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Research Article

On the life history of spirlin *Alburnoides bipunctatus* (Bloch, 1782) in the qanat of Uzineh, northern Iran

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Abstract: Within the wide distribution of spirlin in Iran, populations of this species inhabit a great variety of habitats, including qanats. We hypothesized that qanats may contribute to habitat-specific variation in the life history of the fish. To test this, a total of 240 specimens of *Alburnoides bipunctatus*, caught in the qanat of Uzineh (northern Iran) from October 2007 to August 2008, were examined for life history attributes. The population had a 5-year life cycle. The weight-length relationship (WLR) was estimated as $W = 0.0068TL^{3.2559}$ for males, $W = 0.0079TL^{3.2067}$ for females, and $W = 0.0072TL^{3.2387}$ for the population, having a positive allometric growth in all considered groups. The von Bertalanffy growth function (VBGF), fit to back-calculated size at age data, were: $L_t = 14.07(1 - e^{-0.27(t + 0.92)})$, $L_t = 15.37(1 - e^{-0.23(t + 1.08)})$, and $L_t = 14.83(1 - e^{-0.24(t + 1.04)})$ for males, females, and the population, respectively. The sex ratio was not significantly different from parity. The reproductive season, evaluated from the gonadosomatic index (GSI), extended from April to August, with 3 peaks in April, June, and August for females and 2 peaks in April and June for males. The absolute fecundity ranged between 234 and 7728 eggs with a mean of 1407 eggs. The relative fecundity ranged from 60 to 550 eggs g^{-1}, with a mean value of 255 eggs g^{-1}. The oocytes ranged in diameter from 0.50 to 1.70 mm with a mean value of 1.06 mm. Comparison of these results with those previously reported in the literature implies that the life history of the species is variable. This variability may be interpreted as phenotypic plasticity and respond to habitat characteristics to improve fitness locally.

Key words: *Alburnoides bipunctatus*, age, growth, reproduction, qanat, Iran

Introduction

Spirlin *A. bipunctatus* (Bloch, 1782) is a cyprinid species that commonly inhabits the upper and middle parts of rivers. Its distribution ranges from eastern Europe, in nearly all of the rivers draining to the southern Baltic, North, Black, and Azov seas; the Caspian Basin, in upper Volga; and from the Kura drainage, southward to the Iranian tributaries of the Caspian Sea (Berg, 1964; Kottelat and Freyhof, 2007). Within such a broad geographical distribution, spirlin populations are subject to different climatic conditions, forming different local populations and the life history of each of these populations is probably of great importance as an expression of phenotypic plasticity of the species. This species is considered to be in the "least concern" IUCN category, as it is widespread and is regionally abundant (Kottelat and Freyhof, 2007), but in many European waters it is reported as "endangered" or "threatened" due to stream regulation or organic pollution (Lelek, 1987; Lusk et al., 1995, 1998; Hensel and Mužik, 2001). However, in the south Caspian Basin it is considered

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to be in the "least concern" IUCN category (Kiabi et al., 1999), due to its high abundance and because it is not subject to commercial exploitation.

Spirlin is widespread in Iran (Abdoli, 2000), and it is common in the rivers of the northern, western, and central basins of Iran. This broad geographical distribution of this species in Iran is of particular interest, and one characteristic complexity of his distribution appears in the qanats, a Persian water provision technology constructed as a series of well-like vertical shafts, connected by gently sloping tunnels. Qanats are known to have been used in countries around the Persian Gulf and originated as man-made specially designed wells around the deserts of central and eastern Iran. It is thought that many of the qanats in Iran are hundreds of years old and even date back to the pre-Islamic era. Although qanats still exist and some regions use qanats for agricultural purposes, they are falling out of use.

Qanats are unique and exceptional environments with almost stable environmental conditions and they are habitats for a range of fish fauna (Abdoli, 2000), including spirlin. Accurate information on the growth and reproduction of this species would be a useful guideline in modeling the life-history plasticity of fishes in different habitats, as variations in the life history parameters of noncommercial species could be explained on the basis of the different ecological conditions. In this sense, we hypothesized that qanats, as unique and different habitats, could contribute to habitat-specific variation in the life history traits of different fish species. Therefore, the aim of this study was to describe the age structure, growth, and reproduction of a qanat spirlin population, as a model, providing insight into the life history of this species to test whether the almost stable environmental conditions of the qanat had promoted locally differentiated life history strategies in this species.

Material and methods

This study was carried out in the qanat of Uzineh, a well-known active qanat irrigating 500 ha of agricultural lands in the Uzineh region (central Golestan Province, northern Iran). Its overall length runs up to 1000 m, the mother well depth is 10 m and the downward gradient is about 1:500. The average water flow in the outlet was 5.82 L/s during the period of 2002 to 2007 (annual discharge of 94,608 m^3). The qanat stream had clear and colorless water, a temperature of 12-18 °C, pH of 7.5-7.9, and salinity of 1.30‰-1.38‰ (unpublished data of the regional department of water resources of Golestan province). The current was slow and the bed of the outlet stream was mud.

