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Original Article

Population dynamic parameters of the highly endemic fish, *Alburnoides qanati* Coad and Bogustkaya 2009, (Teleostei: Cyprinidae) in the Kor River Basin, Iran

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Abstract: The present study provides the data on the population parameters of an endemic qanat spirlin, *Alburnoides qanati* from the endorheic Kor River basin of Iran to assess the stock status of this cyprinid fish species, which is highly important from management and conservation points of views. Fish specimens (387) were collected from Moshkan Stream, Kor River basin, Iran in 2011-2012. Asymptotic length (L_∞) and growth coefficient (*K*) were estimated at 123.9 mm and 0.31/year for females and 93 mm and 0.49/year for males, respectively. Growth performance index (Ø') was calculated as 8.47 and 8.35 for female and male specimens, respectively. Total mortality (*Z*) of females (1.56/year) was higher than males (1.14/year) whereas natural mortality (*M*) of female specimens (0.44/year) was lower than male specimens (0.65/year). Data on growth and mortality parameters and also length-weight relationship of *A. qanati* revealed significant differences with corresponding data from other *Alburnoides* species from Iran and other countries, which could be attributed to habitat's differences and specific species characteristics.

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Introduction

Alburnoides bipunctatus (Bloch, 1782) was the name applied to most populations of spirlins (riffle minnows or tailor fish) across Europe and the Middle East from France north of the Alps eastwards to the Black, Caspian and Aral Sea basins (Coad and Bogutskaya, 2012) and reportedly to be one of the abundant and widespread groups in Iranian endorheic and exoreic basins (Esmaeili et al., 2010). However, ongoing research was revealed a greater diversity and presence of at least seven species in different basins of Iran, including the Caspian Sea, Lake Orumiyeh (Urmia), Tedzhen River, Kavir, Namak Lake, Tigris River, Persian Gulf drainage and Kor River basins (Bogutskaya and Coad 2009, Coad and Bogutskaya, 2009, 2012; Esmaeili et al., 2010, 2014a) of which the Kor River populations have been assigned to *Alburnoides qanati*, qanat tailor fish by Coad and Bogustkaya (2009).

Members of the genus *Alburnoides* are lithophilic and rheophilic fishes, which inhabit in barbell and grayling zones and spawn on gravel and rubble (Breitenstein and Kirchhofer, 2000). The spirlins are very sensitive to human activities and levels of dissolved oxygen. Having low tolerance to water polluted by industrial, agriculture or urban wastes makes these cyprinid fishes a good biological indicator of the environment quality (Čihăr, 1999). In European waters, spirlins are extremely threatened and nearly close to extinction because of this sensitivity (Kirchhofer, 1997; Lusk et al., 1998). The freshwater fishes of Iran are also faced to recent severe droughts, climate change, pollutions, introduction of exotic fishes and anthropogenic impacts, and as a consequence, many fish populations have been intensively affected

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especially sensitive fishes, like the spirlins (Esmaeili et al., 2014a, b). Hence, there is a constant need for an increase in knowledge on different aspects of biology of these fishes, including estimating growth parameters as an indicator of fish health and habitat quality to implant effective management and conservation measures.

However, many of these aspects on *A. qanati* have not been documented in Iran, partly because of narrow endemic range and no commercial importance due to its slow growth rate and small size.

Therefore, due to the information scarcity on the population dynamics of *A. qanati*, coupled with the need to provide much-needed scientific data for the management and rational exploitation of this valuable resource, the present study was undertaken to evaluate and to estimate the growth characteristics (growth parameters) of this species to assess the stock status of this endemic fish species from a spring-stream system in Kor River basin of Iran for the first time.

