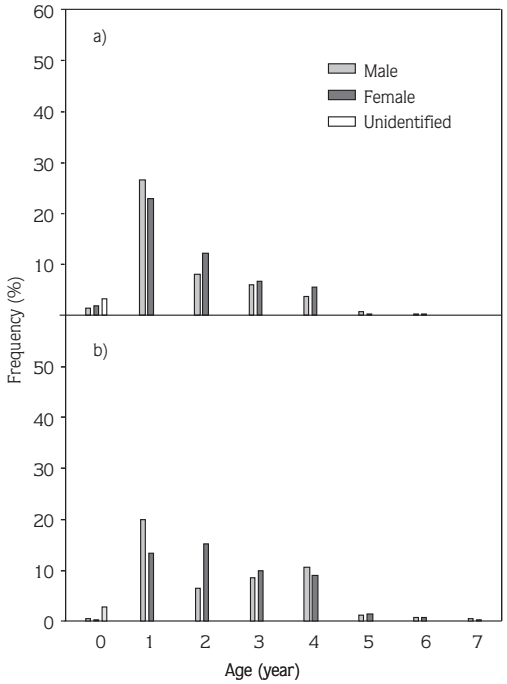

Figure 2. Age distribution of brown trout from the Anuri (a) and Cenker (b) streams.

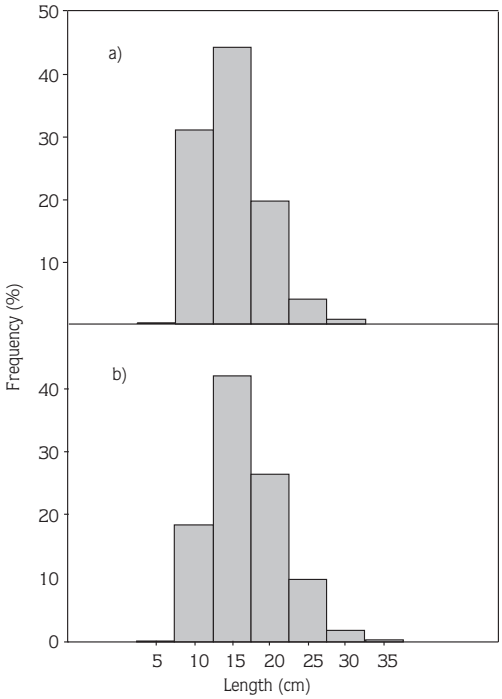

Figure 3. Length distribution of brown trout from the Anuri (a) and Cenker (b) streams.

