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Age and growth of spirlins, *Alburnoides eichwaldii* and *A. namaki*, from the Caspian, Kavir and Namak basins of Iran

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Abstract: This study presents data on age structure, sex ratio, growth, length-weight relationships and condition factor of four populations (n=312) of two *Alburnoides* species, collected in 2005 and 2006 from the Tajan River (Caspian Sea Basin), the Ghara-Chai and Jajrud rivers (Namak Lake Basin), and Cheshmeh-Ali Spring (Kavir Basin) of Iran. Sex ratio of the fish, in the studied localities, except in Jajrud River, was not significantly deviated from the equal sex ratio. The female fish had higher weight, length and condition factor compared to the male fish. The growth pattern of the female fish in Cheshmeh-Ali Spring was isometric, but allometric in other localities. The growth pattern of all male fish, except the ones from Jajrud River, was allometric. The age groups were 0^+-5^+. The prevailing age groups were 0^+, 1^+, 2^+, and 3^+, in Jajrud River, Ghara-Chai River, Tajan River, and Cheshmeh-Ali Spring, respectively. Fish in Jajrud River had higher overall growth performance and K-values, compared to the other populations.

Keywords: Back calculation, Condition factor, Prevailing age group, Sex ratio.

Introduction

Riffle minnows of the cyprind genus *Alburnoides*, formerly considered as *A. bipunctatus* species complex are distributed across the Europe and the Middle East from France eastwards to the Black, Caspian and Aral Sea basins (Bogutskaya et al. 2010; Coad & Bogutskaya 2009; Esmaeili et al. 2010). They inhabit both running and stagnant waters, middle and upper reaches of rivers, mountainous freshwater lakes and lower parts of some rivers, and feed mainly on small planktons and benthic organisms (Abdoli 2000). The spirlin populations reflect the changes in habitats (Jurajda & Hohausova 1996); constructions in rivers can critically endanger this species (Lusk et al. 1995). It has been revealed that more species of spirlin inhabit freshwaters of Iran, compared to what was known previously. *Alburnoides eichwaldii* and *A. namaki* are new species of spirlin described from Iran (Bogutskaya & Coad 2009; Coad & Bogutskaya 2009). *Alburnoides eichwaldii* is one of the most abundant species in the Caspian Rivers that prefers well-oxygenate, unpolluted waters and hard stream beds (Coad 2014). Some morphological features shared between *A. eichwaldii* and *A. namaki* are small size, deep body, large eyes, and moderately rounded caudal fin. The species feed mostly on insect larvae including Simuliidae, Plecoptera, Ephemeroptera, Chironimidae and Trichoptera and during the latter stages of life cycle, feed on terrestrial organisms falling into the water (Abdoli 2000; Coad 2014).

Information on fish age structure is one of the most important biological data, because such data are the basis for calculation of growth and birth-death rates (Campana 2001). Length-weight relationships allow fisheries scientists to convert growth-in-length equations to growth-in-weight in stock assessment models (Ozaydin & Taskavak 2006). Length-weight relationships are also useful for the estimation of biomass (Dulčić & Kraljević 1996), fish condition (Petrakis & Stergiou 1995), weight corresponding to a given length, growth rate, length and age structure, and other components of fish population dynamics for which the length and weight data are needed (Cherif et al. 2008; Froese 2006).

The growth parameters of spirlin species can significantly reflect the condition of niche used by the species and can be used to compare different habitats (Treer et al. 2000). To estimate the potential vulnerability of stocks to excessive exploitation, the growth coefficient (k) can be useful (Ma et al. 2010). The life history of spirlin in the qanat (a traditional water transfer system in Iran) of Uzineh (Patimar et al. 2012b) as well as length-weight relationship in Tajan River (Patimar et al. 2012a) were studied. However, there is no published data on age and growth of them in the mentioned River. Hence, as a preliminary step, this study was conducted to explore the age structure, growth, length-weight relationships and condition factors of *A. eichwaldii* in the Tajan River (south Caspian Sea basin) and *A. namaki* in Ghara-Chai and Jajrud rivers (Namak Lake basin) and Cheshmeh-Ali Spring (Kavir Basin).

Materials and methods

Fishes (n= 312) were collected by electrofishing in four localities from the Caspian Sea, Kavir, and Namak Lake basins (Table 1, Fig. 1). The number of specimens collected in each locality was limited by the fish availability. The specimens were preserved in 4% formalin after death from over-anaesthetization using Clove extract. The sex of the specimens was determined visually or using a binocular microscope. The specimens that could not be sexed, excluded from the sex based analyzes. Chi-Square test (x^2) was applied to compare the observed sex ratios to the equal (1:1) sex ratio. The Total length and weight were measured to the nearest 1mm and 0.1g, respectively (Table 2). For the age determination, 10-15 scales were taken from left side of the fish, between the dorsal fin and lateral line (Kamal et al. 2009).