The specimens were collected in the outlet of the qanat (36°50′48″N, 54°29′23″E). Due to the difficulties of applying common sampling procedures in the wells of a qanat, the spirlins were caught using rotenone (a natural alkaloid toxin produced in plants and used in small quantities to kill a part of the spirlin population in the qanat). Specimens were sampled monthly from October 2007 to September 2008, and a total of 240 specimens were captured and analyzed. In the field, all fish specimens were immediately preserved in 10% formaldehyde solution until they could be examined.

In the laboratory, the total length was measured to the nearest 1 mm for all of the fish sampled. The total weight of the gonads and its sub-samples were recorded with an electronic analytical balance to the nearest 0.01 g. The age was determined from scales taken from the right side. The scales were reviewed for banding patterns 3 times, each time by a different person using a binocular microscope under reflected light at 20-30×.

The relationship between the total length and total weight were determined by fitting the data to a potential relationship in the form of: $TW = aTL^b$, where TW is the weight in grams; TL, the total length in centimeters; and a and b are the parameters to be estimated, with b being the coefficient of allometry based on the test given by Pauly (1984). The lengths at age were back-calculated using the equation $L_i = S_i S_c^{-1}(L_c - c) + c$, where L_i is the total length of the fish at age i; L_c, the total length of the fish at capture; S_i, the largest radius of the scale at age i; S_c, the largest radius of the scale at capture; and c, the intercept of the regression of body lengths on scale radii (Johal et al., 2001). The adopted growth model was the specialized von Bertalanffy growth function (VBGF), whose expression is: $L_t = L_\infty(1-e^{-k(t-to)})$, with L_∞ being the predicted asymptotic length; L_t, the size at age t;

k, the instantaneous growth coefficient; and t_o, the point at which the von Bertalanffy curve intersects the age axis. The parameters were estimated using the method of Ford-Walford (Everhart and Youngs, 1975).

Sex was determined by examination of the gonad tissue, either by eye or with the aid of a binocular microscope. The gonadosomatic index (GSI%) = (gonad weight/total body weight) × 100 was calculated for each fish and all values were averaged for each sampling date. We used the ripe ovaries of 39 specimens at stage IV maturity, from females caught between April and June to estimate the absolute and relative fecundities. They were removed, weighed, and then placed in Gilson's fluid for 3-4 weeks to harden eggs and dissolve ovarian membranes. The absolute fecundity (AF) was estimated by the gravimetric method, using 3 pieces removed from the ovary. The relative fecundity index was calculated as $RF = AF/TW$, where *AF* is the absolute fecundity and *TW* is the total weight (Bagenal and Tesch, 1978). The average egg diameter was examined by measuring 30-40 eggs, taken randomly from pieces of the ripe ovary of 39 females, caught between April and June. Measurements were made to the nearest 0.05 mm with an ocular micrometer microscope.

An analysis of co-variance (ANCOVA) was performed to test significance differences in the weight-length relationships between sexes. The overall sex ratio was assessed using the chi-square test (Zar, 1984). Comparison of GSI values during the reproductive period and its temporal variation in each sex was carried out by analysis of variance (ANOVA). Statistical analyses were performed with SPSS 11.5 and a significance level of 0.05 was accepted.

Results

The spirlin caught ranged in size from 4.8 to 11.1 cm total length (TL) and in total weight from 0.89 to 15.95 g. Of the 240 specimens collected, 129 (53.75%) were identified as males, ranging from 4.9 to 11.0 cm and 0.89 to 14.68 g, while 111 (46.25%) were females ranging from 4.8 to 11.1 cm and 0.92 to 15.95 g. Considering size and sex distributions, no significant differences were observed between months (χ^2_{size} = 0.16, χ^2_{sex} = 0.05, P > 0.05). Females were slightly heavier than males. Even though the overall ratio of females to males was 1:1.16 and an unequal sex ratio was observed among the length classes, the χ^2 analysis showed no significant differences from the ration 1:1 (χ^2 = 0.24, P > 0.05). The dominant length class was 6.0-6.5 cm for both sexes (Figure 1), corresponding to the 1+ age groups. In the population, scale readings showed that the oldest specimens of the fish were 4+ years old in both sexes.

