Ann. Limnol. - Int. J. Lim. 2020, 56, 26
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https://doi.org/10.1051/limn/2020025

Available online at:
www.limnology-journal.org

RESEARCH ARTICLE

Age and growth of a newly described barb, *Capoeta coadi* (Cyprinidae), in Beheshtabad River, Tigris basin

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Received: 27 March 2020; Accepted: 22 October 2020

Abstract – The Coad barb, *Capoeta coadi* Alwan, Zareian and Esmaeili, 2016, is a newly described endemic fish in Beheshtabad River, Tigris basin of Iran and little is known about its life-history. Life history characteristics were examined in 426 specimens collected monthly from Beheshtabad River (central Iran) during May 2013 to May 2014. The sex ratio was 1M:0.7F. Based on scale and opercular readings, the maximum ages of the population were 8^+ years for females and 7^+ for males. The most frequent age groups were 3^+ and 4^+ in males and females, respectively. Size varied from 8.94 to 42.95 cm in fork length and weight between 10.3 and 1255.5 g. Length–weight relationship implied that the growth was negatively allometric for both sexes. The von Bertalanffy growth model was estimated as $Lt=35.97[1-e^{-0.205(t+0.586)}]$ and $Lt=49.31[1-e^{-0.162(t-0.208)}]$ for males and females, respectively. The growth performance index was estimated as 5.58 and 5.97 for males and females, respectively, indicating a faster growth rate for females.

Keywords: Growth performance / Iran / LWR / sex ratio / von Bertalanffy

1 Introduction

There are about 290 freshwater fish in Iran, mostly belonging to the Cyprinidae family (Esmaeili *et al.*, 2017). The cyprinid fish, Coad barb, *Capoeta coadi* Alwan, Zareian and Esmaeili, 2016, previously included in *C. damascina* (Valenciennes, 1842) species group, is an abundant endemic fish in the Karun River basin of Iran (Alwan *et al.*, 2016a,b; Keivany *et al.*, 2016). Although many characteristics of the other barbs in Middle East have been studied extensively (Khalaf, 1987; Stoumboudi *et al.*, 1993; Fishelson *et al.*, 1996; Esmaeili *et al.*, 2007; Abdoli and Mostafavi, 2009; Soofiani and Asadollah, 2010; Asadollah *et al.*, 2011; Samaee and Patzner, 2011; Marammazi *et al.*, 2014; Keivany *et al.*, 2015; Razavipour *et al.*, 2015a,b; Asadollah *et al.*, 2017), there are few articles on the biology of this fish in Karun River basin, where it is caught for consumption by locals and is not under any protection law (Siami *et al.*, 2017).

The aim of this study was to determine some growth characteristics of *C. coadi* including the age and size compositions, length–weight relationship, von Bertalanffy growth model and growth performance index, in Beheshtabad River, a tributary of Karun River in Tigris basin of Chaharmahal-va-Bakhtiari province, Iran, to provide the basic data for its management and conservation in this basin.

2 Material and methods

Beheshtabad River is located approximately 40 km southwest of Shahrekord. Monthly samples were collected from May 2013 to June 2014 using gill nets with different mesh sizes (1−6 cm, 30 m long, 2 m depth) and a total of 426 specimens were caught. Some environmental factors including water temperature, pH, conductivity (EC) and total dissolved solids (TDS) of water were measured and recorded by a HANNA water quality measuring instrument model HI 98129.

