

Biology of *Chondrostoma fahirae* (Ladiges, 1960) (Actinopterygii: Cyprinidae), an Endangered and Endemic Fish of Turkey

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Abstract: The population structure of *Chondrostoma fahirae* (Ladiges, 1960) was studied based on 85 specimens. Males made up 60.0% (51) and females 40.0% (34) of the population. The length-weight relationship and Von Bertalanffy growth equation were estimated as $W = 0.019 \times L^{3.0761}$ $r = 0.983$, $L_t = 15.62(1 - e^{-0.17(t+3.06)})$, respectively. *Gammarus pulex*, aquatic insects and Ochrophyta are the major food resources for *C. fahirae*. Water abstraction and agricultural pollution has led to the near extirpation of the species at its type locality Başpınar Spring.

Key words: *Chondrostoma fahirae*, Anatolia, endangered species, fish biology

Introduction

The genus *Chondrostoma* Agassiz, 1832 is reported throughout South and Central Europe, from the Atlantic to the Caspian Sea, from the Mediterranean to the Baltic Seas (KOTTELAT & FREYHOF 2007). The genus is also distributed in Asia Minor, the Caucasus and Mesopotamia (ELVIRA 1997, DURAND et al. 2003). It comprises of 27 species according to the studies based on osteological and morphological characters (BOGUTSKAYA 1997, DURAND et al. 2003, ELVIRA 1997, ROBALO et al. 2007). According to the most recent faunal inventories, 13 of these species are distributed in Turkish inland waters (FREYHOF & ÖZULUĞ 2009, KÜÇÜK et al. 2013, 2017, ÇIÇEK et al. 2015). *Chondrostoma fahirae* has been included in the IUCN Red List (Version 2017.3) as Endangered B2ab (i, ii, iii, iv, v) (EN). The species is known from the Başpınar Spring (type locality) in the Karamusa Village near Tefenni County, Karamanlı Reservoir and Değirmendere Stream (SW Turkey). The spe-

cies had been assigned to the genus *Pseudophoxinus* Bleeker, 1860 but was moved to *Chondrostoma* without detailed morphological study (FREYHOF & ÖZULUĞ 2009). FREYHOF & ÖZULUĞ (2009) justified that with the lack of keratin layer in the lower jaw and because it was sharp and well ahead of rostral cap. GEIGER et al. (2014), in a molecular study (COI gene) of 498 freshwater fish species from 23 ecoregions of the Mediterranean, demonstrated that *C. fahirae* (Tefenni County – Burdur) was in a separate branch. Also, they stated the species was close to *Iberochondrostoma* Robalo, Almada, Levy & Doadrio, 2007, spread in the Iberian Peninsula. According to the revision of *Chondrostoma* in Turkey by KÜÇÜK et al. (2013) and ÇIFTÇI et al. (2015), *C. fahirae* has not the characteristics of *Chondrostoma*. This is also supported by the molecular features. Nevertheless, the current name of this species is *Chondrostoma fahirae*.

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In order to develop conservation strategies for *C. fahirae*, knowledge of life history traits of this species is important. The present study provides the first data on the life history traits of *C. fahirae* from the Başpınar Spring.

Materials and Methods

The Başpınar Spring (37°11'4.40''N – 29°45'20.72''E, 1225 m a.s.l.) is full of submerged vegetation but with clear, cold spring water. Environmental parameters are approximately stable throughout the year: water temperature 15.6°C, dissolved oxygen 9.26 mg/L, oxygen saturation 91.4%, pH 7.9, conductivity 570 µS/cm at 25°C, salinity 2‰. There is a small pond about 2 hectares in front of spring. It flows into the creek, which is 1 km in long with regulator in the north direction. It is further connected with the Dalaman Stream. Other fish species in the spring are *Cobiitis phrygica* Battalgazi, 1944 and *Oxynoemacheilus anatolicus* Erk'akan, Özeren & Nalbant, 2008.