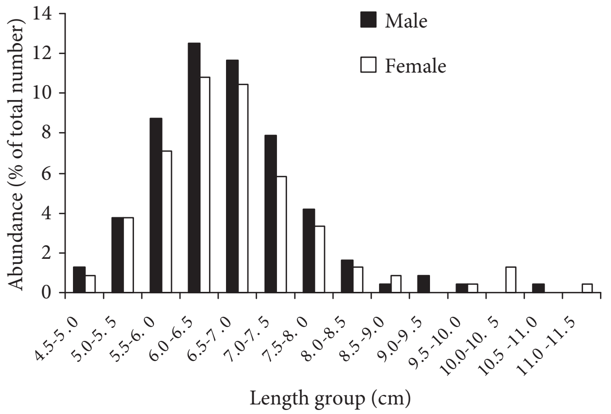

Figure 1. Total length (mm) abundance of males and females of spirlin *Alburnoides bipunctatus* in the qanat of Uzineh, Golestan Province, northern Iran.

Significant differences obtained from the statistical comparison of the length-weight relationships between males and females (ANCOVA, F = 187.77, P < 0.05). The b-values of the relationships imply that the body shape of males, females, and the population display positive allometric form, with a 95% confidence interval for the b-value of 3.102-3.410 for males, of 3.054-3.360 for females, and of 3.129-3.349 for the population (t-test, t_{male} = 17.02, t_{female} = 10.35, $t_{sexes\ combined}$ = 12.09, P < 0.05) (Figure 2).

The mean back-calculated total lengths of each group were smaller than the observed lengths (Table 1). The back-calculations showed rapid growth during the first year of life and a steady, less rapid decline in the relative length increments occurred during subsequent years. The mean back-calculated length of individuals assigned to each age group was used to fit the von Bertalanffy growth model. The von Bertalanffy growth functions were $L_t = 14.07(1 - e^{-0.27(t + 0.92)})$ for males, $L_t = 15.37(1 - e^{-0.23(t + 1.08)})$ for females,

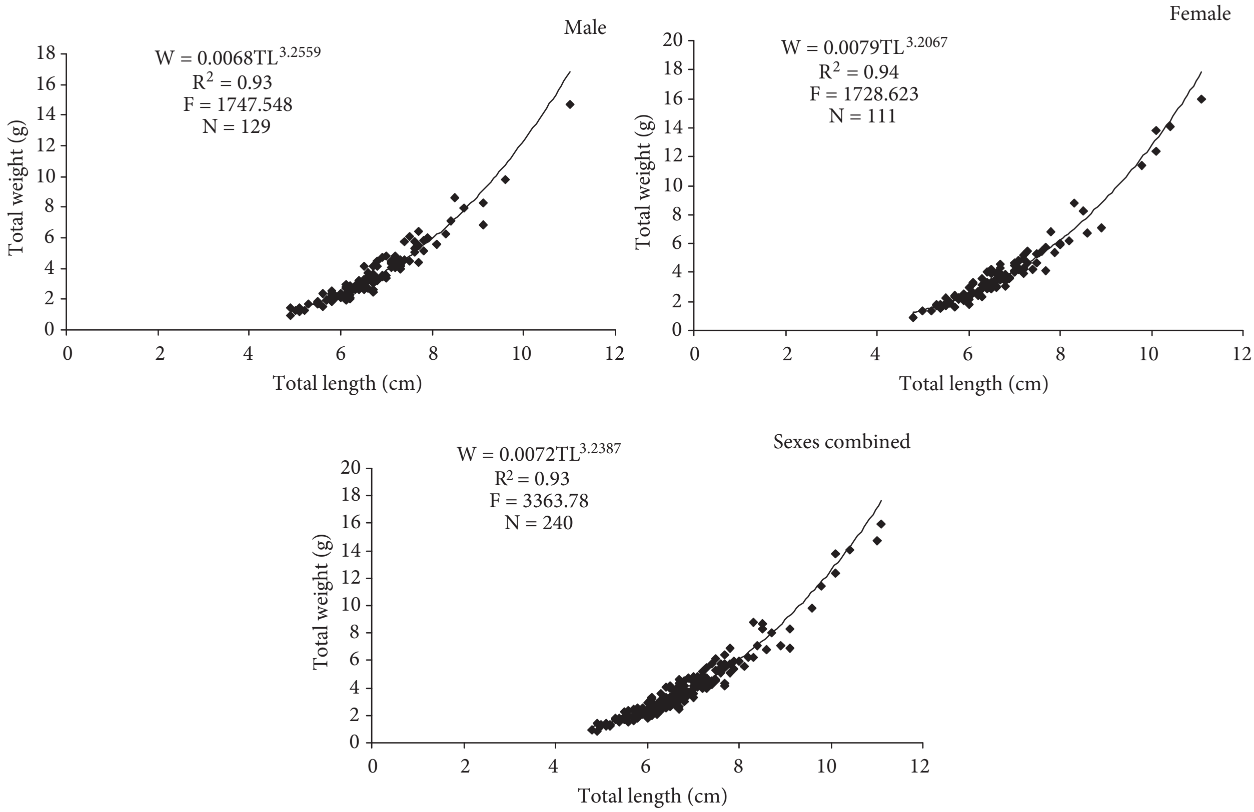

Figure 2. Relative growth curves (total length-total weight) for males, females, and sexes combined of spirlin *Alburnoides bipunctatus* in the qanat of Uzineh, Golestan Province, northern Iran.

