Original Article

Growth and condition factor of *Capoeta damascina* in the Azad dam Lake and the Komasi River in Kurdistan Province, Iran

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Abstract: The objective of the present study was to estimate the population parameters, including length-weight relationship (LWR), condition factor (KF), relative condition factor (K_n), age, growth, and mortality of *Capoeta damascina* in the Azad Dam and Komasi River in the Kurdistan Province, Iran. Total length and weight were 51-350 (180.6±68.63) mm and W: 2.5-465 (93.3±110.89) g in the river and 120-260 (191.5±30.76) mm and 14.7-216 (75.9±39.89) g in the dam Lake and river, respectively. The length-weight regression was $W=0.0122 \times FL^{2.9338}$. The sex ratio (M:F) was 1:0.47, for adult *C. damascina* which differed significantly from the expected 1:1 (*P*<0.001). The von Bertalanffy growth parameters were estimated as L_∞ = 373.3 mm, K = 0.17 yr^{-1} and t_0 = -0.58 yr. The instantaneous coefficient of natural mortality was estimated as 0.36 yr^{-1}. The average KF values were 1.13±0.14 and 0.98±0.18, and K_n were 1.11±0.12 and 0.98±0.18, in the river and the lake, respectively. In conclusion, *C. damascina* showed an isometric growth pattern, which the rapid growth is occurred during the two first years of life. The K_n showed that the fish were at suitable welfare conditions in the Azad Dam.

Introduction

The freshwater Mesopotamian barb, *Capoeta damascina*, is a cyprinid species native to Asia, with a wide distribution. It is known as siahmahi and sardeh, which is mainly caught for consumption and sports fishing (Froese and Pauly, 2017; Asadollah et al., 2017; Esmaeili et al., 2016, 2018). Knowledge of length-weight relationship (LWR), length-length relationship, condition factor (KF), growth and recruitment are important tools for the adequate management of fish species (King, 2007). The LWR parameters are important in fish biology providing information on the stock condition, condition indices and several aspects of fish population dynamics (Bagenal and Tesch, 1978; Gonçalves et al., 1997; Zamani Faradonbeh et al., 2015). Also, these relationships are used in the conversion of fish length and body weight to provide some measure of biomass (Froese, 1998), to estimate the condition, reproduction, life cycle and general health of the fish species (Pauly, 1983). The KF is used to compare the condition, fatness or well-being of the fish (Bagenal and Tesch, 1978). The relative condition factor (K_n) is influenced by many environmental and biological factors (Le Cren, 1951). KF measures the deviation from a hypothetical ideal fish but K_n measures the deviation from the average weight or length of fish (Anderson and Neumann, 1996). The determination of fish growth is fundamental for population modeling, stock assessments and managing exploited species (Gulland, 1988).

Despite the wide distribution of *C. damascina* in Iran, knowledge on the life history parameters of this species is limited. Previous studies on the life history parameters of *C. damascina* in Iranian inland waters were limited to distribution (Keivany et al., 2016), age and growth (Asadollah and Soofiani, 2008; Bahrami Kamangar et al., 2015; Asadollah et al., 2017).

Therefore, the aim of the present study was to estimate the population parameters, including LWR, KF, K_n, age, growth and mortality of *C. damascina* in the Azad Dam and the Komasi River in the Kurdistan Province Iran.

Materials and Methods

The study was performed at the Azad Dam and the Komasi River located on 75 km west of the city Sanandaj, at an altitude of about 1400 m above sea level (Fig. 1). Azad Dam is an earthen dam with a clay core. The crest length and maximum height of the dam are 595 and 117 m, respectively. The total capacity of the dam is 300 million m^3. Samplings were carried out on August to November 2015 and February-May 2016. Three sampling sites were selected along the dam using multi-mesh gill net (20 m length and 4 m height, with 14, 18, 22, 26, 30, 33 and 40 mm mesh sizes) and electrofishing in the Komasi River.