All the procedures were based on the accepted protocol and procedures employed by the Iranian Department of Environment. Fish samples were anesthetized in 1% clove oil, fixed in 10% buffered formalin and transported to the laboratory for further analyses. The fork length (FL) was measured to the nearest 0.1 mm and total weight to the nearest 0.01 g. For sex identification, specimens were dissected and their gonads were examined under a stereomicroscope. For the age determination, 10−15 scales were taken from above the lateral line, below the anterior part of the dorsal fin and cleaned by 5% KOH. After preparing the scale, age reading was carried out through microscopic examination of annuli (Biswas, 1993). To validate the ageing, opercles were also aged and each structure was read by three people and coincided readings were recorded. Also, the back calculation was performed using the following equation (Johal *et al.*, 2001).

$$L_n = (S_n/S) \times (L - a) + a \quad (1)$$

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where L_n = length of the fish at a specific age (mm), L = fish length (mm), S_n = radius of the annulus, S = total radius of the scale (mm) and a = intercept of the length-scale radius regression equation. Upon examination of the type of relationships between SL and scale diameter, the Fraser-Lee model was used for back-calculating corresponding lengths attained in the previous years of life. This method is believed to describe accurately the linear body–scale relationship, which is given by Ricker (1975), Francis (1990), Holčík (1998) and Klumbs *et al.* (1999) as

$$\mathrm{SLi} = c + (\mathrm{SL} - c) \times (\mathrm{Si}/S) \quad (2)$$

where SLi = the standard length of the fish when annulus i was formed, SL= the standard length at time of capture, Si = the distance from the scale focus to the annulus i, S = the total scale radius, and c is the intercept (correction term) on the length axis of the linear regression between SL and S. The von Bertalanffy growth parameters were calculated using

$$\text{for FL } L_t = L_\infty[1 - e^{-K(t-t_0)}] \quad (3)$$

and

$$\text{for weight: } W_t = W_\infty[1 - e^{-K(t-t_0)}]^b \quad (4)$$

where L_t = length of fish in cm at age t, L_∞ = asymptotic fish length in cm, e = base of natural log (2.71828), t = fish age (year), t_0 = hypothetical time at which the length of the fish was zero, K= rate at which the growth curve approaches the asymptote, W_t = weight of the fish in grams at age t, W_∞ = asymptotic weight of the fish in grams and b = a constant in the length–weight relationship (Ricker, 1975; Sparre and Venema, 1998). t_0 (year) and k were estimated using the L_∞ and plotting the equation $-\ln(1-L_t/L_\infty)$ against the age (t), where k = regression slope and $t_0 = -a/b$ (von Bertalanffy, 1938). The length–weight relationship (LWR) was calculated by the following formula:

$$W = aL^b \quad (5)$$

where W = weight of fish (g), L = total length (cm), a = Intercept and b = the slope of the regression line. The strength of LWR was evaluated by means of regression coefficient (r^2). The growth pattern in both sexes was determined using Pauly (1984) model:

$$t = \frac{sd \ln L_f}{sd \ln W_t} \times \frac{|b-3|}{\sqrt{1-r^2}} \times \sqrt{n-2} \quad (6)$$

where $sd \ln L_f$ = the standard deviation of the natural logarithm of the fork length, sd ln W_t = the standard deviation of the natural logarithm of the body weight, b = the slope, calculated from the length and weight relationship. Growth performance index (phi-prime index) φ' was computed from the equation (7) (Munro and Pauly, 1983; Pauly and Munro, 1984).

$$\varphi' = Lnk + 2^* LnL_\infty \quad (7)$$

Condition coefficients were calculated for both sexes using the equation (8) (Ricker, 1975).

$$K = (W/FL^3)^* 100 \quad (8)$$

Table 1. Changes in some environmental factors of Beheshtabad River water from May 2013 to June 2014.

Factor	Mean ± SD	Range
Water temperature (°C)	12.5 ± 4.7	3.2–19.7
pH	8.6 ± 0.4	7.9–9.4
EC ($\mu s\,cm^{-1}$)	690 ± 158	504–982
TDS ($mg\,L^{-1}$)	343 ± 82	25–495

