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Growth and reproductive biology of *Capoeta damascina* (Valenciennes, 1842) from a tributary of Tigris

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Abstract

Growth and reproductive attributes were determined for *Capoeta damascina*, an endemic fish species from west of Iran. A total of 147 specimens of both sexes were sampled monthly from November 2008 to October 2009. The overall sex ratio was female biased. Males were aged 0-4 years and females 0-5 years. The von Bertalanffy growth parameters were estimated as; L_{inf}=34.81 cm, k=0.27 year^{-1}, t_0=-0.65 for males plus unsexed samples, L_{inf} =46.29 cm, k=0.22 year^{-1}, t_0 =-0.59 for females plus unsexed samples and L_{inf} =67.52 cm, k=0.12 year^{-1}, t_0=-0.79 for whole samples. The length-weight relationships were $W=0.021L^{2.815}$ for males, $W=0.022L^{2.824}$ for females and $W=0.020L^{2.836}$ for combined sexes, all of which exhibited a negative allometric growth. Spawning season started in May, ascending to June and ended in July for both sexes. Length at 50% maturity was estimated as 12.35 cm for males and 15.14 cm for females. Fecundity ranged from 1551 (2 years old) to 20523 (5 years old) eggs per fish. Losing of large individuals and decreasing in size at first maturity were observed in the studied population compared to data reported from other *C. damascina* populations, which could reflect an effect of overexploitation.

Keywords: *Capoeta damascina*, Growth, Reproduction, West of Iran.

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Introduction

The fishes belonging to the genus *Capoeta* are well distributed in southwest Asia and consist of about twenty species of which seven occur in Iran (Coad, 2013). *C. damascina* is a common species in most drainage basins of Iran (Coad, 1998). This species is endemic and also abundant in most rivers of the Tigris basin in the Kurdistan Province, West of Iran. It is caught by people for consumption and sport fishing purposes. Growth and reproductive biology information on natural fish stocks are not only essential for proper stock management but also for economical purposes.

The information about growth and reproductive biology of *C. damascina* are subjected to a few researches (Stoumboudi *et al.,* 1993; Fishelson *et al.,* 1996; Soofiani and Asadollah, 2010; Asadollah *et al.,* 2011). However, these features could be affected by ecological, geographical, climatic conditions and/or by fisheries management. Gheshlagh River is a tributary of the Tigris basin which originates from the north of Sanandaj, Iran. The Gheshlagh Dam (35° 25́ N, 46° 59́ E) was built on this river in 1979. The reservoir of Gheshlagh Dam is located 12 Km away from the north of Sanandaj. Ten endemic and nine exotic fish species were reported from this reservoir (Bahrami Kamangar *et al.*, 2012). *Cyprinus carpio, Hypophthalmichthys molitrix, H. nobilis* and *Ctenopharyngodon idella* were transplanted to Gheshlagh system in order to enhance the Gheshlagh Reservoir fishery. The mean annual fish capture from the Gheshlagh Reservoir is about 170 metric tons which include both exotic and endemic species. Presence of exotic species and overfishing can negatively affect reproductive and growth biology of fishes. Therefore, the aim of this study were to determine growth and reproductive properties of *C. damascina* from one of the tributaries of Tigris basin and to compare them with those reported from other basins, and to achieve a key step toward better fisheries management and conservation programs for this species.

Materials and methods

The samples were collected monthly from Gheshlagh Reservoir and the upstream of Gheshlagh River from November 2008 to October 2009. Gill-nets (20–30 mm mesh size) and cast nets (20 mm mesh size) were used for sampling depending on the site location. Body weight (W) and gonad weight (W_g) were measured to the nearest 0.01 grams. Fork length (L) was also measured to the nearest 1.0 mm. Age was determined using the annuli numbers on the scales (Biswas, 1993). The age of specimens with uncompleted annuli rings was assigned as less than one year (0+). The sample with one completed ring on the scale considered as more than one year old but less than two years old (1+) and so on for additional annuli rings. The relationship of length - weight was calculated separately for each sex and for combined sexes, using the equation:

