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AGE AND GROWTH OF LARGE SCALE SCRAPER (*CAPOETA ACULEATA*) IN THE GIZEHRUD RIVER, TIGRIS BASIN

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Abstract. The large scale barb, *Capoeta aculeata* is a little known species native to Iran. Its age and growth were studied in 377 specimens collected monthly from the Gizehrud River in Lorestan Province (Tigris basin) during May 2014–May 2015. Sex ratio was 1M:2.1F. The maximum age of both female and male specimens was 6^+ years. The most common age group of both male and female fish was 4^+. The fork length ranged from 12.2 to 20.8 cm (17.4 ± 1.2SD) and weight from 32 to 188 g (93.6 ± 21.8SD). The estimated length-weight relationship of male specimens was $W = 0.0161FL^{3.012}$, ($r^2 = 0.82$) and that of female specimens $W = 0.0248FL^{2.87}$, ($r^2 = 0.79$). This relationship showed that growth of both *Capoeta aculeata* sexes was isometric. The estimated von Bertalanffy growth model for males was $Lt = 20.9[1\text{-}e^{-0.57(t+0.2)}]$ and for females $Lt = 20.3[1\text{-}e^{-0.56(t-0.8)}]$. The growth performance index was estimated at 5.4 and 5.5 for males and females, respectively, indicating a similar growth rate for both sexes.

INTRODUCTION

The genus *Capoeta* with 12 species in Iran is one of the most important native cyprinid fishes. The large scale barb or scraper, *Capoeta aculeata* (Valenciennes, 1844), is widely distributed in such Iranian river basins as the Tigris (the Karun and the Karkheh Rivers), Fars, Isfahan, Kavir, Kerman and the Namak (Keivany et al. 2016; Esmaeili et al. 2017). There are several studies on biology of *C. damascina* (Khalaf 1987; Fishelson et al. 1996; Abdoli and Mostafavi 2009; Gharache 2008; Asadollah et al. 2011, 2017; Siami et al. 2017), *C. fusca* (Patimar and Mohamadzadeh 2010), *C. trutta* (Poria et al. 2014a, b), *C. capoeta* (Abdoli et al. 2008; Patimar et al. 2009) and *C. coadi* (Keivany and Siami 2020). Although *Capoeta aculeata* is consumed by locals, its biology is not well documented, because of its low density and lack of commercial importance.

Growth is one of the most important features of fish biology, especially in economically important species. Growth information could be used for multiple purposes, e.g., stock assessment, aquaculture and protection (Kiani et al. 2016; Keivany et al. 2017, 2018). Fish growth is affected by several factors, e.g., temperature, dissolved oxygen, salinity and their interaction. The aim of this study was to investigate the growth biology of *C. capoeta* in the Gizehrud River, a tributary of the Karkheh River (Tigris basin), in Lorestan province, the west-center of Iran, as one of the important habitats for the species, based on such parameters as age and length composition, length-weight relationship (LWR) and van Bertalanffy parameters.

MATERIALS AND METHODS

A total of 377 specimens were collected by monthly sampling with a cast net (2 cm mesh size) from the Gizehrud River (Table 1) in Lorestan Province, western Iran (34°08′01″ N, 47°49′18″ E), a tributary of the Karkheh River in the Tigris basin of Iran, from July 2014 to June 2015. Fish samples were anesthetized in 1% clove oil, fixed in 10% neutralized formalin and transported to the laboratory. Standard (SL), fork (FL) and total lengths (TL) were measured to the nearest 0.1 mm and the total weight to the nearest 0.01 g. For fish age determination, scales and the whole transparent sagittal otoliths were taken out and age reading was carried out by three fish age-readers and the coinciding readings were recorded to validate the ageing (Biswas 1993; Johal et al. 2001). All the procedures were carried out in accordance with the accepted procedural protocol employed by the Iranian Department of Environment. Also, the back calculation was performed using the following equation (Johal et al. 2001).