Material and Methods

The samples were collected from Moshkan spring-stream system in Kor River basin located at N 30˚36'16.9" and E 52˚56'40.1". Sampling was performed monthly from March 2011 to April 2012 by electrofishing device. Samples were fixed in 10% formalin solution and transported to the laboratory. Some morphological characters, including: total length (TL), fork length (FL), standard length (SL) and maximum and minimum body width were measured to the nearest 0.01 mm and fish weight (gr) to the nearest 0.1 gr. Sexes were determined by investigation of the gonads. The relationship between the length and weight were determined by fitting the data to a potential relationship in the form of: $W = \alpha L^b$, where W is the fish weight; L, fish length; and α and b are the parameters to be estimated, with b being the coefficient of allometry based on the test given by Pauly (1980). Prior to regression analyses, log–log plots of length and weight values were performed for visual inspection of outliers (Froese, 2006). One-way analysis of variance (ANOVA) was used to test significant relationship between length and weight.

To calculate growth performance and measure the back-calculation of growth in length, data were put in to the FISATII software. The von Bertalanffy growth function was used to study the overall growth performance using the values of growth in length and Phi-Prime (Ø') (Bertalanffy, 1934; Sparre and Venema, 1992), as follows:

$$L_t = L_\infty(1\text{-}e^{-k(t-t_0)})$$

$$\emptyset' = lnK + lnL_\infty$$

where L_t is total length at age t, L_∞ is the ultimate total length that an average fish should achieve if it continues to live and growth, K is the growth coefficient that determines how fast the fish approaches to L_∞, t_0 is hypothetical age L_t=0, and Ø' is overall growth performance.

Estimations of the mean total mortality rate (Z) was obtained from using length converted catch curve analysis. Natural mortality (M) was calculated using the equation of Pauly (1980):

$$Log_{10}M = 0.0066 - 0.279Log_{10}L_\infty + 0.6543Log_{10}K + 0.4634Log_{10}T$$

Where, M is the natural mortality; $L\infty$ is the asymptotic length; K is the growth co-efficient of the von Bertalanffy growth function (VBGF) and T is the mean annual water temperature (°C) of sampling site. Mortality rate was calculated by Length Converted Catch Curve Method (Pauly, 1980):

$$F = Z - M\ , E = {}^{F}/_{Z} = {}^{F}/_{F\,+\,M}$$

Where Z is total mortality, F is fishing mortality, E is exploitation coefficient and M is natural mortality.

Results

The descriptive statistics on *A. qanati* specimens, collected from Moshkan spring-stream, Kor River basin are presented in Table 1. Minimum and maximum total length (TL) for female and male specimens were 24.76 and 118.66 and 24.88 and 87.07, respectively (Table 1). One-way analysis of variance (ANOVA, P<0.05) showed a high significant relationship between length and weight of *A. qanati* in both sexes and the estimates of the

Table 1. Descriptive statistics and estimated parameters of the length-weight relationships (LWRs) for females and males of *Alburnoides qanati* collected from Kor River Basin, during 2011-2012.

Length parameter (mm)	Sex	Min	Max	*b*	*a*	r^2	N
TL	Female	24.76	118.66	3.45	0.0033	0.98	209
	Male	24.88	87.07	3.44	0.0033	0.98	155
FL	Female	23.00	110.1	3.35	0.0044	0.97	196
	Male	23.42	81.86	3.32	0.0047	0.97	141
SL	Female	21.02	102.96	3.30	0.0055	0.98	219
	Male	20.76	75.06	3.35	0.0047	0.98	168

TL, total length; FL, fork length; SL, standard length; *b*, regression slope; α, intercept; r^2, coefficient of determination; N, number of specimens.