A total of 130 specimens of *C. damascina* were collected. The fork length (FL), standard length (SL) and total length (TL) were measured to the nearest 1 mm and total weight to the nearest 0.1 g (for overall individuals). Sex was determined by visual inspection. Scales were collected from the middle of the body behind the pectoral fins above the lateral line and preserved in the envelopes for future treatment in the laboratory. The scales were washed in petri dishes with tap water. The organic layers were removed by rubbing and washing the scales between the fingers in tap water. Then, the age of fish determined by counting the number of annuli on the scales.

The length-weight relationship was derived by applying an exponential regression as the following equation:

$$W = aFL^b$$

Where W is the total weight (g), FL = the fork length (mm), and a and b are parameters to be estimated (Ricker, 1975). Parameters estimation was conducted by least squares linear regression on log-log transformed data:

$$\ln(W) = \ln(a) + b \times \ln(FL).$$

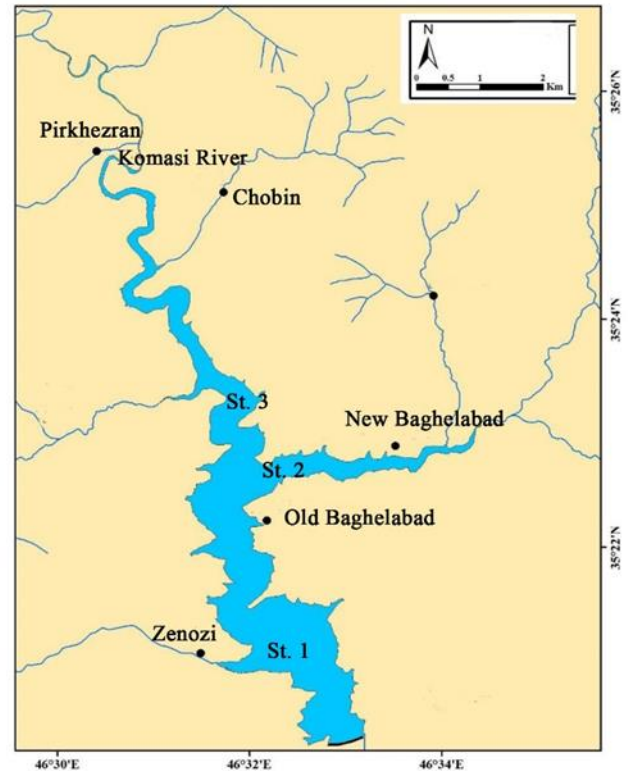T-test was used to investigate for the departure from isometry (b = 3) based on Pauly (1984):

Figure 1. Map of Azad Dam located at northwest of Iran with sampling stations (St.).

$$t = \frac{s.d.\ln(FL)}{s.d.\ln(W)} \times \frac{|b-3|}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Where s.d.ln (FL) and s.d.ln (W) are standard deviations natural logarithm of the fork length (cm) and weight, respectively, and *a* and *b* are parameters and r^2 is regression coefficient between length and weight and n is sample size. The condition factor (*KF*) was calculated as the following equation (Froese, 2006):

$$KF = \frac{W}{TL^3} \times 100$$

Where W (g) is weight and TL (cm) is the total length. The relative condition factor (K_n) that compensates the changes in form or condition factor with an increase in length was calculated using the following equation (Froese, 2006):

$$K_n = \frac{W}{aTL^b}$$

Where W is weight (g), TL is total length (mm), *a* and *b* are respectively the exponential form of the intercept and slope, of the logarithmic length–weight equation. The Pearson correlation coefficient was calculated to investigate the relationship of K_n and K

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Table 1. Descriptive statistics of weight, total length, condition factor (KF) and Relative condition factor (Kn) of *Capoeta damascina* in Azad Dam.