Table 1. Mean observed (MOL) and mean back-calculated (BCL) lengths (mm) for age (± S.D.) of spirlin *Alburnoides bipunctatus* in the qanat of Uzineh, Golestan Province, northern Iran.

Age (year)	**0+**	**1+**	**2+**	**3+**	**4+**
			Female		
Mean observed TL	---	60.14 ± 8.20	77.68 ± 8.13	91.40 ± 9.79	111.00 ± 0.00
Mean back-calculated	32.85 ± 6.26	59.58 ± 7.03	76.52 ± 8.13	89.32 ± 9.79	106.03 ± 0.00
			Male		
Mean observed TL	---	58.47 ± 7.80	76.99 ± 8.01	88.08 ± 8.74	110.00 ± 0.00
Mean back-calculated	30.80 ± 6.27	58.64 ± 6.61	75.53 ± 6.37	88.23 ± 7.35	103.97 ± 0.00
			Population		
Mean observed TL	---	59.09 ± 7.86	77.21 ± 8.08	89.65 ± 8.97	110.50 ± 0.71
Mean back-calculated	31.84 ± 6.26	58.82 ± 6.85	76.00 ± 7.45	87.27 ± 8.02	104.84 ± 0.71

and $L_t = 14.83(1 - e^{-0.24(t + 1.04)})$ for sexes combined, indicating that males grew faster than females ($k_{male} > k_{female}$), while the asymptotic value of the length was higher for females than for males.

Significant changes were obtained in the temporal variation of the gonad activity (ANOVA, $F_{female} = 39.09$, $F_{male} = 5.11$, $P < 0.05$). The GSI values of the males were significantly lower than those of the females, using the size of the fish as a covariate (ANCOVA, F = 75.51, P < 0.05). The highest average values of the GSI were 3.458 and 8.031 in April for males and females, respectively. The GSI of both sexes followed almost the same pattern (Figure 3). Based on the GSI, the reproductive period for this species in the qanat was from April to August with 3 peaks in April, June, and August for females, and 2 peaks in April and June for males. It thereafter decreased in September, showing the start of the resting period.

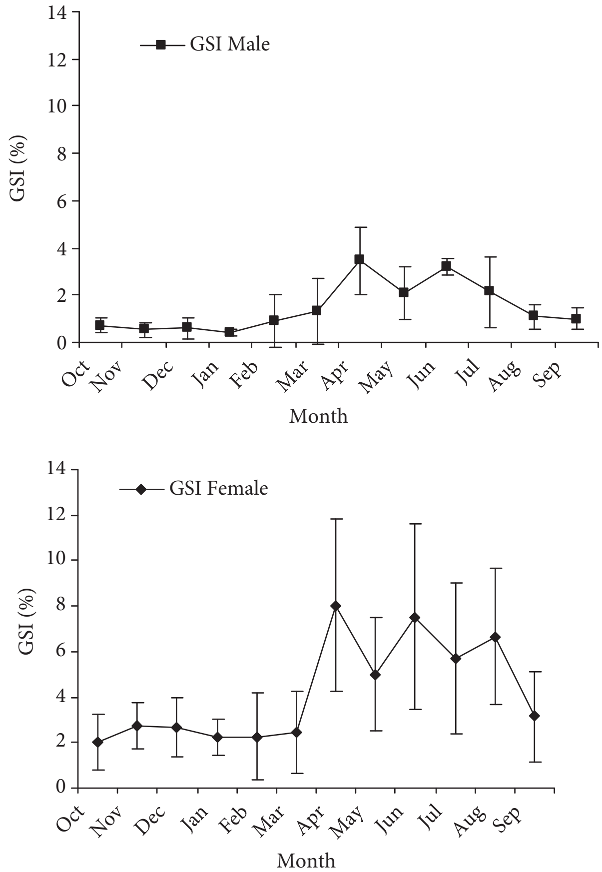

Figure 3. Monthly distribution of the GSI in spirlin *Alburnoides bipunctatus* in the qanat of Uzineh, Golestan Province, northern Iran.

Different size eggs were found in the ovaries during the spawning period from April to August. In this period, the diameter of the oocytes ranged from 0.50 to 1.70 mm with a mean value of 1.06 ± 0.25 (Figure 4).