$W = aL^b$, where W, L, a and b are the total weight, the total length, coefficient related to body form and an exponent indicating isometric growth when equal to 3, respectively (Le Cren, 1951). The least square regression analysis was used to estimate parameters a and b of the equation: $\log W = \log(a) + \log(b) \times L$, where W is the body weight in g and L is the fork length in cm. The von Bertalanffy growth equation was used to describe the relationship of length at age; $L_t = L_{inf}(1 - e^{-k(t-t_0)})$, where L_t, L_{inf}, k, t and t_0 are the expected fish length at age t, the average asymptotic fork length, the relative growth coefficient, the fish age (year) and the hypothetical time at which the length of fish is zero, respectively (Sparre and Venema, 1992). To ensure that von Bertalanffy growth curves are efficiently described in the early life stages, the unsexed age data were used to fit male, female and whole samples age curves (Sutton, 2011). Hence, three fits were applied; all males plus unsexed fish data, all females plus unsexed fish data and whole samples. The equation parameters for males, females and whole samples were estimated by applied Marquardt's algorithm for nonlinear least squares method using FISHPARM software (Prager *et al.*, 1989). Growth performance index (φ') was calculated to compare growth between males and females (Pauly and Munro, 1984).

Gonads were identified as ovaries, testes or unsexed by examination of the gonad tissue either directly by eye or with the aid of a microscope for large and small specimens, respectively. The maturity stages were classified as six stages as: stage I; immature or virgin, stage II; maturity virgin or resting adult, stage III; developing, stage IV; developed, stage V; gravid and stage VI; spawning (Biswas, 1993). The changes of gonadosomatic index were monthly calculated as follows; $GSI = 100\times(W_g/W)$ to determine spawning season (Biswas, 1993), where W_g and W are gonad weight and body weight, respectively. The lengths at 50% maturity were estimated for male and female sexes according to the percentage of individual with mature gonads at the stage III-VI. The logistic function; $P = 1/(1+ e^{(-r(L - L_m))})$ was used to estimate lengths at 50% maturity, where P, r and L_m are the proportion of maturity in each size class, the parameters which control the shape of curve and the size at 50% maturity, respectively (Turkmen *et al.*, 2002). To estimate the model parameters, the logistic functions were transformed to linear function; $\ln((1-P)/P) = r(L_m - L)$ where the slop $b = -r$ and the intercept $a = rL_m$ (Arana, 2009). Mean ova diameter was measured from sub-sampling eggs taken from the anterior, middle and posterior part of each ovary (Biswas, 1993). Fecundity; the number of ripe eggs (Bagenal, 1957), was calculated gravimetrically by counting eggs in one gram subsamples of ovaries at the stages III-VI. The relationships between fecundity-body weight, fecundity-fork length, fecundity-gonad weight and fecundity- age were estimated by the equation: $F_e = aX^b$, where F_e, is the fish fecundity, X is one of the independent variables of body weight, fork length, gonad weight or fish age (T), a is constant and b is the exponent coefficient. Linear model of least square regression was applied to logarithmic transformation of the equation to estimate coefficient a and b (Bagenal, 1967).

Water temperature was measured monthly at each sampling site. Circannual rhythm of day length data were calculated using Ray Man 1.2 software (Matzarakis *et al.*, 2007) for the geographic coordinates of the studied area.

Sample size in each age-class was checked based on Kritzer *et al.,* (2001) recommendation to achieve at least 10% precision. Independent sample *t*-test was used to compare body weight and fork length between males and females at each age class. One way analysis of variance followed by Duncan multiple range tests was used to reveal any significant difference between ova diameter at each maturity stage and fecundity at each age class. The ratio of females to males was assigned statistically with chi-square test. Statistical analysis was performed using SPSS ver. 16, FISHPARM ver. 3.0 (Prager *et al.*, 1989) and Excel software.

Results

A total of 147 specimens were caught during the survey of which 31.97% were males, 57.14% were females and 10.88% were unsexed. The overall sex ratio of males to females was 1:1.79 which revealed significant difference from 1: 1 ($p<0.05$). Fig. 1 shows the fork length frequency distributions for males, females and unsexed samples. The age classes ranged from 0 to 4 years for male and from 0 to 5 for female specimens. The most frequent observed fork length was in the range of 23.1-27 cm within the female specimens and 11.1-15.0 cm within the male specimens. These lengths mostly belong to male and female age classes of 1 and 3, respectively. The mean fork length and the mean body weight at each age class are presented in Table 1. The maximum length and weight recorded were 37.2 cm and 620.0 g for females and 27.0 cm and 227.0 g for males, respectively. The length and weight of males and females were not significantly different in age class 1 ($p>0.05$); however, females were significantly larger and heavier than males in the older age classes ($p<0.05$).