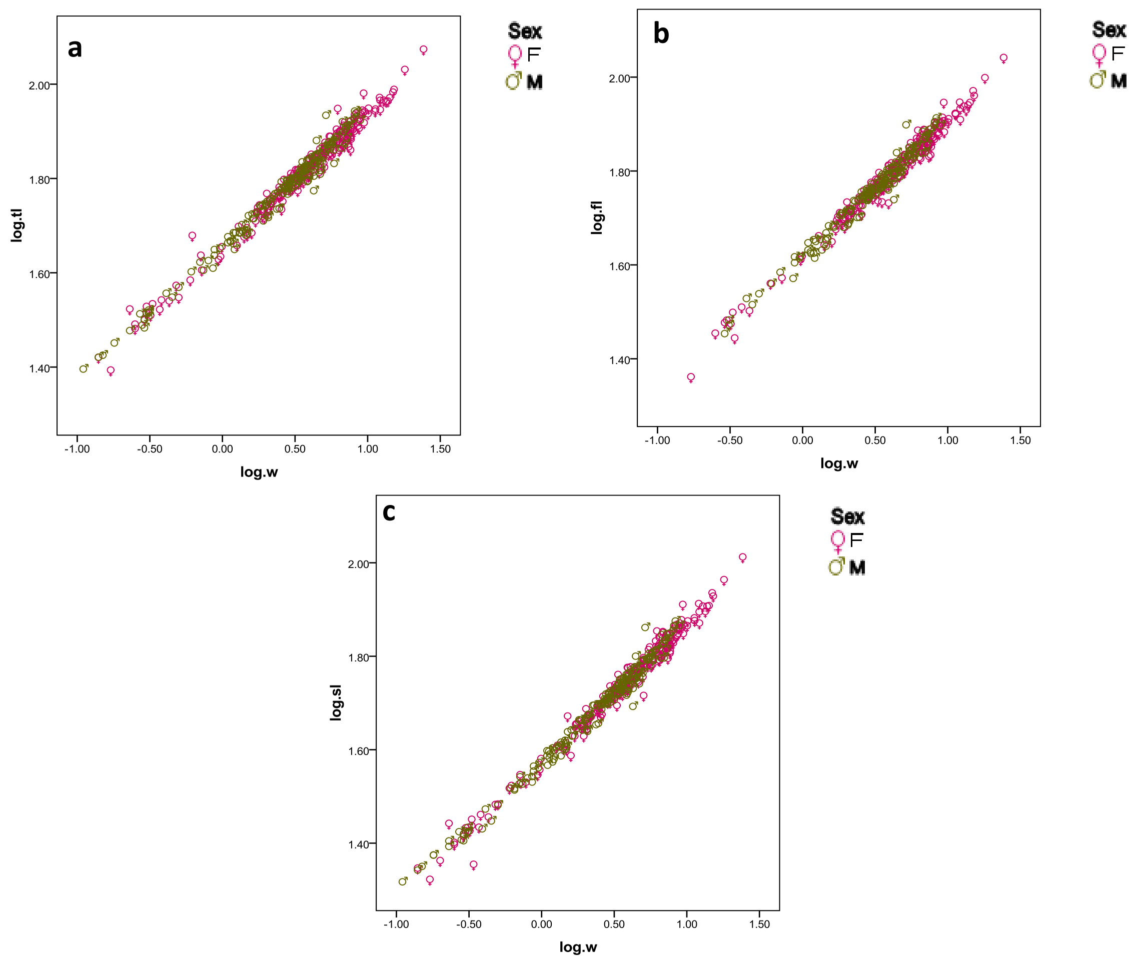

Figure 1. Length- Weight relationship of *Alburnoides qanati* from Kor River Basin, Iran.

parameter *b*, varied between 3.30 and 3.45 for females and 3.32 and 3.44 for males with high r^2 values of 0.97 to 0.98 for both sexes (Table 1, Figs. 1a, b). The parameters of growth including growth coefficient (*K*), asymptotic length (L_∞), overall growth performance (Ø'), and total, fishing, natural and exploitation mortality (*Z*, *F*, *M*, *E*) for females and males of *A. qanati* are given in Table 2 and von Bertalanffy growth curves are shown in Figure 2. It can be realized that infinity length (L_∞) of females is greater than males (123.9 vs. 93 mm, respectively) and value of *K* parameter for females is lower than

Table 2. Growth parameters for females and males of *Alburnoides qanati* from Kor River basin, Iran.