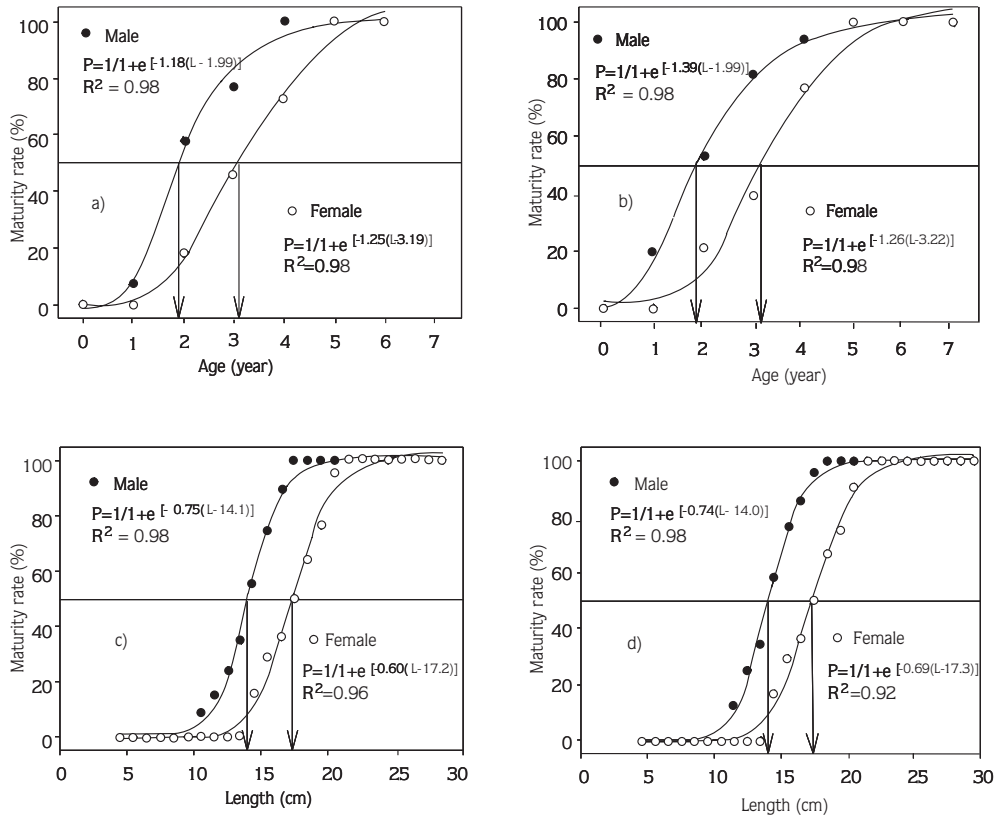

Figure 4. Age and length at first maturity of brown trout for each sex from the Anuri (a and c) and Cenker (b and d) streams, respectively.

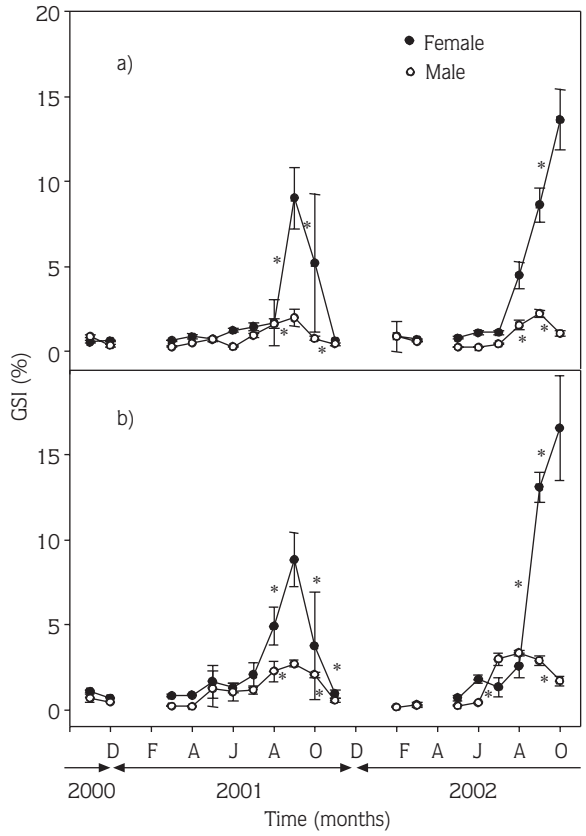

Figure 5. Gonadosomatic index cycle of brown trout over the study period for the Anuri (a) and Cenker (b) streams. Data are presented mean ± SE. * indicates statistically significant differences between adjacent points at P < 0.05 from Duncan's test.

between 0.58 and 13.66, and 0.35 and 12.25 in the Anuri and Cenker streams, respectively. Monthly GSI values varied significantly over the study period in the Anuri (P < 0.05) and Cenker (P < 0.05) streams. Monthly GSI values were significantly higher (P < 0.05) during the reproduction seasons than those in the rest of the years (Figure 5). The maximum GSI values in females were in September for the first year and in October for the second year of the study period in both streams, whereas the minimum values were in November 2000 for the Anuri Stream and in March 2002 for the Cenker Stream. In November 2000 and 2001, there were no females with eggs, indicating that the spawning activity lasted until November in both streams.

In the Anuri Stream, fecundity varied from 106 to 669 with a mean of 308 ± 27 in 25 females, whereas it ranged from 67 to 1250 with the mean of 392 ± 46 in 27 females in the Cenker Stream (Table). Mean fecundity was significantly higher in the Cenker Stream than in the Anuri Stream (P < 0.05). While a linear relationship was found between fecundity and total weight, there was a non-linear relationship between fecundity and fork length in both populations (Figure 6).

Discussion

In the 2 streams of the Çoruh River, the brown trout showed significant between-site differences in age and length frequency, and fecundity.

Table. Fecundity of brown trout in different ages from the Anuri and Cenker streams.