W_∞ was estimated by replacing length by L_∞ and b by 3. The condition factor was calculated by Hile (1936) formulae:

$$CF = (W/L3) \times 100 \quad (9)$$

where CF = condition factor, W = total body weight (g) and L = total length (cm). The relative length of gut was calculated following Al-Hussaini (1949) as:

$$\mathrm{RLG} = \mathrm{Li}/\mathrm{TL} \quad (10)$$

where RLG = relative length of gut, Li = gut length (cm) and TL = total length (cm). The feeding intensity was calculated following Desai (1970) as:

$$FI = Wi/W \quad (11)$$

where FI = feeding intensity, Wi = gut weight (g) and W = total body weight (g). For estimating the longitudinal growth, the increased length in both sexes was calculated separately. For mass growth, first mean length was transformed to mean weights using the LWR and then the spontaneous growth was calculated by

$$r = Ln(W_{(t+1)}) - Ln(W_{(t)})/\Delta t \quad (12)$$

where r = specific growth, $W_{(t+1)}$ mean weight of fish at $(t+1)$ year, W_t = mean weight of fish at t year and Δt = time difference between t year and $t+1$ year which is usually considered one year. For comparisons of two means, t-test, and for multiple comparison of means, one-way ANOVA followed by Duncan posthook test at 95% confidence level was used. Chi square test was used for comparing the sex ratio. Statistical analyses were carried out in SPSS 20 and Excel 2016 computer software.

3 Results

3.1 Physicochemical properties of the water

The mean values ± SD and range for water temperature, pH, conductivity (EC) and total dissolved substances (TDS) are indicated in Table 1.

3.2 Length frequency and sex ratio

Amongst the 426 fish examined, 241(56%) were male, 169 (40%) female and 16 (4%) undetermined. The fork length ranged from 8.94 to 42.95 (23.32 ± 6.53 SD) cm and weight

Table 2. Descriptive statistics of length and weight in *C. coadi* in Beheshtabad River in 2013.

Sex	Number	Fork length (cm)		Weight (g)	
		Min–Max	Mean ± SD	Min–Max	Mean ± SD
Undetermined	16	13.2–8.9	10.9 ± 1.2	32.4–10.3	20.8 ± 6.8
Males	241	35.2–11.2	4.5 ± 21.6	594.5–21.8	114.2 ± 175.9
Females	169	42.5–11.7	6.8 ± 27.0	1255.5–24.1	270.0± 359.7
Total	426	42.5–8.9	6.5 ± 23.3	1255.5–10.3	213.4± 242.6

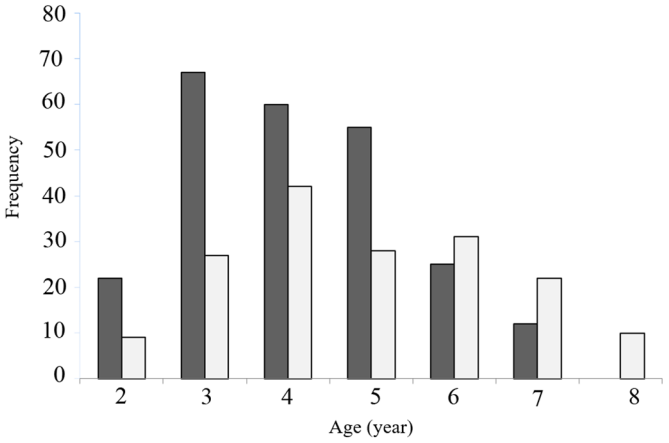

Fig. 1. Age frequency of males (black) and females (white) of *C. coadi* in Beheshtabad River in 2013.

ranged between 10.3 and 1255.5 (242.59 ± 213.5) g. The majority of fish were in the range of 19.10–23.00 cm for males and 23.10–27.00 cm for females (Tab. 2). The maximum age of the population based on scale reading was 7^+ years for males and 8^+ years for females (Fig. 1). The overall sex ratio of males to females was 1M:0.7F and Chi-square analysis showed a significant difference from the expected 1:1 ratio ($\chi^2 = 12.64$, $P < 0.05$).

The smallest mature males and females were in the 11.1–15 and 15.1–19 cm length classes, respectively (The smallest mature male was 11.19 cm and the smallest mature female was 18.50 cm in fork length) (Tab. 2). The mean age at first maturity of *C. coadi* for males was ≤2 years (all specimens at age 2^+ (100%) were mature), and the age at first maturity for females was 3^+ years. Females had a wider length range and were larger than the males ($p < 0.05$) (Tab. 3 and Fig. 2).