Growth Parameters	**L∞(mm)**	***K***	**Ø'**	***Z***	***M***	***F***	***E***
Female	123.9	0.31	8.47	1.56	0.44	1.12	0.72
Male	93	0.49	8.35	1.14	0.65	0.49	0.43

von Bertalanffy growth parameters (L∞, *K*,), overall growth performance (Ø'), total mortality (*Z*), fishing mortality (*F*), natural mortality (*M*) and exploitation mortality (*E*).

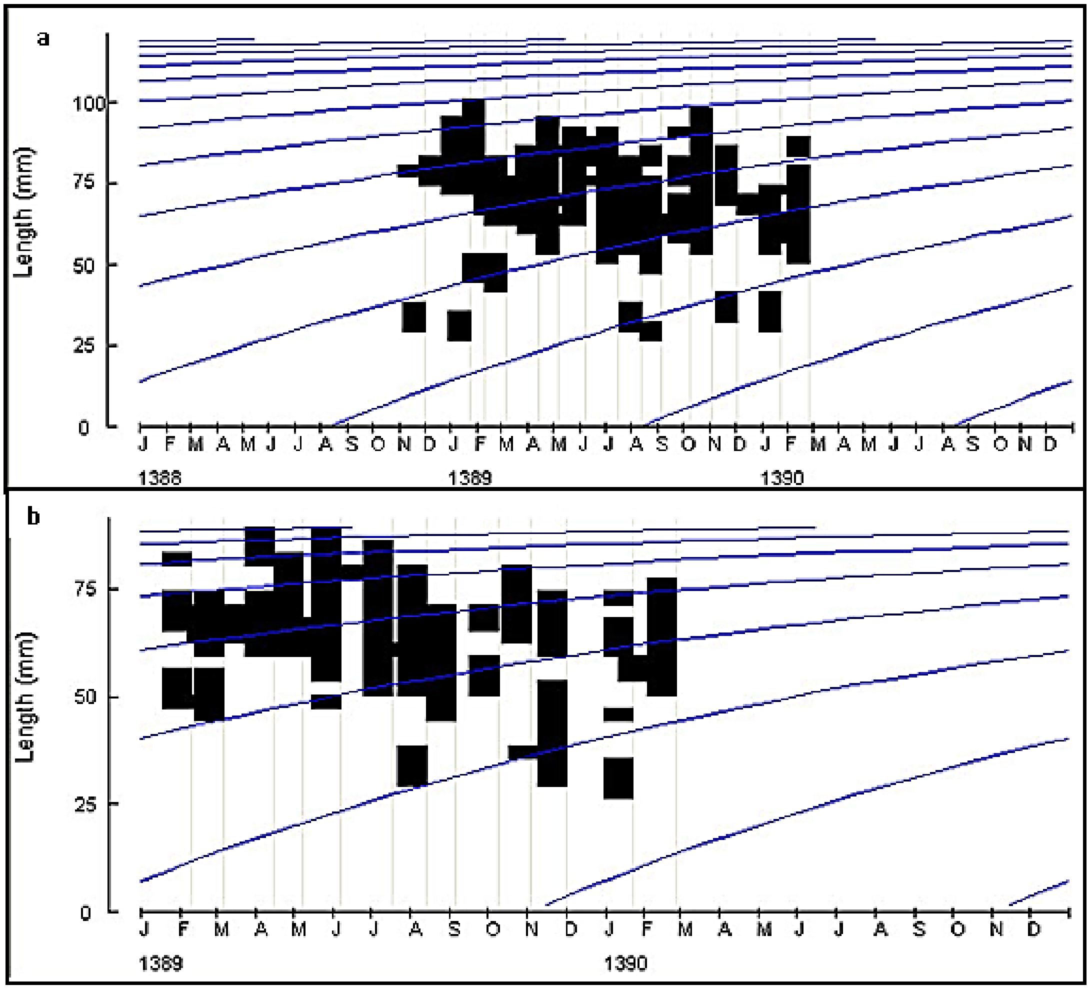

Figure 2. Von Bertalanffy growth curves of *Alburnoides qanati* (a., female; b. male).

males (0.31 vs. 0.49, respectively) (Table 2).