Parameter	Place	N	Mean	SD	Min	Max	t-test
Weight, g	River	40	93.3	110.89	2.5	465.0	t=0.96
	Lake	90	75.9	39.89	14.7	216.0	P>0.34
	Total	130	81.3	69.86	2.5	465.0	
Total length, mm	River	40	180.6	68.63	51	350	t=0.97
	Lake	90	191.5	30.76	120	260	P>0.35
	Total	130	188.2	45.85	51	350	
KF	River	40	1.13	0.14	0.95	1.88	t=4.9
	Lake	90	0.98	0.18	0.59	1.61	P<0.001
	Total	130	1.03	0.18	0.59	1.88	
Kn	River	40	1.11	0.12	1.0	1.7	t=5.0
	Lake	90	0.98	0.18	0.6	1.6	P<0.001
	Total	130	1.02	0.18	0.6	1.7	

length. The von Bertalanffy growth curve (von Bertalanffy, 1938) was fitted to the observed lengths at age for the resulting age-length key using a non-linear estimation method as following:

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

Where L_t is the total length at age t, L_∞ is the theoretical maximum length, K is a growth coefficient and t_0 is the hypothetical age for L_t=0. The parameter $\varphi`$, the growth performance index, was calculated as (Pauly, 1983):

$$\varphi` = logK + 2logL_\infty$$

Where K is the growth coefficient and L_∞ is the theoretical maximum length (cm). The instantaneous coefficient of natural mortality was estimated using the methods in Pauly model (Pauly, 1980) with von Bertalanffy growth parameters.

$$\ln(M) = -0.0152 - 0.279\ln(L_\infty) + 0.6543\ln(K) + 0.463\ln(T)$$

Where M is the instantaneous coefficient of natural mortality, K is the growth coefficient and T is the mean annual habitat temperature, T=12.0°C. The comparison between the average values for sexes was carried out by t-test and for seasons by analysis of variance (ANOVA). Differences in sex ratios from the expected 1:1 were analyzed by chi-square tests (Zar, 2010).

Results
A total number of 130 specimens were caught in this study, with 90 specimens caught by gillnet in Azad Lake and 40 specimens caught by electrofishing in the Komasi River. The TL and W of *C. damascina* ranged from 51 to 350 mm and 2.5 to 465.0 g and averaged (±SD) 188.2 (±45.85) mm and 81.3 (±69.86) g, respectively (Table 1). Total length ranges 51-350 and 120-260 mm in the river and lake, respectively. The length group of 181-190 mm was prevailing and formed 14.2%, followed by the length group of 171-180, comprising 12.6% of the total catch (Fig. 2). The mean TL and W were 180.6±68.63 mm, 93.3±110.89 g in the river and 191.5±30.76 mm and 75.9±39.89 g in the lake, respectively. No significant differences were found in the parameters between the river and lake samples (t-test; P>0.05; Table 1).

Length-length relationships and the coefficient of determination r^2 are given in Table 2. The length-length relationships were found to be highly correlated (in all cases: r^2=0.99, P<0.001). The TL and W regression of whole samples was: W=0.0122×TL$^{2.9338}$ (r^2= 0.955, n=130, standard error of b = 0.057 and a = 0.004). The value of b was 2.9338, significantly not different from 3.0 (t-test, P>0.05), indicating an isometric growth (Fig. 3).