The fork length and body weight in males up to two years were higher than females, but reveresed in older ages (Tab. 3). In all ages the back calculated lengths were higher than the observed lengths (Tab. 4).

The length–weight relationship for males, females and all individuals was as $W = 0.026FL^{2.826}$ ($r^2 = 0.95$), $W = 0.0199FL^{2.920}$ ($r^2 = 0.97$) and $W = 0.0202FL^{2.910}$ ($r^2 = 0.97$), respectively, indicating a negative allometric growth pattern for the females, males and all fish specimens (Figs. 3–5) (Pauly, 1984).

3.3 Age, growth and feeding parameteters

The age–length relationships in males, females and all specimens were estimated as $L_t = 56.82[1-e^{-0.162(t+0.208)}]$, $L_t = 35.97[1-e^{-0.205(t+0.586)}]$, and $L_t = 62.52\ [1-e^{-0/09(t+1.12)}]$, respectively (Fig. 3). The age–weight relationships in males and females were estimated as $W_t = 1242.85[1-e^{-0.205(t+0.586)}]^{2.82}$, $W_t = 3357.5\,[1-e^{-0.162(t+0.208)}]^{2.92}$ and $W_t = 3402.7\ [1-e^{-0.09(t+1.12)}]^{2.91}$, respectively (Figs. 6 and 7).

The growth performance index was higher in the females, indicating a faster growth in the females (Tab. 5). The mean

Table 3. Descriptive statistics of length and weight of different ages in *C. coadi* in Beheshtabad River in 2013. Astrix indicate significant differences.

Age	Sex	Number	Fork length	Weight (g)
1	Unknown	16	10.9 ± 1.2	20.8 ± 6.8
2	Male	22	16.2 ± 2.4	76.5 ± 30.8
	Female	9	14.7 ± 2.8	62.4 ± 62.4
3	Male	67	19.0 ± 2.0	113. ± 44.3
	Female	27	20.6 ± 2.8	145.1 ± 1.5
4	Male	60	20.5 ± 1.9	148.4 ± 50.8
	Female	42	24.5 ± 3.3*	240.6 ± 2.41*
5	Male	55	24.0 ± 4.4	229.2 ± 117.7
	Female	28	26.5 ± 4.9*	311.1 ± 3.1*
6	Male	12	26.7 ± 3.9	292.8 ± 132.0
	Female	31	31.2 ± 4.1*	454.6 ± 4.6*
7	Male	9	29.0 ± 3.6	359.7 ± 148.8
	Female	22	34.6 ± 4.8*	695.5 ± 7.0*
8	Male	–	–	–
	Female	10	36.2 ± 4.4	805.7 ± 8.1

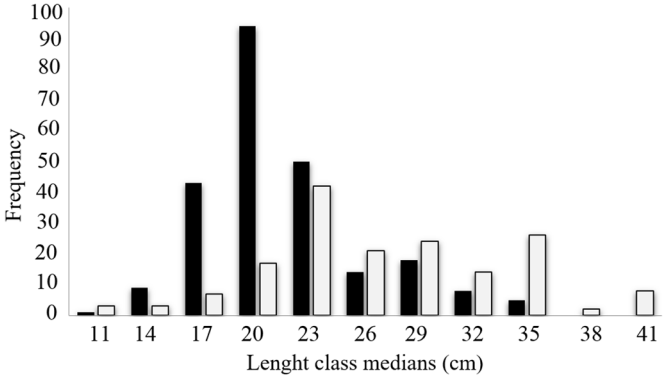

Fig. 2. Length classes of males (black) and females (white) of *C. coadi* in Beheshtabad River in 2013.

Table 4. Mean ± SD of back calculated and observed lengths in *C. coadi* in Beheshtabad River in 2013.