Discussion

The ranges of *A. qanati* length obtained in this study is in the rages reported for other *Alburnoides* species from different regions. It indicates that females are almost larger than males (Table 3). This attribute could be interpreted as an inter-population pattern related to nature of water body (river, stream, spring, qanat), different habitat quality, growth rate and some intrinsic factors. Length-weight relationships (LWRs) showed highly significant positive relationships for *A. qanati* as it can be seen in other reports of this genus (Table 4) in the range of 2.5-3.6 (Treer et al., 2000; Patimar et al., 2012; Tabatabaei et al., 2014). The estimation of *b* parameter is remained within the expected range of 2.5–4 reported by Tesch (1971). The upper limit showing deep body form and that fish getting more weight as its length increases. The reasons for the variation of *b* in the different regions are reported to be due to seasonal fluctuations in environmental parameters,

Table 3. Maximum observed length (TL, cm) and age (years) for different *Alburnoides* species in the European region and Iran. A.B., *A. bipunctatus*; A.E., *A. eichwaldii*; A.N., *A. namaki*; A.Q, *A. qanati*; F, female; M, male; U, unsexed; * mean TL.

Species	Sex	TL	Age	Country	Reference
A.B.	F	10.3	6+	Velika Morava River, former Yugoslavia	Soric and Ilic (1985)
A.B.	F	12.53	6+	Oltu stream, Coruh Basin, Turkey	Yıldırım et al. (1999)
A.B.	U	11.72	---	Rudava River, Slovakia	Siryova (2004)
A.B.	F	11.0	4+	Sava River, Croatia	Treer et al. (2006)
A.B.	U	13.0 (SL)	---	European freshwater systems	Kottelat and Freyhof (2007)
A.B.	U	16.0	3+	Azerbaijan	Abdurahmanov (1962)
A.B.	U	12.5	---	Madarsu Stream, National Park of Golestan, northern Iran	Akbaripasand (1999)
A.E.	U	15.0	---	Sardabroud River, northern Iran	Abdoli (2000)
A.E.	M	9.5	4+	Zarrin-Gol River, northern Iran	Patimar and Dowlati (2007)
A.E.	F	11.0	4+	Zarrin-Gol River, northern Iran	Patimar and Dowlati (2007)
A.E.	U	14.0	6+	Rivers of northern Iran	Abdoli and Naderi (2009)
A.E.	M	11.0	4+	Qanat of Uzineh, northern Iran	Patimar et al. (2012)
A.E.	F	11.1	4+	Qanat of Uzineh, northern Iran	Patimar et al. (2012)
A.N.	M	6.06*		Gharachai, Namk basin, Iran	Tabatabaei et al. (2014)
A.N.	F	7.45*		Gharachai, Namk basin, Iran	Tabatabaei et al. (2014)
A.N.	M	6.49*		Jajrud, Namak basin, Iran	Tabatabaei et al. (2014)
A.N.	F	6.91*		Jajrud, Namak basin, Iran	Tabatabaei et al. (2014)
A.N.	M	8.41*		Cheshme Ali, Kavir basin, Iran	Tabatabaei et al. (2014)
A.N.	F	8.62*		Cheshme Ali, Kavir basin, Iran	Tabatabaei et al. (2014)
A.E.	M	8.01*		Tajan River, Caspian basin, Iran	Tabatabaei et al. (2014)
A.E.	F	8.70*		Tajan River, Caspian basin, Iran	Tabatabaei et al. (2014)
A.Q.	M	8.71		Kor River basin, Iran	Present study
A.Q.	F	11.87		Kor River basin, Iran	Present study

physiological conditions of the fish at the time of collection, sex, gonad development, food availability and quality in habitat, diet, stomach fullness, health and the preservation techniques of the samples (Tesch, 1971; Esmaeili, 2001; Esmaeili and Ebrahimi, 2006; Esmaeili et al., 2014c).