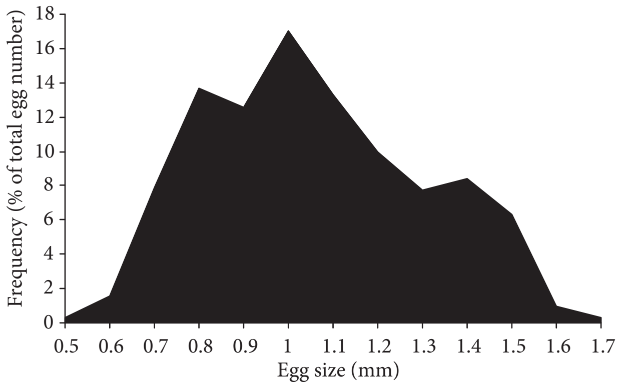

Figure 4. Size frequency distribution of oocyte diameters of female spirlin *Alburnoides bipunctatus* at stage IV maturity in the qanat of Uzineh, Golestan Province, northern Iran.

Absolute fecundity increased with age; a minimum value of 234 eggs was from a 2+ year-old female, weighing 3.90 g and a maximum value of 7728 eggs was from a 4+ year-old fish weighing 14.05 g. The mean value of absolute fecundity was 1407 ± 1347 (S.D.) eggs/female. The regression between egg number and fish size (total length and weight) was statistically significant (P < 0.05) (Figure 5).

The fecundity relative to total weight fluctuated from 60 to 550 eggs/g, with a mean value of 255 ± 121 (SD), and relative total length from 4 to 74 eggs/mm, with a mean value of 18 ± 14 (SD). The relationship of relative fecundity with fish size (total weight and total length) was found to be statistically significant (P < 0.05) (Figure 6).

Discussion

This study has established key population parameters of *A. bipunctatus* in the qanat environment, a unique environment with almost stable conditions, different from rivers and lakes. Therefore, the characteristics of the population under consideration can have important ecological consequences. The consequence is the existence of life-history variability among spirlin populations in different habitats. The comparison of the population under consideration with previous reports on some studied spirlin populations inhabiting the southern Caspian Basin and the European region shows that the maximum

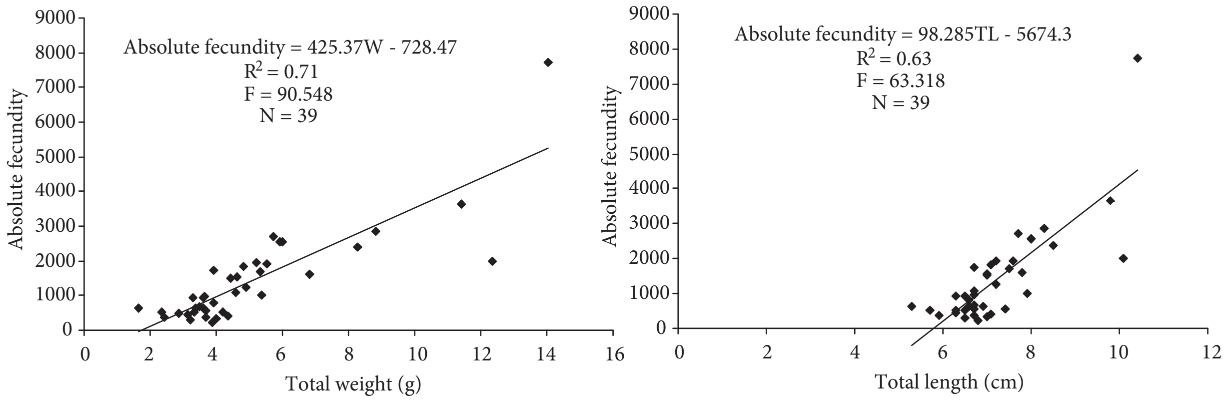

Figure 5. Relationship between absolute fecundity, fish total length (mm), and total weight (g) of female spirlin *Alburnoides bipunctatus* in the qanat of Uzineh, Golestan Province, northern Iran.

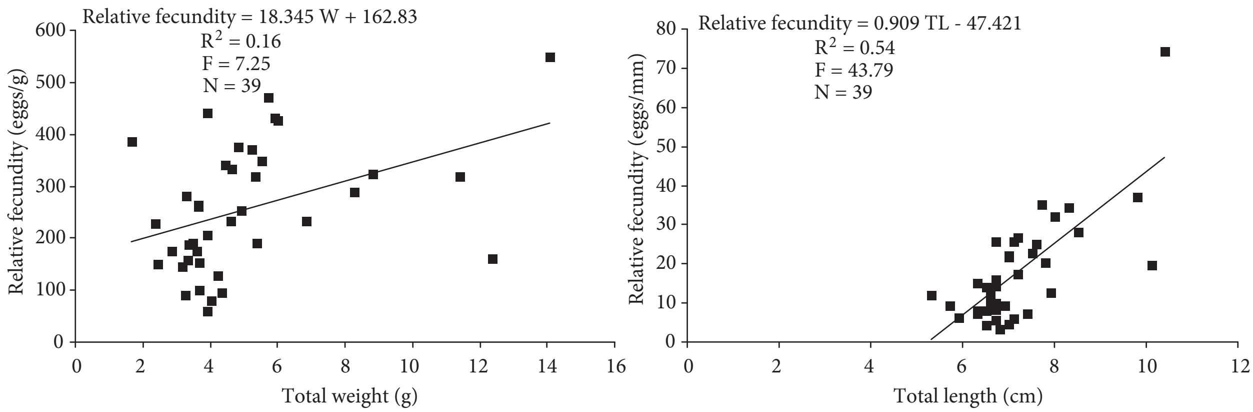

Figure 6. Relationship between relative fecundity, fish total weight (g), and total length (mm) of female spirlin *Alburnoides bipunctatus* in the qanat of Uzineh, Golestan Province, northern Iran.