The length-weight relationship and Condition factor (Cf) were calculated applying the following equations (Froese 2006), respectively, where W = weight in grams, L= total length in centimeters, and α and b are the constants.

$$W=aL^b$$

$$Cf=\frac{100\times W}{L^3}$$

Condition factor values were exposed to ANOVA to test the mean differences at intra-locality (t-test between male and female at each locality) and inter-locality levels. To compare the calculated b-values to the b value of isometric growth (b=3) t-test was conducted using following equation (Pauly 1984):

$$\hat{t}=\frac{s.d._{(X)}}{s.d._{(y)}}\times\frac{|b-3|}{\sqrt{1-r^2}}\times\sqrt{n-2}$$

Where $s.d._{(X)}$ is the standard deviation of the $log\ L$ values, $s.d._{(y)}$ is the standard deviation of the $log\ w$ values, n is the number of fish included in the calculation, r^2 is the coefficient of determination, and b is the slope of log transformed linear regression. The back calculation of the growth in length was studied using the Fraser-Lee equation (4) (Kamal et al. 2009):

$$L_i = a + S_i\,(L_a - a)\,S_a^{-1}$$

Where L_i = the total length at age i, a = the regression constant of body length and scale radius, S_i = the mean scale radius at age i, L_a = the total length at sampling, and S_a = the mean scale radius. Length at age was modeled using von Bertalanffy growth function (equation 5) (Ricker 1975):

$$L_t = L_\infty\,(1-e^{-k\,(t-t0)})$$

Where L_t = total length at age t, L_∞= the maximum

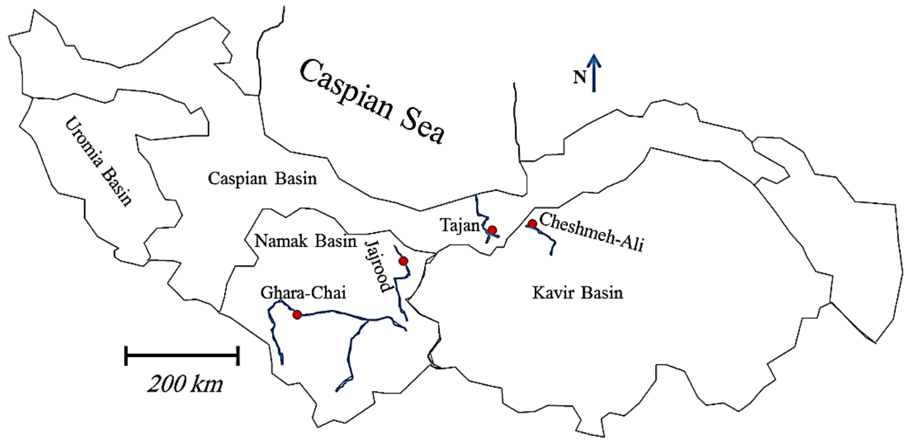

Fig.1. Map of the sampling localities in the three studied basins of Iran.

length or the asymptotic length to which a fish should reach if it continue to live and grow, K= the growth coefficient that shows the rate at which fish approaches L_∞, and t_0= the hypothetical age of the fish for L= 0. The overall growth performance (Φ) (Munro & Pauly 1983) was calculated using the following equation:

$$\Phi = ln(K) + 2\ ln(L_\infty)$$

The calculations were conducted using SYSTAT 9.0, online Graphpad (www.graphpad.com) and Excel 2010 software.

Results

The sex ratios except in Jajrud River were not deviated significantly from 1:1 sex ratio (P>0.05, Table 2). In all the studied populations, females were of higher length, weight and condition factors compared to the male counterparts (Table 2). Condition factor values of *A. namaki* females in Ghara-Chai and Cheshmeh-Ali were significantly higher than the Cf values calculated for males (P<0.05), while the inter-sex difference in Jajrud (*A. namaki*) and Tajan rivers (*A. eichwaldii*) was not significant (P≥0.05). The pairwise differences of the *Cf* values at inter-locality level were significant (P<0.05), except between the samples from Tajan and Jajrud rivers (P≥0.05).