Fish specimens were collected in 2015 using pulsed DC electrofishing and fixed in 10% formalin. The population structure of *C. fahirae* in the Başpınar Spring was studied on the basis of 85 fish individuals. Number of individuals of each sex, age and size composition, the relationship between fecundity and fish total length, body weight and gonad weight, the gonadosomatic index and egg diameter were explored. The gonadosomatic index (GSI) was calculated in order to determine the peak reproductive period of the sampled population, using the formula $GSI = (\text{Gonad weight} / \text{Total weight}) * 100$, where GW was the gonad weight and W, the total body weight of the fish (GIBSON & EZZI 1980). Gonad weight was determined from those females that had completed their egg development. Fecundity was estimated gravimetrically from the number of mature oocytes in mature females. The number of eggs per female

and egg diameters was determined from 1 g samples per female (weighed to the nearest 0.01 g). The eggs were taken from different parts of the gonads and diameters were measured by microscopic micrometer. The data were used to calculate total fecundity in relation to total length, body weight and gonad weight (BAGENAL & BRAUM 1978). The relation of weight to total length was established using the exponential regression equation $W = a TL^b$, where W was the body weight in g, TL the total length in cm, a and b the parameters to be established (RICKER 1975). The growth of the population of *C. fahirae* was estimated with the following von Bertalanffy growth equation: $L_t = L_\infty(1 - e^{-k(t-t_0)})$, where L_t was the total length in cm at age "t", L_∞ the average asymptotic length in cm, k the body growth coefficient, "t₀" the hypothetical age and "a" and "b" constants (KARA 1992). A study of the food uptake was carried by examination of the content of the digestive tract.

Results

The overall ratio of males to females in the studied population of *Chondrostoma fahirae* was 1.50:1.00 and χ^2 analysis showed this sex ratio was not significant ($P > 0.05$) (Table 1). The fish size and age classes (Table 2) demonstrated that the individuals of the age groups I, II, III and IV contained 94.41% of the population. The von Bertalanffy growth equation based on the present results (combined for both sexes) was $L_t = 15.62(1 - e^{-0.17(t+3.06)})$. The differences between observed and expected total lengths were not statistically significant in all age groups (t-test, $P > 0.05$). The growth performance index (Φ') was 1.61. The total length-weight relationships were calculated based on all *C. fahirae* samples (Fig. 2). The growth of *C. fahirae* in the Başpınar Spring was found to be isometric. The b values were often 3.0 and generally between 2.0 and 4.0.



Fig. 1. *Chondrostoma fahirae* (male, 121.45 mm SL), Spring Başpınar, Karamusa Village, Tefenni County, Burdur, Turkey.

The mean fecundity per individual and gr/gonad weight was 2942.66 ± 257.98 , 1130.34 ± 107.54 respectively. Fecundity-length, fecundity – body weight and fecundity – gonad weight relationships of *C. fahirae* (n=19) were described as $F = 2.9485 \times L^{0.16}$ ($r = 0.456$), $F = 0.8958 \times W^{0.4265}$ ($r = 0.3721$), $F = 0.0012 \times GW^{0.936}$ ($r = 0.3944$), respectively. The mean egg (ripe) diameter was calculated as 1.22 ± 0.03 mm. The gonadosomatic index and ovary condition suggested that the reproductive season

of *C. fahirae* had a maximum GSI value (5.64) in May. Based on our observations, we found that eggs were adhesive and were attached to aquatic plants in small patches.

The seasonal analyses of the stomach content were presented as the percent distribution of organisms identified from the alimentary canal (Table 3). *Gammarus pulex*, aquatic insects and Ochrophyta were the major food resources for *C. fahirae*.

Table 1. Age and sex distribution of *C. fahirae*. Legend: N – number of samples, N% – percent of samples, F – females, M – males.