age and size (length as well as weight) vary quite a lot among the regions (Table 2). This attribute could be interpreted as interpopulation pattern related to different habitat quality, growth rate, and natural selection. In this sense, spirlin inhabiting the qanat appeared to be one of the populations having a smaller life span. The fact that a proportion of the age 4+ specimens was low indicates that very few individuals survive to a maximum age, as is typical of most fishes (Matthews, 1998). This also concurs with the general patterns observed in most other populations of spirlin thorough out the species distribution range in the southern Caspian Basin (Abdoli and Naderi, 2009).

The exponents of the total length-somatic weight relationship of *A. bipunctatus*, estimated in the qanat, showed that the somatic weight grows allometrically (Ricker, 1975) with total length. Differences between males and females in the TL-W relationship are explained by the differences in size distribution of the 2 sexes as a consequence of inter-sexual differences in growth. The b-value of both sexes as a coefficient of allometry was larger than 3 in the qanat population of spirlin, showing that large specimens have increased in height or width more than in length and the fish became less rotund as length increased. The coefficient values estimated in the studied population were different from those found in Zarrin-Gol River (northern Iran), being a negative allometric growth for both sexes. The river is located 30 km east of Elburz Mountain in the Gorganroud Basin (Patimar and Dowlati, 2007). Furthermore, the values in the qanat

Table 2. Maximum observed length (TL, cm) and age (years) for spirlin *Alburnoides bipunctatus* in the European region and southern Caspian Basin.

Sex	TL	Age	Area	Reference
Female	10.3	6+	Velika Morava River, former Yugoslavia	Soric and Ilic (1985)
Females	12.53	6+	Oltu stream, Coruh Basin, Turkey	Yıldırım et al. (1999)
Unsexed	11.72	---	Rudava River, Slovakia	Siryova (2004)
Female	11.0	4+	Sava River, Croatia	Treer et al. (2006)
Unsexed	13.0 (SL)	---	European freshwater systems	Kottelat and Freyhof (2007)
Unsexed	16.0	3+	Azerbaijan	Abdurahmanov (1962)
Unsexed	12.5	---	Madarsu Stream, National Park of Golestan, northern Iran	Akbaripasand (1999)
Unsexed	15.0	---	Sardabroud River, northern Iran	Abdoli (2000)
Male	9.5	4+	Zarrin-Gol River, northern Iran	Patimar and Dowlati (2007)
Female	11.0	4+	Zarrin-Gol River, northern Iran	Patimar and Dowlati (2007)
Unsexed	14.0	6+	Rivers of northern Iran	Abdoli and Naderi (2009)
Male	11.0	4+	qanat of Uzineh, northern Iran	Present study
Female	11.1	4+	qanat of Uzineh, northern Iran	Present study

population are different from those found in some European regions (Table 3). This reflects a change in body form with population, which is itself probably an effect of different environmental conditions influencing as a local selective condition on the fish. It seems that habitat and associated environmental condition can significantly affect the value of *b* in *A. bipunctatus*; the variations could be attributable to species responses to different habitats. Considering b-values in this study as species response, the qanat population of spirlin has higher b-values in the range of reported values, indicating good fitness of the fish population in the qanat.

Fitting the von Bertalanffy growth formula to back-calculated lengths resulted in the estimation of higher values of L-infinity than the maximum observed total lengths. This length is seen as a capacity for growth (Bagenal and Tesch, 1978) and inter-sex differences in this parameter of the VBGF correspond to different growth rates of the sexes. On the other hand, a different VBGF can be a result of resource allocation between growth and reproduction. Therefore, differences between sexes in the VBGF parameters could also reflect differences in the reproductive effort of the fish. The higher coefficient (k) for males emphasizes that they grow rapidly initially and approach their asymptotic length (L_∞) earlier. As well as other species of the family Cyprinidae, the females of *A. bipunctatus* were found to have reasonably larger L_∞ and smaller k-value than males. This may be regarded as a biological feature of the fish in the qanat, and no exception from the usual known trade-off between growth rate (k) and maximum size (L_∞). Treer et al. (2000, 2006), and Patimar and Dowlati (2007) reported different functions in Croatia and northern Iran (Table 4). Taking into account significant inter-population variations in the parameters of the VBGF, the growth rate (k) of the spirlin population in the qanat was much slower than those of river populations. These differences (larger L-infinity in the qanat than rivers and much larger k-value in the rivers) can be attributed to differences of population characteristics, a consequence of different growth rates in populations of spirlin from different regions.