Age	1^+	2^+	3^+	4^+	5^+	6^+	7^+	8^+
Females								
Back calculated FL	–	14.71 ± 2.82	20.63 ± 2.7	24.54 ± 3.28	26.54 ± 4.8	31.21 ± 4.03	34.63 ± 4.64	36.23 ± 4.13
Observed FL	9.1 ± 1.67	12.4 ± 1.29	18.3 ± 2.1	22.1 ± 2.22	25.1 ± 2.94	29.7 ± 3.86	33.1 ± 2.93	35.2 ± 1.97
Males								
Back calculated FL	–	16.16 ± 2.36	18.95 ± 1.96	20.54 ± 1.88	23.95 ± 4.31	26.7 ± 3.84	28.94 ± 3.46	–
Observed FL	10.2 ± 1.06	13.5 ± 1.34	16.08 ± 1.04	18.7 ± 1.41	22.1 ± 3.15	25.3 ± 2.94	27.5 ± 2.96	–
Total								
Back calculated FL	10.9 ± 1.17	16.3 ± 2.68	19.93 ± 2.33	23.11 ± 3.23	27.83 ± 4.65	29.19 ± 4.54	32.62 ± 5.06	36.23 ± 4.13
Observed FL	9.31 ± 1.42	12.85 ± 1.42	17.34 ± 2.04	20.58 ± 2.52	23.74 ± 3.37	27.71 ± 4.1	30.28 ± 4.04	35.2 ± 2.97

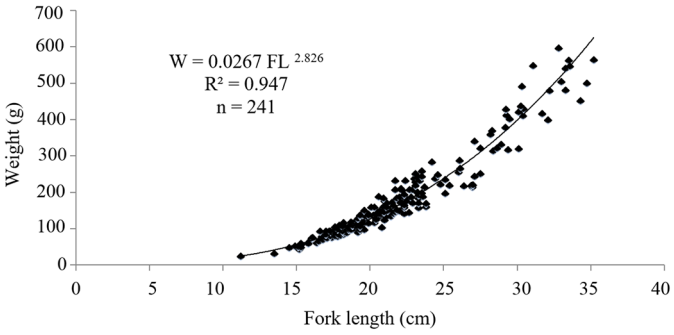

Fig. 3. Length–weight relationship in males of *C. coadi* in Beheshtabad River in 2013.

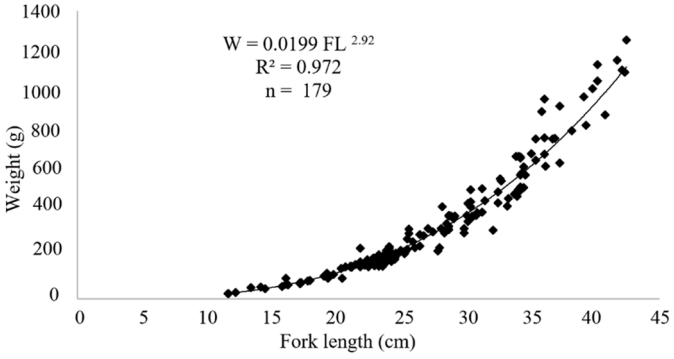

Fig. 4. Length–weight relationship in females of *C. coadi* in Beheshtabad River in 2013.

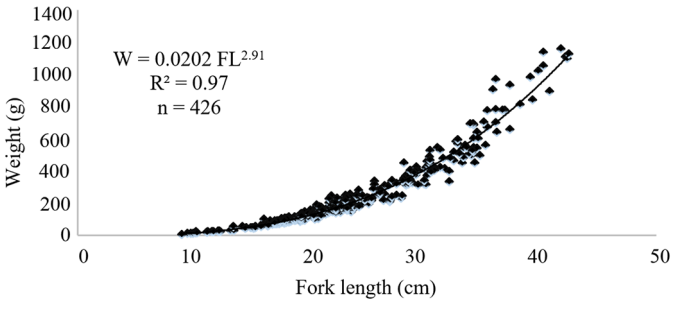

Fig. 5. Length–weight relationship in all specimens of *C. coadi* in Beheshtabad River in 2013.