The average of KF values were 1.13±0.14 and 0.98±0.18 in the river and lake, respectively. These averages were significantly different (*t*-test, P<0.001; Table 1). Kn were calculated in the river and lake using the LWR. There was a significant difference between
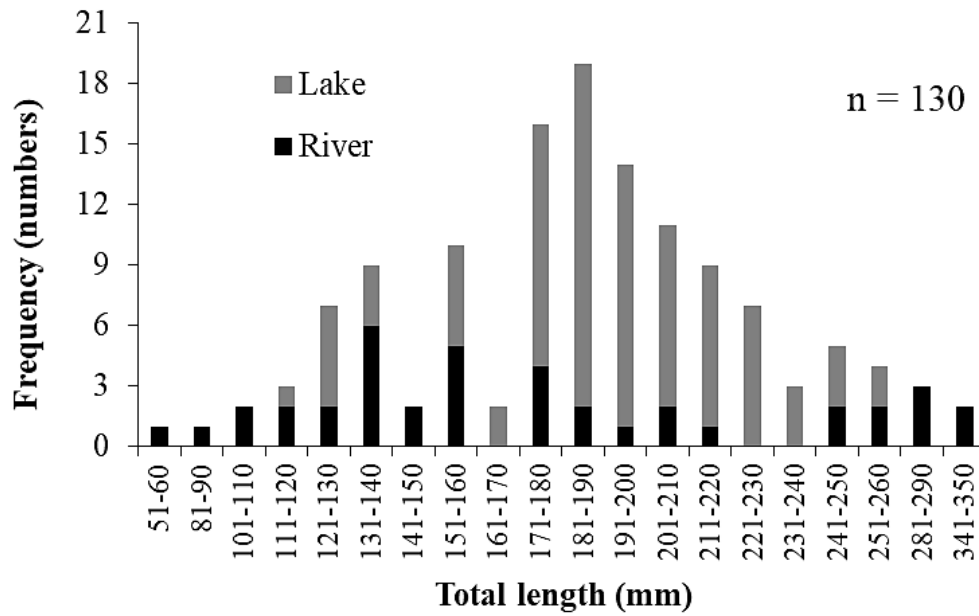
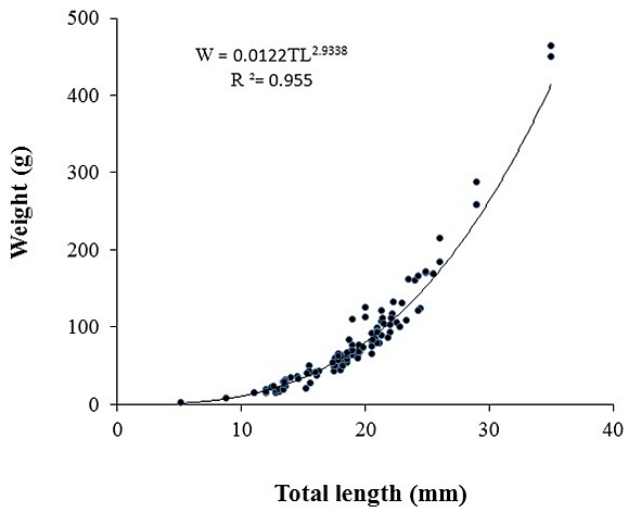Figure 2. Size distribution of *Capoeta damascina* in Azad dam, n = sample size.

Figure 3. Length-weight relationship of *Capoeta damascina* in Azad Dam.

Figure 4. Theoretical growth curve calculated for total length of *Capoeta damascina* in Azad Dam.

the average of K_n values 1.11±0.12 and 0.98±0.18, respectively, with significant difference (*t*-test, *P*<0.001; Table 1).

The age of *C. damascina* ranged 1-7 years. Ages 3 and 4 were the most dominant age groups, representing 55.9% of the samples. The von Bertalanffy growth equation was estimated as shown in Figure 4:

$$L_t = 373.3(1 - e^{-0.17(t-(-0.58))})$$

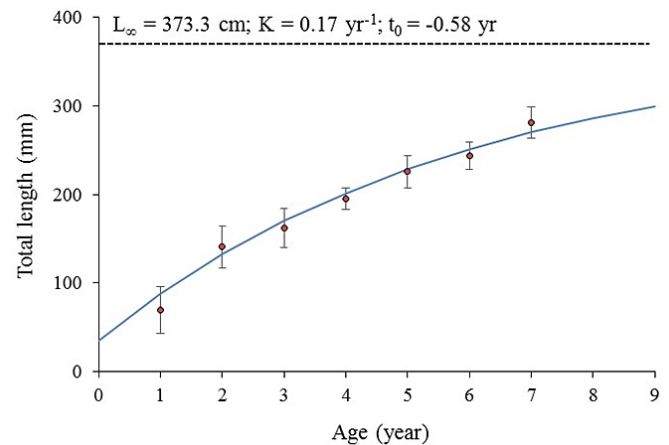The growth performance index (φ`) of *C. damascina* was computed as 2.37. Estimates of the

instantaneous coefficient of natural mortality for *C. damascina* obtained from the Pauly method was 0.36/yr. The sex ratio (M:F) was 1:0.47, for adult *C. damascina* (n = 87), which differed significantly from the expected 1:1 (χ^2=11.0, *P*<0.001).