The length-weight relationship parameters a, b, R^2 for females, males and the pooled sexes were estimated (Table 3). There was a significant relationship between the length and weight of females, males and all specimens for all the species in the studied localities (P<0.001). Based on the t-test values, female fish in Cheshmeh-Ali Spring showed isometric growth, but all female fish in the other three localities showed allometric growth pattern (P<0.05, Table 4). All the male individuals, except the ones from Jajrud River, showed isometric growth (P>0.05, Table 4).

Ages of the fishes ranged from 0^+ to 5^+ for both sexes (Fig. 2). The age classes of *A. namaki* were 0^+-3^+ in the Ghara-Chai River, 0^+-3^+ in the Jajrud River, and 1^+-5^+ in the Cheshmeh-Ali Spring. The age classes of *A. eichwaldii* were, 2^+-5^+ in the Tajan River (Fig. 2); and the most abundant age classes were 1^+ in the Ghara-Chai River, 0^+ in the Jajrud River, 3^+ in the Cheshmeh-Ali Spring, and 2^+ in the Tajan River (Fig. 2).

The Von Bertalanffy growth functions were $L_t = 122.43\ (1-e^{-0.27(t+0.76)})$ in Ghara-Chai, $L_t = 123.01\ (1-e^{-0.29(t+1)})$ in Jajrud, $L_t = 120\ (1-e^{-29(t+1)})$ in the Cheshmeh-Ali Spring, and $L_t = 112.66\ (1-e^{-0.54(t-0.18)})$ in Tajan River (Table 5). The overall growth performance and K-values in Jajrud River were higher compared to the values in the other localities and the asymptotic length (L_∞) in the Jajrud River was smaller compared to the value in other localities (Table 5).

Table 1. Locations, geographic coordinates, details of sampling and some physic-chemical parameters of water in studied regions (the data for Ghara-Chai are for September 2006; while for other stations the annual means are presented).

Species	Basin	Locality	Geographic coordinates	Date	Sampling method	Altitude (m)	pH	EC (µs/cm)	Temperature (°C)
A. namaki	Namak Lake	Ghara-Chai	49° 36 ´ 6.42 " E, 34° 49 ´ 47.19" N	September 2006	Electro fishing	1592	8.22	1605	19.7
A. namaki		Jajrood	51° 41 ´ 37.49" E, 35° 45 ´ 41.27"N	March. 2005	Electrofishing	1410	8.40	-	21
A. namaki	Kavir	Cheshmeh-Ali	54° 05' 29.86" E, 36° 16 ´ 37.41" N	September 2006	Cast net	1980	7	537	14.46
A. eichwaldii	Caspian Sea	Tajan	53° 22 ´ 37.92" E, 36° 08 ´ 27.36" N	September 2006	Electrofishing	800	8.38	538	12.9

Table 2. Locations, geographic coordinates, details of sampling and some physic-chemical parameters of water in studied regions (the data for Ghara-Chai are for September 2006; while for other stations the annual means are presented).

Species	Locality	Female				Male				All				
		N	TL	BW	CF	N	TL	BW	CF	N	TL	BW	CF	Sex ratio M/F
A. namaki	Ghara-Chai	68	74.51±10.42	4.78±1.92	1.09±0.16	76	60.62±12.29	2.66±1.63	1.06±0.11	147	66.74±13.58	3.61±2.07	1.08±0.10	$1:0.89^{ns}$
A. namaki	Jajrud	21	69.14±20.24	5.63±4.35	1.29±0.17	50	64.92±18.46	4.50±3.75	1.26±0.14	82	63.37±19.06	4.33±3.88	1.26±0.15	$1:0.42^{*}$
A. namaki	Cheshme Ali	17	86.29±16.01	10.76±5.37	1.57±0.19	23	84.09±10.29	8.74±3.17	1.48±0.17	40	85.03±12.89	9.60±4.31	1.47±0.19	$1:0.74^{ns}$
A. eichwaldii	Tajan	26	87.04±12.26	9.32±4.89	1.31±0.09	17	80.06±4.63	6.67±1.45	1.28±0.09	43	84.28±10.44	8.27±4.09	1.30±0.09	$1:1.53^{ns}$

ns: none significant; *: Significant differences

Table 3. Parameters of length- weight relationships (a, b, r^2).