Fitting the von Bertalanffy growth formula (VBGF) to back-calculated lengths resulted in the estimation of higher values of L-infinity than the maximum observed total lengths for both sexes. 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 (see Bagenal and Tesch, 1978; Patimar et al., 2012). It is theoretically admitted that growth parameters L_∞ and *K* are negatively correlated (Gaertner et al., 2008). The parameters of von Bertalanffy's equation obtained for linear growth of *A. qanati* confirm the theoretical assumption explained in Raikova-Petrova et al. (2011) that the smaller (L_∞), shows a faster growth rate (*K*) which is remarkably exhibited in male and female populations of *A. qanati*. The *K* parameter of male specimens is higher than females (0.49 vs. 0.31, respectively) revealing that the male grows rapidly initially and approaches its asymptotic length (L_∞=93 mm) earlier in life. The same as other species of the family Cyprinidae, the females of *A. qanati* were found to have reasonably larger L_∞ (123.9 vs. 93 mm, respectively) and smaller *K*-values than males (0.31 vs.0.49, respectively).

A comparison between estimates of von Bertalanffy

Table 4. Parameters of the length-weight relationship of spirlins, *Alburnoides* species. A.B., *A. bipunctatus*; A.E., *A. eichwaldii*; A.N., *A. namaki*; A.Q., *A. qanati*; F, female; M, male; C, combined sex; P, population.

Species	Area	Sex	Length	α	*b*	Reference
A.B.	Dobra River, Croatia	C	TL	0.0059	3.2245	Treer et al. (2000)
A.B.	Bednja River, Croatia	C	TL	0.0150	2.7970	Treer et al. (2000)
A.B.	Middle Korana River, Croatia	C	TL	0.0088	3.1043	Treer et al. (2000)
A.B.	Lower Korana River, Croatia	C	TL	0.0030	3.5567	Treer et al. (2000)
A.B.	Sava River, Croatia	C	TL	0.0044	3.4032	Treer et al. (2000)
A.B.	Çoruh River, Turkey	C	FL	0.0249	2.79	Torcu-Koç et al. (2006)
A.B.	Çoruh River, Turkey	F	FL	0.0375	2.62	Torcu-Koç et al. (2006)
A.B.	Çoruh River, Turkey	M	FL	0.0166	2.95	Torcu-Koç et al. (2006)
A.B.	Sava River, Croatia	C	TL	0.0083	3.025	Treer et al. (2006)
A.B.	Seyhan Dam Lake, Turkey	C	TL	0.0028	2.72	Ergüden and Goksu (2009)
A.B.	Emajõgi River Basin, Estonia	C	SL	0.0103	3.251	www.fishbase.org
A.E.	Zarrin-Gol River, northern Iran	M	TL	0.0054	2.59	Patimar and Dowlati (2007)
A.E.	Zarrin-Gol River, northern Iran	F	TL	0.0088	2.52	Patimar and Dowlati (2007)
A.E.	Qanat of Uzineh, northern Iran	M	TL	0.0068	3.2559	Patimar et al. (2012)
A.E.	Qanat of Uzineh, northern Iran	F	TL	0.0079	3.2067	Patimar et al. (2012)
A.E.	Qanat of Uzineh, northern Iran	P	TL	0.0072	3.2387	Patimar et al. (2012)
A.Q.	Gharachai, Namk basin, Iran	F	TL	0.01	2.87	Tabatabaei et al. (2014)
A.Q.	Gharachai, Namk basin, Iran	M	TL	0.01	3.05	Tabatabaei et al. (2014)
A.Q.	Jajrud, Namak basin, Iran	F	TL	0.01	3.26	Tabatabaei et al. (2014)
A.Q.	Jajrud, Namak basin, Iran	M	TL	0.01	3.20	Tabatabaei et al. (2014)
A.Q.	Cheshme Ali, Kavir basin, Iran	F	TL	0.02	2.77	Tabatabaei et al. (2014)
A.Q.	Cheshme Ali, Kavir basin, Iran	M	TL	0.01	3.05	Tabatabaei et al. (2014)
A.E.	Tajan River, Caspian basin, Iran	F	TL	0.01	3.26	Tabatabaei et al. (2014)
A.E.	Tajan River, Caspian basin, Iran	M	TL	0.01	3.30	Tabatabaei et al. (2014)
A.Q.	Kor River basin, Iran	F	TL	0.0033	3.45	Present study
A.Q.	Kor River basin, Iran	M	TL	0.0033	3.44	Present study