Age	Fecundity (mean ± SE)			
	N	Anuri Stream	N	Cenker Stream
2	2	174 ± 62	1	260
3	9	267 ± 24	10	251 ± 122
4	12	318 ± 36	14	426 ± 49
5	2	572 ± 97	1	632
6	-	-	-	-
7	-		1	1250
Total	25	308 ± 27	27	392 ± 46

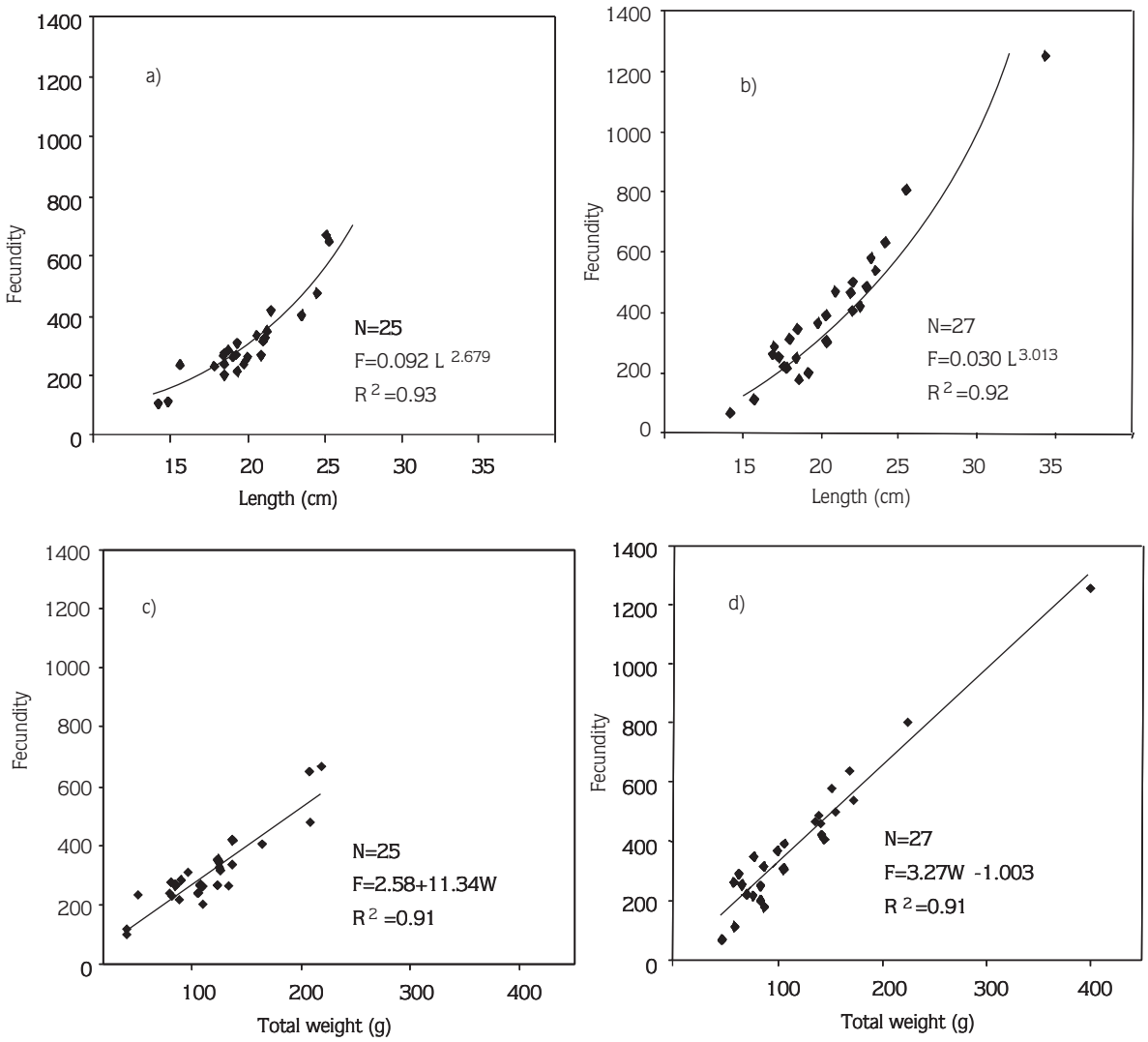

Figure 6. Relationship between fecundity-length, and fecundity-weight of brown trout from the Anuri (a and c) and Cenker (b and d) streams, respectively.