$$L_n = (S_n / S) \times (L\text{-}a) + a$$

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 the corresponding lengths attained in the previous years of life. This method is believed to describe the linear body–scale relationship accurately (Ricker 1975; Klumbs et al. 1999).

$$Sli = c + (SL–c) \times (Si/S)$$

where SLi = the standard length of the fish when annulus i was formed, SL = the standard length at the 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:

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

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

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 et al. 1989). 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 $t_0 = -a/b$ (Bertalanffy 1938). The length-weight relationship (LWR) was calculated according to the formula:

$$W = aL^b$$

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 the following model (Pauly 1984):

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

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 using the following equation (Munro and Pauly 1983; Pauly and Munro 1984):

$$\varphi` = Lnk + 2*LnL_\infty$$

Condition coefficients were calculated for both sexes using the equation (Ricker 1975):

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

W∞ was estimated by replacing length by L∞ and b by 3. The condition factor was calculated according to the formula (Hile 1936):

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

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:

$$RLG = Li/FL$$

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

$$FI = Wi/W$$

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

$$R = Ln(W_{(t+1)})\text{-}Ln(W_{(t)})/\Delta t$$

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 to be 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 using SPSS 20 and Excel 2016 computer software.

Table 1. Number of *Capoeta aculeata* specimens caught in the Gizehrud River in different months (2014–2015).

FL ± SD	No.	Sex	Months
17.63 ± 0.91	6	Male	July
17.35 ± 1.09	24	Female	
17.18 ± 1.04	15	Male	August
17.66 ± 1.03	15	Female	
17.37 ± 1.03	10	Male	September
18.11 ± 0.82	22	Female	
17.80 ± 1.03	8	Male	October
17.82 ± 0.67	23	Female	
16.76 ± 0.67	8	Male	November
17.80 ± 1.15	24	Female	
16.12 ± 0.63	8	Male	December
17.70 ± 0.85	24	Female	
17.10 ± 0.87	11	Male	January
17.10 ± 0.65	21	Female	
17.00 ± 0.44	9	Male	February
16.85 ± 0.64	22	Female	
16.55 ± 0.81	12	Male	March
17.74 ± 1.05	20	Female	
17.00 ± 0.59	12	Male	April
18.00 ± 1.60	20	Female	
18.90 ± 1.48	7	Male	May
18.82 ± 0.90	25	Female	
15.50 ± 1.35	14	Male	June
16.50 ± 1.76	17	Female	
16.69 ± 1.19	120	Male	Average
17.65 ± 1.14	257	Female	

RESULTS

A total of 377 fish were examined, 120 (30%) of which were male and 257 (70%) female specimens. The overall sex ratio of males to females was 1M:2.1F and the performed Chi-square analysis showed a significant difference from the 1:1 ratio ($\chi^2 = 12.64$, $p < 0.05$). The fork length ranged from 8.94 to 42.95 (23.32 ± 6.53 SD) cm and weight from 10.3–1255.5 (242.59 ± 213.5) g. The majority of fish were in the body length range of 17.0–19.5 cm (Table 2, Fig. 1). The maximum age of both male and female specimens was 6^+ ($3^+ – 6^+$) years (Fig. 2), and the most common age group was 4^+.

The smallest mature males and females were in the 12.0–14.5 cm length class (the fork length of the smallest mature male was 12 cm and that of the smallest mature female 14 cm) (Table 2). Since all the specimens were mature and older than 3 years, it was not feasible to estimate the mean age at first maturity. Females had a wider length range and were larger than the males ($p < 0.05$) (Tables 1–3 and Fig. 3).

In all age groups, the back calculated lengths were greater than the observed lengths (Table 4). The calculated length-weight relationship for males was $W = 0.0161FL^{3.01}$ ($r^2 = 0.82$) and for females $W = 0.0248FL^{2.87}$ ($r^2 = 0.80$), indicating an isometric growth pattern for males and a negative allometric growth pattern for females (Figs 3–4).