Age	Female		Male		Total		M:F
	N	N%	N	N%	N	N%	
0	-	-	5	5.88	5	5.88	5.00:0.00 (P<0.05)
I	3	3.53	18	21.18	21	24.71	6.00:1.00 (P<0.05)
II	3	3.53	13	15.29	16	18.82	4.33:1.00 (P<0.05)
III	13	15.30	10	11.76	23	27.06	0.76:1.00 (P<0.05)
IV	15	17.65	5	5.8	20	23.52	0.33:1.00 (P<0.05)
Total	34	40.00	51	60.00	85	100	1.50:1.00 (P>0.05)

Table 2. Size and age composition of females (F) and males (M) of *C. fahirae*, total length (TL) in mm.

Class size (mm)	0		I		II		III		IV		Σ
	F	M	F	M	F	M	F	M	F	M	
1		1									1
2		1		1							2
3		2	1	3							6
4		1	1	13	1	4		1			21
5			1	1	2	9	6	7	2	1	29
6							4	2	6	2	14
7							3		5	2	10
8									2		2
Σ	0	5	3	18	3	13	13	10	15	5	85

Table 3. Frequency of occurrence of seasonal diet items in the alimentary canal of *C. fahirae* (++++Very frequent, +++frequent, ++few, + rare)

Organisms	Winter	Spring	Summer	Autumn
Ochrophyta	++	+++	+	+
Chlorophyta	+	+	+	
Cyanophyta		+		
<i>Gammarus pulex</i> (Amphipoda)	++	++++	+++	++++
<i>Chironomus thummi</i> (Diptera larvae)		+	+	+
Ephemeroptera imago		++	+	
not identified Insect larvae		+	+++	++
Ostracoda		+	+	
Others				
Fish scale	+		+	+
Fish bones		+		
Fish egg			+	
Empty stomach	+		+	+

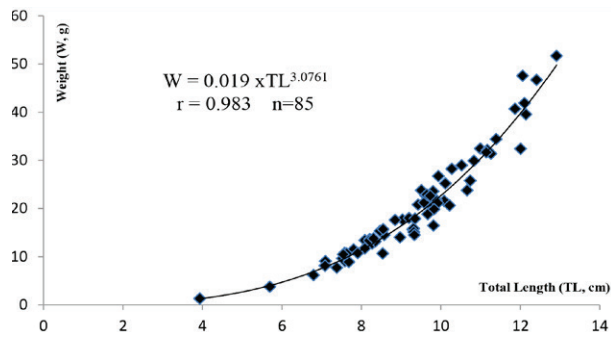


Fig. 2. Total length-weight relationships of *Chondrostoma fahirae*.

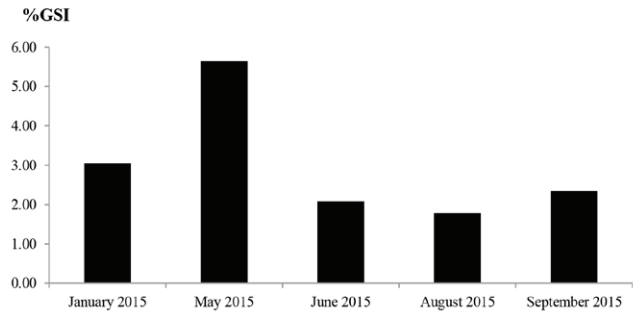


Fig. 3. Average gonadosomatic index (% GSI) of all sexes of *Chondrostoma fahirae*

Table 4. Comparison of growth parameters of *Chondrostoma* species in Turkey reported by different studies (Ref.: Reference, 1.ÇOBAN & ŞEN 2006; 2.YÜCE et al. 2015; 3. SAYLAR & YILMAZ 2014; 4. SUIÇMEZ et al. 2011; 5. ÖZCAN 2008a; 6. OYMAK 2000; 7. KARA & SOLAK 2004; 8. ERGÜDEN et al. 2010; 9. ÜNLÜ et al. 1990; 10. ŞEVİK 1997; 11. KALKAN & ERDEMLİ 2003; 12. ÖZCAN & ALTUN 2016; 13. ÖZCAN 2008b; 14. ÖZCAN & BALIK 2011; 15. ÖZCAN 2009; 16. SARI et al. 2003; 17. BALIK et al. 1992; 18. BALIK et al. 2007; 19. İLHAN et al. 2010; 20. KORKMAZ et al. 2017)