Discussion

Study on the population characteristics of *C. damascina* in Iranian inland waters are scarce and limited to the Caspian basin, west and center of Iran (Asadollah and Soofiani, 2008; Bahrami Kamangar et al., 2015; Asadollah et al., 2017; Table 3). The *b* value usually varies between 2 and 4 (Tesch, 1971) or ranges

Table 2. Length-length relationships of *Capoeta damascina* in Azad Dam.

Equation	N	a	b	R^2
FL=a+b×TL	113	-3.08	0.918	0.99
FL=a+b×SL	113	5.38	1.069	0.99
SL=a+b×TL	113	-7.16	0.854	0.99

Table 3. The von Bertalanffy growth Parameters and length-weight relationships of *Capoeta damascina* from different locations.

Study area	Sex	Age	b	L_∞	K	t_0	φ`	Author (s)
Hana Dam, Iran	M	1^+-6^+	3.23	52.4	0.177	-0.30	2.69	Asadollah and Soofiani, 2008
	F	1^+-6^+	3.17	64.9	0.151	-0.45	2.80	
Gheshlagh Reservoir and River, Iran	M+F	0-5	2.84	67.52	0.12	-0.79	2.74	Bahrami Kamangar et al., 2015
Zayandehrud River, Iran	M	1^+-9^+	2.95	56.2	0.098	-0.63	2.49	Asadollah et al., 2017
	F	1^+-10^+	2.99	117.1	0.05	-0.43	2.84	
Azad Dam, Iran	M+F	1-7	2.94	37.3	0.17	-0.58	2.37	Present study

from 2.50 to 3.50 (Froese, 2006). According to the present study, the exponent *b* of LWR was 2.94, remained within the expected range and indicating an isometric growth. Similar results were reported by Asadollah et al. (2017). In contrast, Bahrami Kamangar et al. (2015) reported a lower *b* value (2.84 in Gheshlagh Reservoir and River, Iran) and Asadollah and Soofiani (2008) reported a higher *b* value (3.23 for both males and females in Hana Dam, respectively). The sampling gear might influence the size range covered and cause deviations from existing values LWR parameters. In addition, geographical location and associated environmental conditions such as water temperature, which is the determining factor of feeding capacity, seasonality, stomach fullness, disease and parasite loads can affect the value of *b* (Bagenal and Tesh, 1978; Froese, 2006).

KF reflects information on physiological states of fish in relation to welfare (Kumolu and Ndimele 2010). Higher KF value indicates favorable environmental conditions (Blackwell et al., 2000). In the present study, the Komasi River fish were in suitable condition. According to George et al. (1985), K_n indicates the general well-being of the fish. If the values of K_n>1 indicates that the well-being of the fish is good; whereas, value <1 reflects poor feeding activity and low well-being of the fish. In the present study, the K_n of *C. damascina* were close to 1 (in the lake) and higher than 1 (in the river). These results suggested that the well-being of the fish was good in the Azad dam region. Similar results were reported for

Alburnus mossulensis in the Azad Dam (Fazli et al., 2018a). In contrast, the average of K_n *Carassius gibelio* was lower than 1 (Fazli et al., 2018b).

According to Helfman et al. (1997), knowledge of fish age and growth is necessary for stock assessment, develop management or conservation plans. The results showed that the rapid growth of *C. damascina* was found during the first two years of life, followed by a period of slow growth rate in the rest of life. The age of *C. damascina* varied from 1 to 7 yr. Similar results were reported in the Hana Dam (Asadollah and Soofiani, 2008). In contrast, Bahrami Kamangar et al. (2015) found a lower (between 0 and 5) and Asadollah et al. (2017) a higher age ranges (1^+-9 and 1^+-10^+ years for males and females, respectively). Holmgren and Appelberg (2001) and Bautista et al. (2012) reported that range of age distribution in a population is closely related to the nutritional status of the environment.