The growth performance index was higher in the females indicating their faster growth (Table 5). The mean condition factor did not differ significantly between the two sexes and among different age classes, although in some months, it differed significantly ($F = 5.62$, $p < 0.05$). The highest value (1.9) of the condition factor of male specimens was recorded in May and the lowest in June (1.5), and the highest value (2.1) of females was observed in May and the lowest in August (1.6) (Fig. 5). Spontaneous growth of fish was observed to decrease with fish age (Table 5).

The estimated age-length relationships in males were $L_t = 20.94[1\text{-}e^{-0.57(t+0.2)}]$ and in females $L_t = 20.3[1\text{-}e^{-0.56(t+0.8)}]$ (Fig. 3). The age-weight relationships in males and females were $W_t = 1242.85[1\text{-}e^{-0.205(t+0.586)}]^{2.82}$, and $W_t = 3357.5[1\text{-}e^{-0.162(t+0.208)}]^{2.92}$, respectively (Fig. 6). The spontaneous growth rate of males was estimated at 0.19 and that of females at 0.15 indicating a faster growth rate for the males.

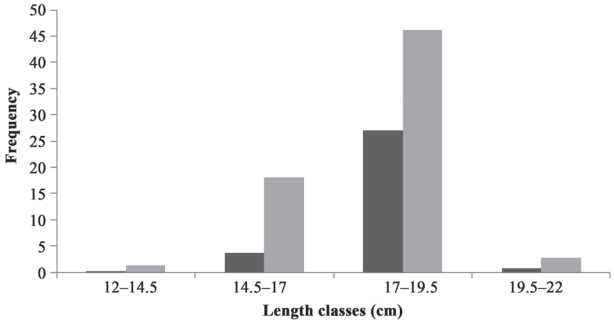

Figure 1. Length frequency of *Capoeta aculeata* males (dark) and females (light) in the Gizehrud River in 2014–2015.

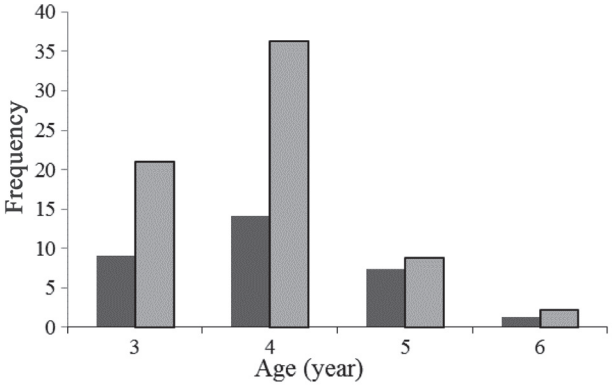

Figure 2. Age frequency of *Capoeta aculeata* males (dark) and females (light) in the Gizehrud River in 2014–2015.

Table 2. Length and weight of *Capoeta aculeata* in the Gizehrud River in 2014–2015.

Sex	No.	FL (cm)		Weight (g)	
		Min–Max	SD ± Mean	Min–Max	SD ± Mean
Male	120	12–21	17 ± 1.2	159–32	20 ± 84
Female	257	14–21	18 ± 1.1	188–47	21 ± 98
All	377	12–21	17.4 ± 1.2	188–32	21.81 ± 93.55

Table 3. Length of *Capoeta aculeata* at different ages in the Gizehrud River in 2014–2015.

Age	Sex	No.	Mean fork length
3^+	Male	34	16.2 ± 1.19
	Female	79	16.9 ± 1.04
4^+	Male	53	17.1 ± 0.84
	Female	137	17.8 ± 1.01
5^+	Male	28	17.2 ± 0.96
	Female	33	18.3 ± 0.72
6^+	Male	5	19.6 ± 1.05
	Female	8	19.4 ± 0.85

Table 4. Back-claculated and observed lengths of *Capoeta aculeata* at different ages in the Gizehrud River in 2014–2015.