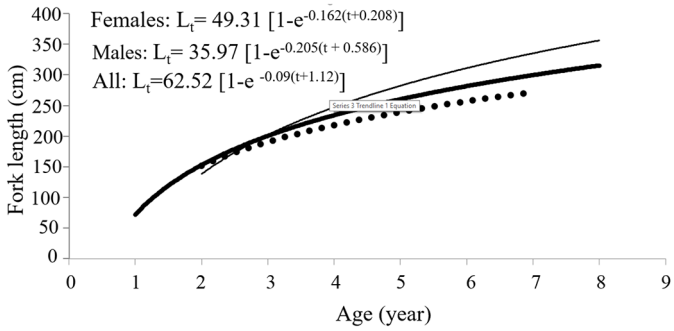

Fig. 6. Length–age relationship in males (dotted line), females (thin line) and all the specimens (thick line) of *C. coadi* in Beheshtabad River in 2013.

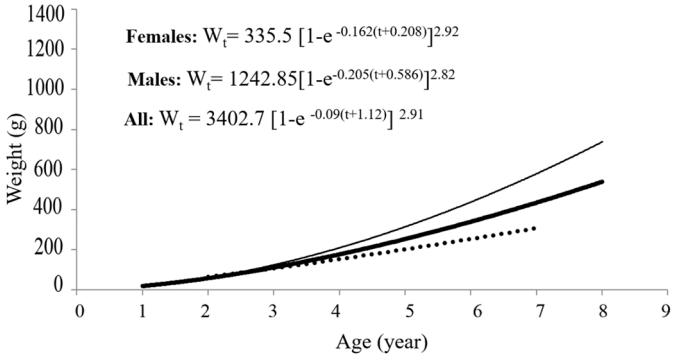

Fig. 7. Weight–age relationship in males (dotted line), females (thin line) and all the specimens (thick line) of *C. coadi* in Beheshtabad River in 2013.

Table 5. von Bertalanffy growth parameters and growth performance index in *C. coadi* in Beheshtabad River in 2013.

Sex	L_∞ (cm)	t_0 (year)	k	φ
Males	35.97	−0.586	0.205	5.58
Females	49.31	−0.208	0.162	5.97
All	62.52	−1.12	0.09	5.86

Table 6. Comparison of instant growth and condition factor in different ages of *C. coadi* in Beheshtabad River in 2013.

Age	1^+	2^+	3^+	4^+	5^+	6^+	7^+	8^+
Male								
Condition factor	–	1.54 ± 0.21	1.6 ± 0.17	1.66 ± 0.19	1.58 ± 0.24	1.45 ± 0.18	1.42 ± 0.19	–
spontaneous growth	–	0.39	0.27	0.43	0.25	0.21	–	–
Female								
Condition factor	–	1.78 ± 0.35	1.57 ± 0.21	1.55 ± 0.19	1.51 ± 0.17	1.42 ± 0.16	1.59 ± 0.18	1.64 ± 0.21
spontaneous growth	–	0.84	0.51	0.26	0.38	0.43	0.15	–
All								
Condition factor	1.55 ± 0.26	1.61 ± 0.28	1.59 ± 0.18	1.62 ± 0.2	1.56 ± 0.22	1.44 ± 0.17	1.53 ± 0.2	1.62 ± 0.21
spontaneous growth	1.25	0.52	0.42	0.32	0.4	0.4	0.33	–

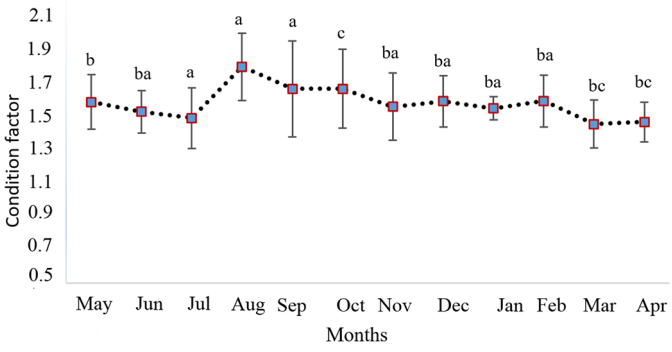

Fig. 8. Monthly variations in condition factor of males of *C. coadi* in Beheshtabad River in 2013. Similar letters indicate non-significant differences.