length-at-age growth parameters for different species and populations of spirlins (Skorva, 1972; Breitenstein and Kirchhofer, 2000; Treer et al., 2000; Treer et al., 2006; Raikova-Petrova et al., 2011; Seifali et al., 2012; Patimar et al., 2012; Tabatabaei et al., 2014 and present study) reveals that these parameters vary for different populations, species at different water bodies (e.g. qanat, stream, river) and different distribution ranges (Table 5). The L_∞ and *K*-values ranges from 93 to 123.9 and 0.31 to 0.49, respectively. Many studies have revealed that under different environmental conditions, biological features such as life span (Abdoli et al., 2007; Mann et al., 1984; Ricker, 1975), age at maturity (Lobón-Cerviá et al., 1996), age structure and growth rate (Abdoli et al., 2007; Kamal et al., 2009; Patimar et al., 2012b; Basilone et al., 2004; Naddafi et al., 2005; Tabatabaei et al., 2014), the maximum length (L_∞) (Basilone et al., 2004; Kamal et al., 2009; Naddafi et al., 2005; Tabatabaei et al., 2014) can change. For example, according to Saifali et al. (2012), population parameters for south Caspian spirlin (*A. eichwaldii*) are as follows: Asymptotic length (L_∞) =104.48 mm; Growth co-efficient (*K*/year)= 1.19; Natural mortality (*M*/year)= 0.97; Fishing mortality (*F*/year)= 2.43; Total mortality (*Z*/year) =3.4 and Exploitation level (*E*)= 0.71.

In the present work, Ø' was estimated to be 3.86 and 3.75 for female and male (based on the L_∞ of 9.3 cm and 12.39 cm) specimens of *A. qanati*, respectively, which is less than other spirlins (Table 6). According to Pauly (1979), phi prime values are very similar within related taxa and have narrow normal distributions. However, similarity of this index in

Table 5. Estimates of von Bertalanffy length-at-age growth parameters for populations of different *Alburnoides* species in the distribution area (Iran and European regions). A.B., *A. bipunctatus*; A.E., *A. eichwaldii*; A.N., *A. namaki*; A.Q, *A. qanati*;, F, female; M, male; U, unsexed.