Sex	Fork length	1^+	2^+	3^+	4^+	5^+	6^+
Males	Observed	–	–	20.63 ± 2.7	17.1 ± 0.84	18.3 ± 0.72	19.4 ± 0.85
	Back-calculated	4.72 ± 1.56	8.87 ± 2.04	12.9 ± 2.54	16.06 ± 2.97	17.12 ± 2.64	–
Females	Observed	–	–	16.19 ±1.19	17.1 ± 0.84	17.19 ± 0.96	19.62 ± 1.05
	Back-calculated	5.86 ± 2.02	9.39 ± 2.38	12.15 ± 2.41	14.87 ± 2.53	17.34 ± 2.84	–

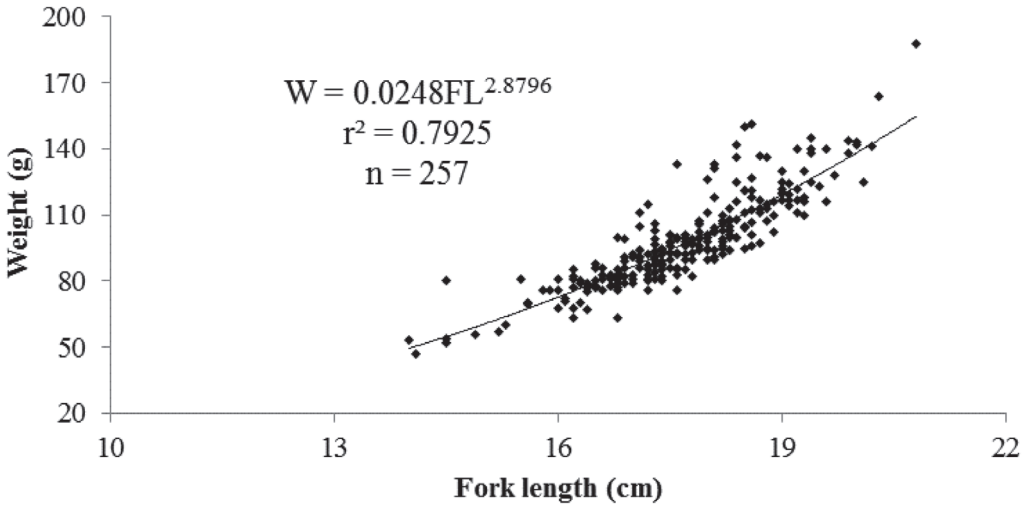

Figure 3. Length-weight relationship of *Capoeta aculeata* females in the Gizehrud River in 2014–2015.

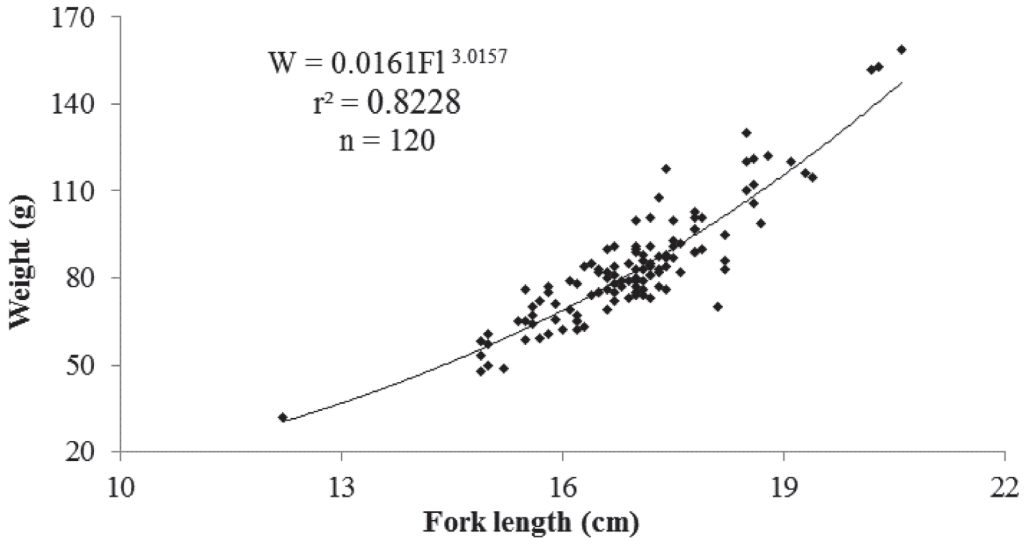

Figure 4. Length-weight relationship of *Capoeta aculeata* males in the Gizehrud River in 2014–2015.