Species	Habitat	Ref.	n	Age	F:M	a	b	r	L_{∞}	t_0	k	\emptyset
<i>C.regium</i>	Keban Dam Lake	1	-	-	1.00:1.24	-	-	-	-	-	-	-
<i>C.regium</i>	Keban Dam Lake	2	294	1-8	1.00:0.79	0.00145	2.86	0.93	35.46	-1.74	0.260	2.52
<i>C.regium</i>	Ladik Lake	3	164	2-5	1.00:0.29	0.0029	3.41	0.98	28.15	-1.23	0.300	2.38
<i>C.regium</i>	Almus Dam Lake	4	359	1-6	1.00:0.66	0.0039	3.28	0.99	32.89	-1.57	0.230	2.40
<i>C.regium</i>	Hatay Prov.	5	128	-	-	0.001	3.28	0.84	-	-	-	-
<i>C.regium</i>	Atatürk Dam Lake	6	725	1-8	1.00:0.71	0.005	3.24	0.96	34.81	-2.95	0.169	2.31
<i>C.regium</i>	Sır Dam Lake	7	461	1-5	1.00:0.82	0.0092	3.07	0.91	31.98	-3.36	0.177	2.25
<i>C.regium</i>	Seyhan Dam Lake	8	164	1-5	1.00:0.83	0.0327	2.64	0.96	28.06	-1.86	0.244	2.28
<i>C.regium</i>	Savur Stream	9	289	1-6	1.00:0.53	0.0057	1.84	0.98	26.74	-3.21	0.510	2.56
<i>C.regium</i>	Fırat River	10	281	1-6	1.00:1.06	0.000008	3.04	-	-	-	-	-
<i>C.regium</i>	Karakaya Dam Lake	11	143	2-5	1.00:1.23	0.1953	2.12	-	37.28	-0.35	0.268	2.56
<i>C.kinzelbachi</i>	Gölbaşı Lake	12	33	-	-	0.011	2.76	0.98	-	-	-	-
<i>C.meandrense</i>	Kemer Dam Lake	13	86	-	0.005	3.22	0.95	-	-	-	-	-
<i>C.meandrense</i>	Kemer Dam Lake	14	135	2-6	1.00:0.42	0.030	2.70	0.98	23.20	-6.48	0.11	1.80
<i>C.meandrense</i>	Akçay Stream	15	307	1-6	1.00:0.62	-	-	-	-	-	-	-
<i>C.meandrense</i>	Işıklı Lake	16	674	2-5	1.00:2.51	0.0201	2.86	-	25.36	-1.85	0.241	2.19
<i>C.meandrense</i>	Bafa Lake	17	-	1-5	1.00:3.10	-	3.08	-	23.7	-	0.279	2.20
<i>C.meandrense</i>	Yayla Lake	18	-	1-5	1.00:1.73	-	2.65	-	19.6	-	0.588	2.35
<i>C.holmwoodii</i>	Tahtalı Dam Lake	19	1208	1-5	1.00:0.48	0.011	3.13	-	19.19	-3.26	0.177	2.18
<i>C.holmwoodii</i>	Tahtalı Dam Lake	20	215	0-5	-	-	3.04	-	39.5	-	0.17	2.42
<i>C. fahirae</i> (This Study)	Başpınar Spring		85	0-4	1.00:1.50	0.019	3.08	0.98	15.61	-3.06	0.17	1.61

Discussion

This is the first study on the biological features of *C. fahirae*. Its age varied: 0-IV years for 85 individuals. NIKOLSKY (1980) suggested that wide range of age distribution in a population could be an indication of sufficient food in the ecosystem. We found that males made up 60% and females 40% of the population. This result is similar to the ratio 1.00:1.00 that is recorded for a number of species (NIKOLSKY

1980). According to NIKOLSKY (1980), sex ratio varies considerably from species to species but in the majority of species it is close to one. Our results on age distribution and sex ratio are in accordance with the previous studies (see Table 4).