Species	Locality	Female				Male				pooled sex			
		a	b	r^2	Linear relationship	a	b	r^2	Linear relationship	a	b	r^2	Linear relationship
A. namaki	Ghara-Chai	0.01	2.87	0.96	*LogW*= -1.85+ 2.87 *LogL*	0.01	3.05	0.98	*LogW*=-2.02 + 3.05 *LogL*	0.01	3.05	0.98	*LogW*= -2.10 + 3.05 *LogL*
A. namaki	Jajrud	0.01	3.26	0.99	*LogW*= -2.11 + 3.26 *LogL*	0.01	3.20	0.99	*LogW*= -2.06 + 3.20 *LogL*	0.01	3.22	0.99	*LogW*= -2.07 + 3.22 *LogL*
A. namaki	Cheshmeh-Ali	0.02	2.77	0.95	*LogW*= -1.59 + 2.77 *LogL*	0.01	3.05	0.91	*LogW*= -1.90 + 3.05 *LogL*	0.02	2.90	0.92	*LogW*= -1.73 + 2.89 *LogL*
A. eichwaldii	Tajan	0.01	3.26	0.98	*LogW*=-2.13+3.26*LogL*	0.01	3.30	0.88	*LogW*=-2.16+3.30*LogL*	0.97	3.27	0.01	*LogW*=-2.14+3.27*LogL*

a, intercept; b, regression slope; r^2, coefficient of determination

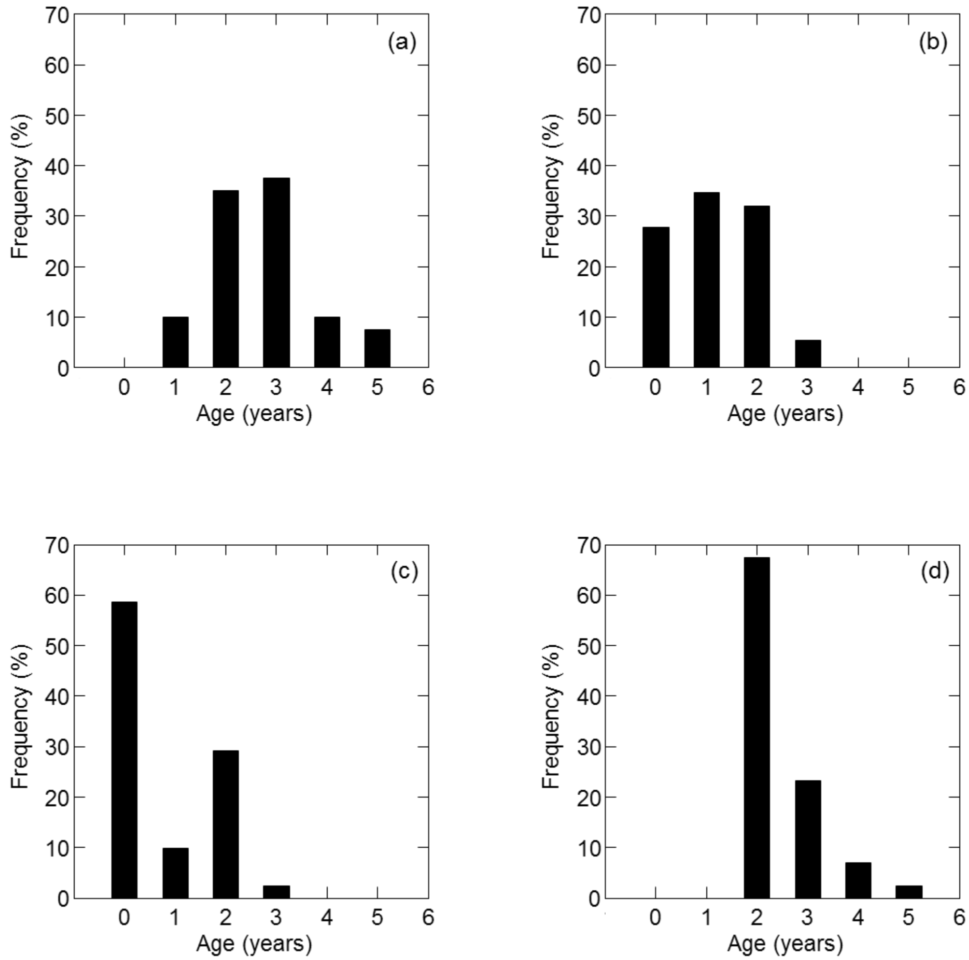

Fig.2. Frequency of age classes in four studied populations (a) *A. namaki* in Cheshmeh-Ali spring, (b) *A. namaki* in Ghara-Chai River, (c) *A. namaki* in Jajrud River and (d) *A. eichwaldii* in Tajan River.

Table 4. Results of t-test analyses used to compare calculated female and male b values to the isometric *b* value (3).