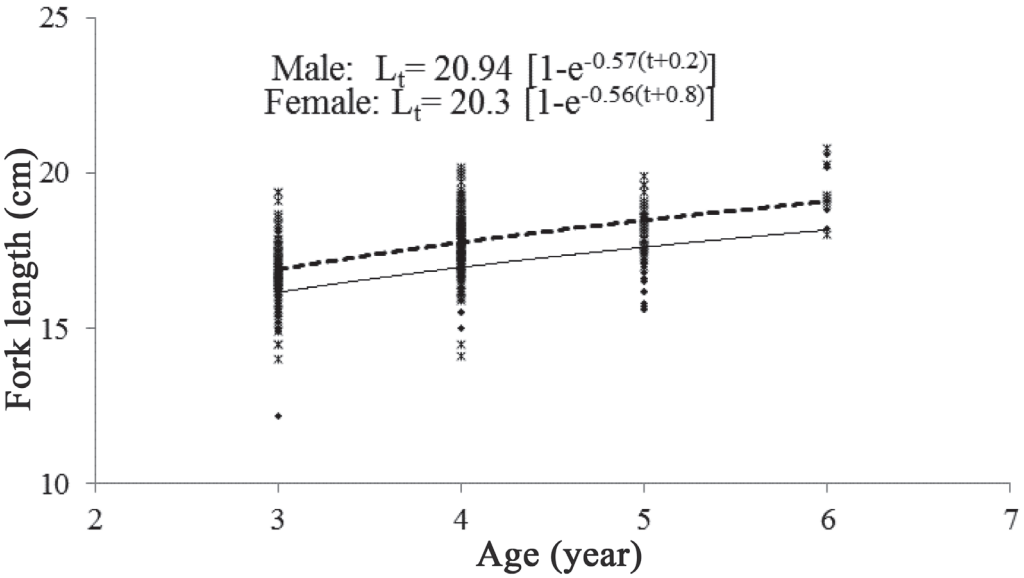

Figure 5. Age-length relationship of *Capoeta aculeata* males (dark) and females (light) in the Gizehrud River in 2014–2015.

Table 5. Maximum age, length, weight and von Bertalanffy growth parameters reported for *Capoeta* spp. from different rivers.