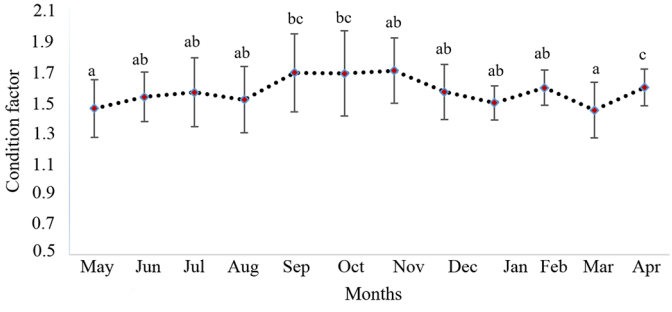

Fig. 9. Monthly variations in condition factor of females of *C. coadi* in Beheshtabad River in 2013. Similar letters indicate non-significant differences.

condition factor was not significantly different in the two sexes and in different age classes, although it was significantly different in some months ($F = 5.62$, $p < 0.05$). The highest value was in August and the lowest in March (Figs. 8 and 9). The spontaneous growth rate was decreasing as the fish got older (Tab. 6). The relative length of gut was 5.0 in females and 4.4 in males indicating a herbivourous habit for both sexes. The feeding intensity was 0.5 in females and 0.06 in males indicating a medium feeding condition in both sexes.

4 Discussion and conclusions

The maximum age for *C. coadi* in this study was 8^+ years observed in the females and the most frequent age class was 4^+ for males and 3^+ for males. Up to the fourth year, both sexes have the same growth rate, but after that, females grow faster. This situation has been observed in other species of *Capoeta* (Mazaheri, 2008; Asadollah *et al.*, 2011, 2017). Asadollah *et al.*, (2011) reported the maximum age of 10^+ for a female *C. damascina* with a fork length of 49 cm and 1935 g from Zayandehrud River. Soofiani and Asadollah (2010) estimated the age of *C. damascina* in Hanna Dam as 6^+ years and Kheyrandish *et al.* (2014) as 5^+. Growth variation could be due to an adaptation to environmental changes (Nikolsky, 1963) (Tab. 7).

The length–weight relationship implied that the growth was negatively allometric for both sexes in this study. Asadollah *et al.* (2011) found a negative allometric growth for females and an isometric growth pattern for the males. Generally, the *b* value lies between 2.5 and 3.5 (Nikolsky, 1963) and is affected by seasonal, geographical, feeding and environmental conditions. Esmaeili and Ebrahimi (2007) reported an isometric growth pattern for *C. damascina* from Sirvan River. Patimar and Mohammadzadeh (2010) reported a negative allometric growth pattern for males and an isometric pattern for females of *C. fusca* Nikolskii, 1897 from eastern Iran.

In this species as in other related species (Tab. 8), the L_∞ was higher in the females. This difference could be due to the higher age at maturity and longer life span of the females. The earlier maturity in the males leads to slower growth of the somatic organs (Wootton, 1998). However, rarely they reach the asymptotic length in the wild, due to natural causes such as predation, diseases and fishing (Biswas, 1993). The growth performance index was higher for males, indicating a faster growth rate for them. In different studies, different results have been achieved. Abdoli *et al.* (2008) in Gorganrud and Kalkan (2008) in Karakaya Dam reported a higher rate in the females. Higher growth rate means that the fish reaches the asymptotic length faster (King, 1995). These parameters are influenced by temperature, salinity, dissolved oxygen and other environmental conditions, thus varying with these factors. Besides, as temperature increases, K is increasing logarithmically and L_∞ decreases (King, 1995).