Species	Location	Sex	L_∞ (mm)	K (year^{-1})	T_0 (year)	Reference
A.B.	Dunajec River, Czechoslovakia	U	20.1	0.15	---	Skora (1972)
A.B.	Turiec River, former Czechoslovakia	U	15.6	0.28	---	Bastl et al. (1975)
A.B.	Radimna River, Romania	U	14.4	0.30	---	Papadopol and Cristofor (1980)
A.B.	Dobra River, Croatia	U	20.5	0.16	–1.38	Treer et al. (2000)
A.B.	Bednja River, Croatia	U	15.5	0.33	–0.42	Treer et al. (2000)
A.B.	Middle Korana River, Croatia	U	15.1	0.28	–0.86	Treer et al. (2000)
A.B.	Lower Korana River, Croatia	U	17.7	0.19	–1.47	Treer et al. (2000)
A.B.	Sava River, Croatia	U	11.5	0.59	–0.47	Treer et al. (2000)
A.B.	Sava River, Croatia	U	12.0	0.59	–0.14	Treer et al. (2006)
A.E.	Zarrin-Gol River, northern Iran	M	99.64	0.51	–0.715	Patimar and Dowlati (2007)
A.E.	Zarrin-Gol River, northern Iran	F	107.23	0.55	–0.548	Patimar and Dowlati (2007)
A.E.	Qanat of Uzineh, northern Iran	M	140.7	0.27	–0.92	Patimar et al. (2012)
A.E.	Qanat of Uzineh, northern Iran	F	153.7	0.23	–1.08	Patimar et al. (2012)
A.E.	Qanat of Uzineh, northern Iran	U	148.3	0.24	–1.04	Patimar et al. (2012)
A.E.	Kesselian Stream, Caspian Sea, Iran	U	104.5	1.19	---	Seifali et al. (2012)
A.N.	Gharachai, Namk basin, Iran	U	122.43	0.27	–0.76	Tabatabaei et al. (2014)
A.N.	Jajrud, Namak basin, Iran	U				
A.N.	Cheshme Ali, Kavir basin,	U	112.66	0.54	0.18	Tabatabaei et al. (2014)
	Iran		120	0.29	–1	Tabatabaei et al. (2014)
A.E.	Tajan River, Caspian basin,	U				
	Iran		123.01	0.29	–1	Tabatabaei et al. (2014)
A.Q.	Kor River basin, Iran	F	123.9	0.31	---	Present study
A.Q.	Kor River basin, Iran	M	93	0.49	---	Present study

Table 6. Phi prime (Ø′) values of different species of Alburnoides from Europe and Iran.

Locality	Species	Ø′	Reference
Turiec ,Slovenian	*A. bipunctatus*	4.22	Bastl et al. (1975)
Radimna, Slovenian	*A. bipunctatus*	4.13	Papadopol and Cristofor (1980)
Croatian- Slovenian	*A. bipunctatus*	4.17	Treer et al. (2000)
Caspian Sea, Iran	*Alburnoides* sp.	4.87	Saifali et al. (2012)
Kor river, Iran	*A. qanati* (F)	3.86	Present study
Kor river, Iran	*A. qanati* (M)	3.75	Present study

northern populations of *Alburnoides* (ex. south Caspian Sea spirlin and the European populations) and its difference with *A. qanati* may reflect the distinctiveness of northern and southern populations of *Alburnoides*.

Mortality parameters are higher for Caspian spirlin than *A. qanati* from Kor Basin; it can be due to more sympatric predator species and over-fishing activities in Caspian Basin. Being small spring, Moshkan has no predatory fish, and *A. qanati* and

Oxynemacheilus persa are the only fish species inhabit in this stream. It also has been reported that the spirlin population reflects the changes in habitats (Jurajda et al., 1996); therefore, water dam construction can critically endanger this species (Lusk, 1995) which can be considered for all species of genus *Alburnoides* including *A. qanati* species (Kirchhofer, 1997; Lusk et al., 1998; Treer et al., 2006).

Based on the available data, it can be concluded that many factors affect growth parameters of fish populations. The commonly proposed explanations include the effects of changes in environment conditions, (most notably temperature and food availability), density-dependent effects, eutrophication, habitat disruption and specific species characteristics. These factors can operate singly or in combination and have positive or negative effects on growth parameters. According to Ma et al. (2010), the slow-growing and long-lived fish tend to be, particularly, vulnerable to excessive mortality and rapid stock collapse and population turnover may be lower than expected recovery. Study of these parameters for the endemic fish, *A. qanati* is highly recommended.

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