Species	Locality	Sex	Age range	Max weight	Max length	L∞ (cm)	t_0	K	b	φ	Reference
C. damascina	Zayandehrud	Male	0^+–8^+			17.30		0.23	2.53		Mazaheri (2007)
		Female	0^+–8^+			49.40		0.18	2.73		
	Hanna wetland	Male	0^+–6^+	1300	40	52.39	–0.30	0.18	3.22		Soofiani and Asadollah (2010)
		Female	0^+–6^+	1545	44	64.91	–0.45	0.15	3.17		
	Zayandehrud	Male	0^+–8^+	690	39	40.67	–0.47	0.30	2.94		Asadollah et al. (2011, 2017)
		Female	0^+–10^+	1935	49	62.61	–0.10	0.14	2.98		
	Beheshtabad River	Male	2^+–7^+	595	35	35.9	–0.50	0.20	2.82		Siami et al. (2017)
		Female	2^+–8^+	1256	43	49.30	–0.20	0.16	2.91		
C. gracilis	Madarsu	Male	$^+1$–$^+5$			24.90	–0.30	0.22	3.03		Rezaei et al. (2007)
		Female	$^+2$–$^+8$			30.60	–0.38	0.21	3.05		
	Gorganrud	Male	0^+–3^+			19.00	–0.10	0.46	3.05		Abdoli et al. (2008)
		Female	0^+–3^+			23.00	–0.70	0.47	3.05		
	Gorganrud	Male	0^+–4^+			19.50		0.54	2.89		Patimar et al. (2009)
		Female	0^+–5^+			27.50		0.33	2.95		
C. fusca	Birjand Qanats	Male									Johari et al. 2009)
		Female			22				2.948		
	Shadmehr Qanat	Male	1–$^+5^+$			18.70	–0.47	0.33	2.93		Patimar and Mohamadzadeh (2010)
		Female	1–$^+5^+$			22.30	–0.43	0.32	2.99		
C. trutta	Mimeh River	Male	0^+–6^+			45.86	–1.45	0.15	2.71		Patimar and Farzi (2011)
		Female	0^+–6^+			50.79	–1.28	0.13	1.72		
	Gamasyab River	Male	1–$^+5^+$	108	21						Poria et al. (2014a)
		Female	1–$^+5^+$	329	31						
	Alvand River	Male	1^+–5^+		37						Poria et al. (2014b)
		Female	1^+–6^+		38						
C. coadi	Beheshtabad River	Male	2^+–7^+	595	35	35.90	–0.50	0.20	2.82		Keivany et al. (2018)
		Female	2^+–8^+	1256	43	49.3	–0.20	0.16	2.91		
C. aculeata	Ghizehrud River	Male	$^+3$-$^+6$	159	20.94	20.94	–0.20	0.57	3.01	5.52	Present study

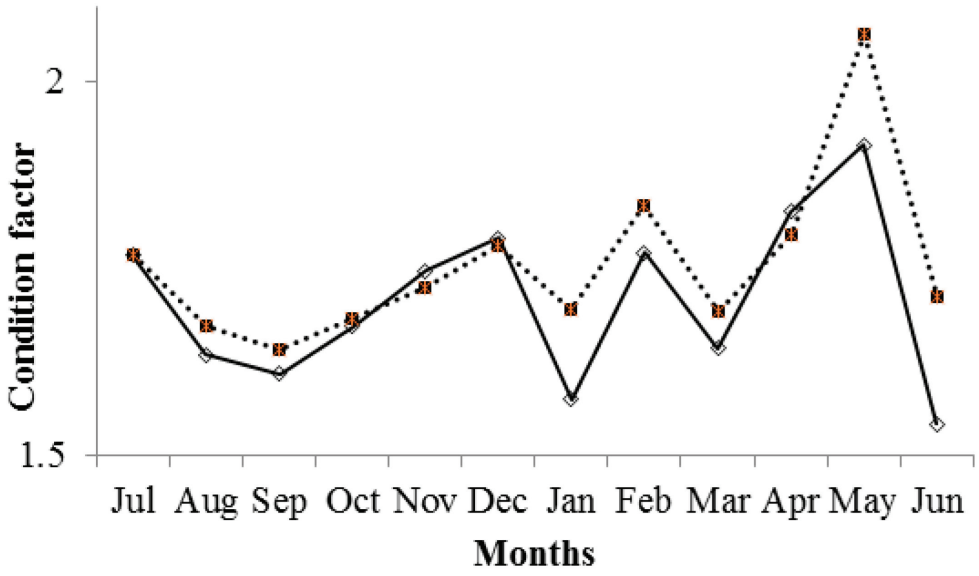

Figure 6. Mean condition factor variations of male (continuous line) and female (dot line) *Capoeta aculeata* in the Gizehrud River in 2014–2015.

The relative length of gut was 5.8 for males and 6.2 for females, indicating a herbivorous feeding habit for this species. This ratio increased from the third year to the fifth year, but significantly decreased in the sixth year ($p < 0.05$). The feeding intensity of male specimens was estimated at 6.9 and that of female specimens at 7.4, indicating a medium feeding intensity for this species.