The sex ratios as males to females were 0.94:1 and 0.97:1 in the Anuri and the Cenker streams, respectively, indicating no significant differences in the numbers of males and females in both streams. In closed populations, the ratio of males to females is expected to be 1:1 (Nikolsky, 1963).

The sex ratios of males to females for brown trout in some of the Turkish inland waters were reported as 1:0.41 in the Çatak Stream (Çetinkaya, 1999), 0.49:1 in the Ataköy Dam Lake (Karataş, 1997), and 0.67:1 in the Fırnız Stream (Alp et al., 2003).

The majority of the fish from both populations comprised individuals smaller than 20 cm and the proportions of these samples were 94.97% in the Anuri Stream and 87.80% in the Cenker Stream, suggesting that overfishing occurred in both streams. Some early studies mentioned the problem of heavy fishing for this species in Turkish inland waters (Geldiay, 1968; Aras, 1974).

Brown trout generally varied in age between 0 and 7 years (Geldiay, 1968; Yıldırım, 1991; Karataş, 1997) in Turkish inland waters with some records higher than 7 years (Çetinkaya, 1999; Alp et al., 2003). However, in

Norway, one 38-year-old brown trout was recorded (Svalastog, 1991). In the present study, age distributions were 0-6 years in the Anuri Stream and 0-7 years in the Cenker Stream, which is consistent with the general pattern of brown trout populations in Turkish inland waters.

Male and female brown trout attained maturity at the age of 1.99 and 3.19, and when they were 14.1 and 17.2 cm in the Anuri Stream while those in the Cenker Stream reached maturity at the age of 1.99 and 3.22 when they were 14.0 and 17.3 cm length, respectively. Geldiay and Balık (1996) reported that the age at first maturity of brown trout inhabiting Turkish waters was between 2 and 4, and there have been some studies reporting age and size at first maturity of this species in different locations in Turkey. The smallest maturity size for brown trout was reported as 15.7 cm in the Hodaçu Stream (Yanar et al., 1987) and as 14.1 cm at the age of 2 in the Barhal Stream (Yıldırım, 1991), ages at first maturity for males and females were reported as 3 and 4 in the Ataköy Dam Lake, respectively (Karataş, 1997), and the smallest male and female brown trout attained maturity were 17.4 and 17.8 cm, respectively, in the Fırnız Stream (Alp et al., 2003). Similar to the present results, the minimum size and age at first maturity for brown trout were reported as 10.5-11.0 cm and 1+, respectively, in Spain (Lobon-Cervia et al., 1997).

In Turkey, the spawning time for brown trout was reported as January-March in the Ataköy Dam Lake (Karataş, 1997), January-March in the Tifi Stream (Karataş, 1999), November-December in some streams such as the Kapsitre, Çağlayan, Fırtına, İyidere, and Solaklı streams in the eastern Black Sea region (Tabak et al., 2001), and November-January in the Fırnız Stream (Alp et al., 2003). However, in the present study, this period was determined to be September-October for both populations, possibly caused by different environmental conditions like water temperature and food availability.

Fecundities were 308 ± 27 and 392 ± 46 per individual in the Anuri and Cenker streams, respectively, with a significant difference between the 2 populations ($P < 0.05$). A significant relationship was found between fish size and the number of eggs produced in the brown trout of both streams. Nicola and Almodóvar (2002) also found significant relationships between size and fecundity in brown trout populations in Spain. They also determined significant differences among fecundities of populations resulting from interpopulation variations in body length. Another record indicated that trout length was the major determinant of fecundity (Lobon-Cervia et al., 1997). The number of eggs can also vary with the environmental changes like food supply and other biotic and abiotic factors (Erkoyuncu, 1995). Although the Anuri Stream seems more favourable for trout than Cenker, the result that brown trout in this stream produced more eggs than those from Anuri can be attributed to the differences in fish length (Figure 5). The number of eggs produced by brown trout was reported as 2000-5000 per kg (Geldiay and Balık, 1996). Çetinkaya (1999) calculated the fecundity as 2340 per individual in the Çatak Stream; egg number was determined as 3230 per kg of brown trout in the Hodaçu Stream (Yanar et al., 1987), as 3113 in the Ataköy Dam Lake (Karataş, 1997), as 2810 in the Tifi Stream (Karataş, 1999), and as 3099 in the Fırnız Stream (Alp et al., 2003). In the present study, the number of eggs per kg of fish weight can be presented as 2730 and 3225 for the Anuri and Cenker streams, respectively. Fecundity per kg of fish weight demonstrated similarity with the other brown trout populations from Turkish fresh waters.