In the qanat, a balanced sex ratio could be attributable probably either to the consequence of the same survival rate and/or to the same longevity of the sexes. The spirlin population in the qanat, in terms of the sex ratio, is investing in both sexes equally. This

Table 3. Parameters of the length-weight relationship of spirlin *Alburnoides bipunctatus*.

Area	**sex**	**Length**	**a**	**b**	**Reference**
Dobra River, Croatia	Sexes combined	TL	0.0059	3.2245	Treer et al. (2000)
Bednja River, Croatia	Sexes combined	TL	0.0150	2.7970	Treer et al. (2000)
Middle Korana River, Croatia	Sexes combined	TL	0.0088	3.1043	Treer et al. (2000)
Lower Korana River, Croatia	Sexes combined	TL	0.0030	3.5567	Treer et al. (2000)
Sava River, Croatia	Sexes combined	TL	0.0044	3.4032	Treer et al. (2000)
Çoruh River, Turkey	combined	FL	0.0249	2.79	Torcu-Koç et al. (2006)
Çoruh River, Turkey	female	FL	0.0375	2.62	Torcu-Koç et al. (2006)
Çoruh River, Turkey	male	FL	0.0166	2.95	Torcu-Koç et al. (2006)
Sava River, Croatia	Sexes combined	TL	0.0083	3.025	Treer et al. (2006)
Seyhan Dam Lake, Turkey	combined	TL	0.0028	2.72	Ergüden and Göksu (2009)
Emajõgi River Basin, Estonia	Sexes combined	SL	0.0103	3.251	www.fishbase.org
Zarrin-Gol River, northern Iran	Male	TL	0.0054	2.59	Patimar and Dowlati (2007)
Zarrin-Gol River, northern Iran	Female	TL	0.0088	2.52	Patimar and Dowlati (2007)
Qanat of Uzineh, northern Iran	Male	TL	0.0068	3.2559	Present study
Qanat of Uzineh, northern Iran	Female	TL	0.0079	3.2067	Present study
Qanat of Uzineh, northern Iran	Population	TL	0.0072	3.2387	Present study

Table 4. Estimates of von Bertalanffy length-at-age growth parameters for populations of spirlin *Alburnoides bipunctatus* in the distribution area (Iran and European regions).

Location	**sex**	L_∞ **(mm)**	K **(year^{-1})**	t_o **(year)**	**Reference**
Dunajec River, Czechoslovakia	unsexed	20.1	0.15	---	Skora (1972)
Turiec River, former Czechoslovakia	unsexed	15.6	0.28	---	Bastl et al. (1975)
Radimna River, Romania	unsexed	14.4	0.30	---	Papadopol and Cristofor (1980)
Dobra River, Croatia	unsexed	20.5	0.16	−1.38	Treer et al. (2000)
Bednja River, Croatia	unsexed	15.5	0.33	−0.42	Treer et al. (2000)
Middle Korana River, Croatia	unsexed	15.1	0.28	−0.86	Treer et al. (2000)
Lower Korana River , Croatia	unsexed	17.7	0.19	−1.47	Treer et al. (2000)
Sava River, Croatia	unsexed	11.5	0.59	−0.47	Treer et al. (2000)
Sava River, Croatia		12.0	0.59	−0.14	Treer et al. (2006)
Zarrun-Gol River, northern Iran	Male	99.64 (mm)	0.51	−0.715	Patimar and Dowlati (2007)
Zarrun-Gol River, northern Iran	Female	107.23	0.55	−0.548	Patimar and Dowlati (2007)
Qanat of Uzineh, northern Iran	Male	140.7	0.27	−0.92	Present study
Qanat of Uzineh, northern Iran	Female	153.7	0.23	−1.08	Present study
Qanat of Uzineh, northern Iran	Population	148.3	0.24	−1.04	Present study

strategy could be interpreted as a characteristic for the spirlin population living in a qanat system with almost stable conditions. This is in contrast with the general pattern of the sex ratio in Cyprinid species in rivers. In fact, the predominance of females is common in Cyprinid populations in rivers and the differences in sex are highly significant. As an example, Yıldırım et al. (1999) reported a significant deviation from parity in the ratio 1:1.26 (males to females) of this species in the Oltu River, Turkey.