Table 7. Results of different studies on the age, weight, length of different *Capoeta* damascina species group.

Sex	Max length (mm)	Max weight (g)	Max age (year)	b	Reference
Combined sexes	249	–	–	2.99	Esmaeili and Ebrahimi (2007)
Males	390	690	8^+	2.94	Asadollah *et al.* (2017)
Females	488	1935	10^+	2.98	
Males	360	675	8^+	2.73	Mazaheri (2007)
Females	390	990	8^+	2.53	
Males	188	78	5^+	2.77	Gharache (2008)
Females	192	66	5^+	2.78	
Males	224	129	5^+	2.84	Abdoli and Mostafavi (2009)
Females	259	226	5^+	2.89	
Males	400	1300	6^+	3.22	Soofiani and Asadollah (2010)
Females	442	1545	7^+	3.17	
Combined sexes	216	–	–	2.97	Birecikligil *et al.* (2011)
Combined sexes	142	–	–	3.22	Hasankhani *et al.* (2013)

Table 8. Results of different studies on the growth parameters of different *Capoeta* damascina species group.

Location	Sex	Age range	b	L_∞ (cm)	t_0	K	Reference
Hanna Dam	Males	0^+–6^+	3.22	52.39	−0.30	0.18	Soofiani and Asadollah (2010)
	Females	0^+–6^+	3.17	64.91	−0.45	0.15	
Zayandehrud River	Males	0^+–8^+	2.53	41.5	–	0.23	Mazaheri (2007)
	Females	0^+–8^+	2.73	49.4	–	0.18	
Zayandehrud River	Males	0^+–8^+	2.94	40.67	−0.47	0.30	Asadollah *et al.* (2011, 2017)
	Females	0^+–10^+	2.98	62.61	−0.10	0.14	
Beheshtabad River	Males	1^+–7^+	2.82	35.97	−0.59	0.21	Present study
	Females	1^+–8^+	2.91	49.31	−0.21	0.16	
	Total	1^+–8^+	2.91	62.52	−1.12	0.09	

The sex ratio of Coad barb in Beheshtabad River was 1M:0.7F. Gharacheh (2008) in a Qanat of southern Isfahan and Stoumboudi *et al.* (1993) in Jordan River reported similar results. This ratio for *C. damascina* in other areas were in favour of females (Mazaheri, 2007; Soofiani and Asadollah, 2010; Asadollah *et al.*, 2011). Differences in sex ratio might be related to the interspecific differences in adapted population of a species to different ecological conditions, different date and time of capture, fishing gear, location, growth rates and mortalities in males and females, migration of mature fishes from the region and different behavioral pattern in males and females (Qasim, 1966; Pitcher and Hart, 1982; Fishelson *et al.*, 1996; Keivany and Soofiani, 2004; Soofiani *et al.*, 2006; Asadollah *et al.*, 2011; Keivany *et al.*, 2012; Abbaszadeh *et al.*, 2013; Ghanbarzadeh *et al.*, 2013, 2017; Tabatabaei *et al.*, 2014; Keivany and Daneshvar, 2015; Kiani *et al.*, 2016).

The mean condition factor was higher in the females and occurred in September; for *C. damascina* in Zayandehrud River it occurred in June (Asadollah *et al.*, 2017). The condition factor is an indicator of interaction between biological and non-biological factors on the fish physiology and used to compare different populations in different conditions and life cycles (Bagenal and Tesch, 1978). In general, this fish is a herbivour species with a medium feeding intensity and a relatively slow growing rate.

Acknowledgements. We would like to thank Mr. M. Aalipour, Ms. S.S. Martazavi and Dr. S. Asadollah for their help in field work. There is no conflict of interest for this study. This research was financially supported by Isfahan University of Technology.

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Cite this article as: Keivany Y, Siami M. 2020. Age and growth of a newly described barb, *Capoeta coadi* (Cyprinidae), in Beheshtabad River, Tigris basin. *Ann. Limnol. - Int. J. Lim.* 56: 26