DISCUSSION

The maximum age of the examined *C. aculeata* specimens was 6^+ years and the most common age class was 4^+. There are no data on other age groups of this species to compare with. As reported by Mazaheri (2007), the maximum age of *C. damascina* collected from the Zayandehrud River was 8^+, and that reported by Soofiani and Asadollah (2010) from the Hanna Dam was 6^+ years. In the Zayandehrud River, the maximum age of the same fish species (a female with a fork length of 49 cm and weight of 1935 g) recorded by Asadollah et al. (2011, 2017) was 10^+, and by Kheyrandish et al. (2014) 5^+ years. The maximum age reported for the congeneric species *C. coadi* is 8^+ years (Keivany and Siami 2020), and that for *C. capoeta* is 5^+ (Abdoli and Mostafavi 2009) (Table 5). Growth variation could be due to the adaptation to environmental changes (Nikolsky 1963). Up to the age of four years, both sexes usually exhibit the same growth rate, but later, females grow faster (Mazaheri 2007; Asadollah et al. 2011, 2017).

The length-weight relationship determined in this study implied that the growth of females was negatively allometric and that of males isometric. Soofiani and Asadollah (2010) and Asadollah et al. (2011) found that the growth of both *C. damascina* sexes is positive allometric. Hasankhani et al. (2013) found a positive allometric growth. Esmaeili and Ebrahimi (2006) reported the isometric growth pattern for *C. damascina* from the Sirvan River. However, Patimar and Mohammadzadeh (2010) reported a negative allometric growth pattern for male and an isometric pattern for female specimens of *C. fusca* from eastern Iran. Patimar et al. (2009) reported a negative allometric growth pattern for *Capoeta gracilis*. Generally, the b value fluctuates between 2.5 and 3.5 (Nikolsky 1963) and is affected by seasonal, geographical, feeding and environmental conditions.

In this species, just like in other related species (Table 5), the $L\infty$ was higher in female specimens. This difference could be due to the higher age at maturity and a longer life span of female specimens. The earlier maturity of the males leads to the slower growth of their somatic organs (Wootton 1998). However, due to natural causes such as predation, diseases and fishing, male specimens rarely reach the asymptotic length in the wild (Biswas 1993). The growth performance index of males was found to be higher indicating their faster growth rate. In different studies, different results have been achieved. Abdoli et al. (2008) reported a higher growth rate of females in the Gorganrud River and Kalkan (2008) in the Karakaya Dam. The 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, therefore vary with these factors. Besides, as temperature increases, K increases logarithmically and L_∞ decreases (King 1995).

The sex ratio of the studied fish in the Beheshtabad River was 1M:2.1F. A similar sex ratio in *C. damascina* was reported by Gharacheh (2008) from the Qanat in southern Isfahan and by Stoumboudi et al. (1993) from the Jordan River. In other areas, this ratio in *C. damascina* was found to be in favour of females (Mazaheri 2007; Soofiani and Asadollah 2010; Asadollah et al. 2011). Differences in the sex ratio might be predetermined by the interspecific differences in abilities of fish to adapt to different ecological conditions, differences in the date and time of capture, in the fishing gear used, in location, differences in growth rates and mortalities between males and females, migration of mature fish from the region and differences in behavioral patterns of male and female fish (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; Abaszadeh et al. 2013; Ghanbarzadeh et al. 2014, 2017; Keivany and Daneshvar 2015; Kiani et al. 2016; Keivany and Siami 2020).

The mean condition factor of female specimens was higher and was recorded in May. In *C. damascina* from the Zayandehrud River it was observed in August (Asadollah et al. 2011) (Table 5). Condition factor is an index reflecting interactions between biological and non-biological factors in fish physiology. It is used to compare different populations in different conditions and life cycles (Bagenal and Tesch 1978). In summary, this fish is a relatively slow growing species with an isometric growth pattern and the maximum age of 7 years, the maximum length of 21 cm and the maximum weight of 188 g.

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