The asymptotic length (L_∞) of *C. damascina* was 37.3 cm is lower than that reported by Asadollah and Soofiani (2008), Bahrami Kamangar et al. (2015) and Asadollah et al. (2017). Also, the growth performance index (φ`) of *C. damascina* (2.37) indicates a lower growth rate in the Azad Dam. Holmgren and Appelberg (2001) and Bautista et al. (2012) reported that the growth characteristics of the local populations of the same species change due to habitat variations, water quality and nutrients.

The present study showed that the overall M:F ratio of *C. damascina* was 1:0.47, the overall sex ratio is unbalanced in favor of males. In contrast, the sex ratio

of this species in other Iranian inland waters was in favor of females (Asadollah and Soofiani, 2008; Bahrami Kamangar et al., 2015). In general, the overall expected sex ratio in many species is 1:1, but it could be affected by some natural and environmental factors (Bohlena and Ritterbusch, 2000).

In conclusion, *C. damascina* has an isometric growth pattern. The rapid growth occurred during the two first years of life. The K_n of *C. damascina* were close to 1 (in the lake) and higher than to 1 (in the river) which suggested that the well-being of the fish was good in Azad dam region.

Acknowledgments

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چکيده فارسی

رشد و ضريب چاقی سياه ماهی *Capoeta damascina* در درياچه سد آزاد و رودخانه کوماسی در استان کردستان، ايران

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چکيده:

هدف از اين مطالعه برآورد پارامترهای جمعيت شامل رابطه طول-وزن (LWR)، ضريب چاقی (KF)، ضريب چاقی نسبی (K_n)، سن، رشد و مرگ و مير طبيعی سياه ماهی (*Capoeta damascina*) در درياچه سد آزاد و رودخانه کوماسی در استان کردستان، ايران بود. مقادير پارامترهای اندازه گيری شده شامل طول کل: ۳۵۰-۵۱ (۱۸۰/۶±۶۸/۶۳) ميلی‌متر، وزن: ۴۶۵-۲/۵ (۹۳/۳±۱۱۰/۸۹) گرم در رودخانه و طول کل: ۱۲۰-۲۶۰ (۱۹۱/۵±۳۰/۷۶) ميلی‌متر، وزن: ۲۱۶-۱۴/۷ (۷۵/۹±۳۹/۸۹) گرم در درياچه بود. رابطه بين طول-وزن $W = 0/0122 \times FL^{2/9338}$ بود. نسبت جنسی (ماده:نر) برای ماهيان بالغ ۰/۴۶: ۱ بوده که با نسبت ۱:۱ اختلاف معنی‌داری داشت ($P<0/001$). پارامترهای رشد برتلانفی شامل L_∞=۳۷۳/۳ ميلی‌متر، $K = 0/17$ yr^{-1} و $t_0 = -0/58$ yr محاسبه شد. ضريب مرگ و مير طبيعی ۰/۳۶ yr^{-1} برآورد شد. در رودخانه و درياچه ميانگين ضريب چاقی به‌ترتيب ۱/۱۳±۰/۱۴ و ۰/۹۸±۰/۱۸ و ضريب چاقی نسبی به‌ترتيب ۱/۱۱±۰/۱۲ و ۰/۹۸±۰/۱۸ به‌دست آمد. به‌عنوان نتيجه‌گيری، اين ماهی دارای رشد ايزومتريک می‌باشد. رشد در دو سال اول زندگی سريع است. ضريب چاقی نسبی نشانگر وضعيت مطلوب سلامت اين ماهی در منطقه سد آزاد می‌باشد.

کلمات کليدی: پارامترهای رشد، رابطه طول-وزن، ضريب چاقی، جمعيت.