In conclusion, the majority of fish from both the Anuri and Cenker streams were younger and smaller than the age and size at first maturity, indicating that both populations are in danger along with the other brown trout populations inhabiting Turkish fresh waters. Further studies should be focused on conservation, management, and restocking.

Acknowledgements

This project was supported by Atatürk University Research Foundation. The authors wish to express their thanks to Dr. Ayhan Yıldırım for his assistance during the field work.

References

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

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.

Avşar, D. 1998. Balıkçılık Biyolojisi ve Populasyon Dinamiği, Baki Kitap ve Yayinevi, Adana.

Bardakçı, F., Tanyolaç J. and Akpınar M.A. 1994. Morphological comparison of trout (*Salmo trutta* L., 1766) populations caught from a Sivas stream. Turk. J. Zool. 18: 1-6.

Çetinkaya, O. 1999. Çatak Çayı (Dicle Nehri) Dağ Alabalıklarının (*Salmo trutta macrostigma*, Dum., 1858) Bazı Biyolojik Özelliklerinin İncelenmesi. Istanbul Üniversitesi, Su Ürünleri Fakültesi Dergisi. 9: 111-122.

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

Erkoyuncu, İ. 1995. Balıkçılık Biyolojisi ve Populasyon Dinamiği, Ondokuz Mayıs Üniversitesi. Sinop Su ürünleri Fakültesi, Sinop.

Geldiay, R. 1968. Kazdağı Silsilesi derelerinde yaşayan alabalık (*Salmo trutta* L.) populasyonları hakkında. VI. Milli Türk Biyoloji Kongresi, 15-21 Ağustos 1968 İzmir, pp. 65-77.

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

Karataş, M. 1997. Ataköy baraj gölünde (Tokat) yaşayan alabalıkların (*Salmo trutta* L.) üreme özelliklerinin incelenmesi. Turk. J. Vet. Anim. Sci. 21: 439-444.

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) (Oral presentation). Symposium Development and Growth of Fishes 5-8 July, 1999. St. Andrews, Scotland.

King, M. 1996. Fisheries Biology, Assessment and Management. Fishing News Books, Malden, MA.

Kuru, M. 1975. Dicle-Fırat, Kura-Aras, Van Gölü ve Karadeniz Havzası tatlı sularında yaşayan balıkların (Pisces) sistematik ve zoocoğrafik yönden incelenmeleri. Doçentlik Tezi, Atatürk Üniversitesi, Erzurum, 180 pp.

Lobon-Cervia, J., Utrilla, C.G., Rincon, P.A. and Amezcua F. 1997. Environmentally induced spatio-temporal variations in the fecundity of brown trout *Salmo trutta* L.: trade-offs between egg size and number. Freshwater Biology 38: 277-288.

Nicola, G.G. and Almodóvar, A. 2002. Reproductive traits of stream-dwelling brown trout *Salmo trutta* in contrasting neighboring rivers of central Spain. Freshwater Biology. 47: 1353-1365.

Nikolsky, G.W. 1963. The Ecology of Fishes, Academic Press, London.

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

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, Trabzon, 203 pp.

Wootton, R.J. 1998. Ecology of Teleost Fishes, Kluwer Academic Publishers, Dordrecht.

Yanar, M., Akyurt, İ. and Bircan, R. 1987. *Salmo trutta* L.'nın gonad gelişimi, yumurta verimliliği, büyüme durumu ve et verim özellikleri üzerine bir araştırma. E. B. K. 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, 44 s.

Yıldız, N. and Bircan, H. 1994. Uygulamalı İstatistik. Atatürk Üniversitesi Yayınları No: 704, Erzurum.