Locality	Female			Male		
	t	***df***	***p***	***t***	***df***	***p***
Cheshmeh-Ali	1.40	15	P> 0.05	0.23	21	P> 0.05
Jajrud	3.45	19	P< 0.05	4.31	48	P< 0.05
Ghara-Chai	1.80	66	P< 0.05	0.98	74	P> 0.05
Tajan	2.74	24	P< 0.05	0.95	15	P> 0.05

Table 5. Growth parameters of spirlin in studied regions. Parameters of von Bertalanffy growth curves (L, K, t_0, r^2), Overall growth performance (Φ).

Species	Locality	L_∞	K	t_0	r^2	Φ
A. namaki	Ghara-Chai	122.43	0.27	-	0.97	8.31
A. namaki	Jajrud	112.66	0.54	0.18	0.98	8.83
A. namaki	Cheshmeh-Ali	120	0.29	-1	0.99	8.34
A. eichwaldii	Tajan	123.01	0.29	-1	0.99	8.40

L∞, asymptotical length; K, growth coefficient; t_0, the hypothethical age of the fish at age of 0; r^2, determination coefficient

Discussion and conclusion

The sex ratios, except in in Jajrud River (P<0.05), were not significantly deviated from the equal sex ratio (P≥0.05). The equal sex ratios are ideal, because

Table 6. Growth parameters reported for spirlin from south Caspian Sea basin.

Locality	L_∞	K	b	Age groups	Reference
Keselian River	104.48	1.19	3.12	-	Seifali et al. (2012)
Uzineh Qanat	14.83	0.24	3.24	0-4	Patimar et al. (2012b)
Branches of Talar River	-	-	2.56 and 2.73	0-3	Ahmadi et al. (2011)
Tajan River	-	-	2.90	-	Patimar et al. (2012a)

in the cases of the sex ratio bias in favor of one sex, the population effective size would decrease (Hallerman 2003), and in turn it can lead to the reduction of the population biological diversity and its fitness. The significant biased sex ratio observed in Jajrud River may be an indication of the environmental pressures on this population and the possible decrease in diversity and fitness of this population. However, it can be clarified by ecological and population genetic studies.

The intersex differences, observed in length-weight relationships developed for the studied populations, can be caused by sex related differences of fish growth (Patimar et al. 2012b). In this study the pooled-sex *b*-value for *A. eichwaldii* in Tajan River was 3.27 that is close to the values reported by Seifali et al. (2012) and Patimar et al. (2012b); but different from the values reported by Patimar et al. (2012a), and Ahmadi et al. (2011) (Table 6). Life stage, sex, season (Froese 2006), sample size, population attributes and local environmental conditions can affect length-weight relationship parameters (Alavi-Yeganeh et al. 2011; Golzarianpour et al. 2011; Daneshvar et al. 2013; Hasankhani et al. 2013; Esmaeili et al. 2014a; Ghanbarifardi et al. 2014; Hasankhani et al. 2014). Any one of the mentioned parameters can bear a role in shaping the results observed in this study. To clarify more effective factors, the populations should be exposed to long term ecological studies.

Growth parameters of *A. eichwaldii* in Tajan River are similar to *A. namaki*, except in Jajrud River. Actually, *A. namaki* in Jajrud River had different growth parameters compared to the fish from other two rivers. 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), the maximum length (L_∞) (Basilone et al. 2004; Kamal et al. 2009; Naddafi et al. 2005), and Condition factor (Sandström et al. 1995) can change. The specimens having higher growth rate (k), approach the asymptotic length (L_∞) earlier (Patimar et al. 2012b). The studied part of Jajrud River is exposed to varying environmental conditions and due to its situation which is downstream to a dam, during some periods, it experiences drought or increased floods in pluvial periods; therefore it would be probable for this population to grow at higher rates and reach sexual maturity and maximum length to insure its persistence under varying environmental conditions, because 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 (Ma et al. 2010).

In Ceshmeali Spring, *A.* cf. *namaki* compared to the studied rivers had higher mean condition factor, mean length, and weight. This observation, probably, can be due to the relatively stable temperature, food abundance and other ecological parameters ruling in spring microhabitat, but it should also be indicated that sampling error may also be a factor. Similar results had been reported for *A. bipunctatus* in a qanat (Patimar et al. 2012b) and *Aphanius kavirensis* (Esmaeili et al. 2014b) in Cheshmeh-Ali Spring (Kamal et al. 2009).

In spite of the fact that producing life history data for a species in different habitats will be useful to compare life history and morphological aspects of its populations inhabiting different localities (Cherif et al. 2008), the results observed here or in the above mentioned studies all indicate that spirlin populations have different life histories in different habitats.

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