The L_{∞} value in the population of *C. fahirae* was similar to *C. meandrense* (ÖZCAN & BALIK 2011, BALIK et al. 2007) and *C. holmwoodii* (İLHAN

Table 5. Comparison of reproductive parameters of *Chondrostoma* species in Turkey reported by different studies (1. İLHAN et al. 2011; 2. ÖZCAN 2009; 3. ÇOBAN & ŞEN 2006; 4. OYMAK 2000; 5. KARA & SOLAK 2004; 6. BALIK et al. 1992; 7. MERMER & BALIK 1991)

Species	Habitat	Ref.	Egg diameter (min-max)	Fecundity (min-max)	Spawning period
<i>C. regium</i>	Keban Dam Lake	3	0.31-1.47	1904-16800	Feb.-June
<i>C. regium</i>	Atatürk Dam Lake	4	0.85-2.18	1680-13280	April-June
<i>C. regium</i>	Sır Dam Lake	5	-	-	April-July
<i>C. meandrense</i>	Bafa Lake	6	0.32-1.58	1330-24500	-
<i>C. meandrense</i>	Akçay Stream	2	0.77-1.50	4255-13760	March-May
<i>C. holmwoodii</i>	Gediz River	7	1.37-2.01	1463-2406	March-May
<i>C. holmwoodii</i>	Tahtalı Dam Lake	1	0.73-2.47	8000-41750	April-May
<i>C. fahirae</i> (This Study)	Başpınar Spring		0.43-1.38	1620-5279	May-June

et al. 2010), while it was very different from other studies. The von Bertalanffy growth parameters show that change from species to species, even for the same species. Growth may vary between different populations of the same species, but may also differ between different years of the same population living in the same geographical area. The \emptyset ' values of the current study were not statistically different from those of other studies (Table 4).

The length-weight relation of the population of *C. fahirae* was very different from the one for *C. meandrense* (ÖZCAN 2008a) but values were close to estimations by other studies (Table 4). The b values in fish vary according to species, sex, age, seasons and feeding. In addition, changes in fish shape, physiological conditions, different amounts of available food, life span or growth increment can all affect the b growth exponent (BAGENAL & TESCH 1978). The length-weight relation parameters reported for different *Chondrostoma* species in Turkey are compared in Table 4.

The egg diameter, fecundity values and spawning period reported for different *Chondrostoma* species in Turkey are presented in Table 5. One of the most important parameters used for determination of the reproductive potential is the variation of egg diameter in ovarian. The egg diameter is related to the amount of that females can metabolise (NIKOLSKY 1963). Fecundity is also affected by age, size, species, feeding of fish, season and environmental conditions (NIKOLSKY 1980). Spawning is intermittent. Such a longer breeding season is an adaptation of short-lived small fishes to environmental conditions (MILLER 1979). Our seasonal analysis of the stomach content has demonstrated that the studied population has been feeding well and mostly preferred benthic pray throughout the year.

Decline in rainfall due to climate change, pollution from agricultural sources and water abstraction are the most important threats to this species. Water

abstraction has led to the near extirpation of the species at its type locality (Başpınar Spring). In the Karamanlı Dam Lake there are invasive fish and it is heavily impacted by pollution, probably from agricultural sources. The Değirmendere Stream is also heavily impacted by pollution. The Başpınar Spring should be protected in order to ensure the survival of natural ecosystems.

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