Nikolsky (1963) pointed out that the spawning characteristics of a fish vary in respect to their species and ecological characteristics of the water system in which they live. In comparison with other fish species inhabiting the southern Caspian Basin, this spirlin population has an extended spawning season (approximately 5 months, from April to August in the qanat), a reproduction feature typical of batch spawners. This more protracted spawning of the qanat population may be interpreted as an increase of reproductive effort (Fernandez-Delgado et al. 1988; Creech, 1992). Considering reported GSI patterns (Yıldırım et al., 1999; Patimar and Dowlati. 2007; Polacik and Kovac. 2006), it is evident that time and the duration of the reproductive season is different among different regions, in April and May in Zarrin-Gol River in northern Iran, between April and June in the Oltu River, Turkey, and between April and July in the Rudava River, western Slovakia. Additionally, the highest average value of GSI was different among populations: 28.50 in May in the Zarrin-Gol River, 13.42 in late May in the Oltu River and approximately 27 in early May in the Rudava River. In the last river, Polacik and Kovac (2006) noted that, due to asynchronous spawning, the fish showed diverse GSI patterns where there were 3 peaks in GSI. Commonly, a higher GSI value is considered a reproductive investment. In the considered population, it seems that a lower investment in the female's reproduction (i.e. lower energetic investment), as expressed by GSI in comparison with whose of river populations (Yıldırım et al., 1999; Patimar and Dowlati, 2007; Polacik and Kovac, 2006), is another important parameter in the reproductive strategy for this fish in the qanat environment.

Considerable variation in oocyte size within females of the studied population is indicative of a batch spawner, and intra-female variation in oocyte size may be optimal for the mother's fitness in this species in the qanat, by decreasing competitive intensity between juveniles of the fish. The observed size range of oocyte yolks (0.50-1.70 mm) was different from that of 0.20 to 1.20 mm reported by Polacik and Kovac (2006) in the Rudava River in western Slovakia and that of 0.50 to 1.40 mm found by Soric and Ilic (1985) in the Velika Morava River in former Yugoslavia. In the qanat, a smaller range of variation in egg size agrees with the hypothesis that there should be lower variation in egg size for the qanat, with almost no selective pressure and absence of other fishes, i.e. decreased competition for niche.

Even though a number of problems result from invalidate estimates of fecundity in batch spawners that are derived from the total number of eggs of batch sizes, including incomplete ovulation (Yamamoto and Yamazaki, 1961), discontinuous addition of recruitment stock eggs to the spawning egg stock (Hunter and Goldburg, 1979), or atresia (Macer, 1974), we made an attempt to estimate absolute fecundity for the fish in the qanat. For the population under consideration, the range of absolute fecundity estimated in the qanat was different from the values obtained for the fish in the European regions (Table 5). The estimated mean relative fecundity (255 eggs g^{-1}) was also different from that of 100 in the Velika Morava River in former Yugoslavia (Soric and Ilic, 1985), of 94 in the Rudava River, western Slovakia (Polacik and Kovac, 2006), and of 597-913 in the Oltu River, Turkey (Yıldırım et al., 1999). Geographical variation in the fecundity is affected by many factors, such as the size and age of females (Thorpe et al., 1984), the life history strategy (Morita and Takashima, 1998), and the food supply and temperature (Fleming and Gross, 1990). Differences in both the absolute and relative fecundities can be attributable to the combination of one or more of the above factors. Considering the lower absolute and relative fecundities of the studied population within the reported range of fecundity in the European regions as an intrapopulation variation, it is clear that the population inhabiting the qanat was less fecund, i.e. total and proportional energetic investments in reproduction tend be decreased in a qanat. As interpopulation traits, a significant positive effect of fish size on both the absolute and relative fecundities

Table 5. Estimates of absolute and relative fecundity for female spirlin *Alburnoides bipunctatus* in the European regions.

Region	Absolute fecundity	Relative fecundity	Reference
Former Czechoslovakia	740-2300	---	Holcik and Hensel (1971)
Transcaucasica	1529-3000	---	Abdurahmanov (1962)
Romania	1581-6110	---	Papadopol and Cristofor (1980)
Former Yugoslavia	752-3085	---	Soric and Ilic (1985)
Turkey	9553-31190	731-913	Yıldırım et al. (1999)
Western Slovakia	975-5206	176-586	Polacik and Kovac (2006)
Qanat of Uzineh, northern Iran	234-7728	60-550	Present study

was observed for the fish. It can be hypothesized, however, that the largest spawners were able to increase total egg production as well as increase the quantity of eggs per unit somatic weight proportionally, suggesting total proportional energetic investment in reproduction tends be higher in the larger member of the fish. The qanat population has lower absolute and relative fecundities, with larger oocytes. It is a known strategy in some fish species. A larger oocyte produces larger fry, and larger specimens have higher survival rates. Therefore, a qanat population could be producing a lower number of fishes but with a larger survival rate.

In conclusion, the findings of this study are important with respect to the life history of the species. There are several possible explanations for the variations relating to growth and reproduction that may be interpreted as phenotypic plasticity and respond to environmental characteristics to improve fitness locally.

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