The estimated growth parameters of von Bertalanffy equations for males plus unsexed, females plus unsexed and whole samples are presented in Table 2. The observed and estimated curves of lengths at ages estimated by these equations are presented in Fig. 2. Growth performance indices ($\acute{\varphi}$) were calculated for males as 2.51 and for females as 2.67.

The length-weight relationships of males, females and combined sexes are given in Table 3. The values of slopes for males, females and pooled individuals were significantly smaller than 3.0 when compared by *t*-test. This means that *C. damascina* population in the Gheshlagh Reservoir exhibited a negative allometric growth and tends to become thinner as they grow larger. The length-weight curve of observed data and fitted data for combined sexes is plotted in Fig. 3.

Table 1: Comparison of fork length and body weight in age classes of *Capoeta damascina* from Gheshlagh Reservoir.

Age class (year)	Sex	N	Fork length (cm) Minimum-Maximum (Mean ± Standard Error)	Body weight (g) Minimum-Maximum (Mean ± Standard Error)
0	Unsexed	16	4.58-6.80 (5.60 ± 0.16)	1.40-4.93 (2.75 ± 0.24)
	Male	1	(7.20)	(3.20)
	Female	1	(7.01)	(3.35)
1	Male	10	8.50-15.70 (12.05 ± 0.74)	18.70-37.32 (26.11 ± 2.22)
	Female	16	9.80-16.00 (12.47 ±0.51)	19.50-42.00 (28.99 ± 1.54)
2	Male	23	11.50-25.00 (17.66 ± 0.96)	20.05-183.00 (80.31 ± 11.48)
	Female	22	16.60-26.30 (22.38 ± 0.62)*	49.00-199.00 (140.21 ± 9.35)*
3	Male	10	19.50-25.00 (21.86 ± 0.59)	80.00-207.00 (131.09 ± 13.53)
	Female	28	20.40-30.10 (24.85 ± 0.42)*	103.67-343.00 (196.01 ± 10.06)*
4	Male	3	23.00-27.00 (24.50 ± 1.26)	168.00-227.00 (188.33 ± 19.34)
	Female	14	22.70-35.00 (26.43 ± 0.89)	178.00-532.00 (265.14 ± 27.39)*
5	Male	0	-	-
	Female	3	29.50-37.20 (34.23 ± 2.39)	297.00-620.00 (510.67 ± 106.84)

Asterisks indicated significant differences between male and female in each age class revealed by independent sample t-test ($p<0.05$).

Table 2: Estimated growth parameters of von Bertalanffy equations of *Capoeta damascina* from Gheshlagh Reservoir (present study) and those reported from Hanna Wetland by Soofiani and Asadollah (2010).

Area[*]	Sex	Ages	L_{inf} (cm)	CV	k (year^{-1})	CV	t_0 (year)	CV
Present Study	M+U	0-4	34.81	0.07	0.27	0.10	-0.65	-0.01
	F+U	0-5	46.29	0.37	0.22	0.70	-0.59	-0.60
	Whole samples	0-5	67.52	0.69	0.12	0.90	-0.79	-0.55
Hanna Wetland	M	1-7	54.7	-	0.174	-	-0.32	-
	F	1-6	66.7	-	0.134	-	-0.40	-

[*] M; male, F; female, U; unsexed and CV; Coefficient of Variation.

Table 3: The length-weight relationships of males, females and combined sexes of *Capoeta damascina* from Gheshlagh Reservoir.

Sex	a	b	r	*p*-value	t- statistic	df = n-2	*p*-value
Males	0.021	2.815	0.991	< 0.001	- 4.09	54	< 0.01
Females	0.022	2.824	0.990	< 0.001	- 3.56	89	< 0.01
Combined	0.020	2.836	0.991	< 0.001	- 5.13	145	< 0.01

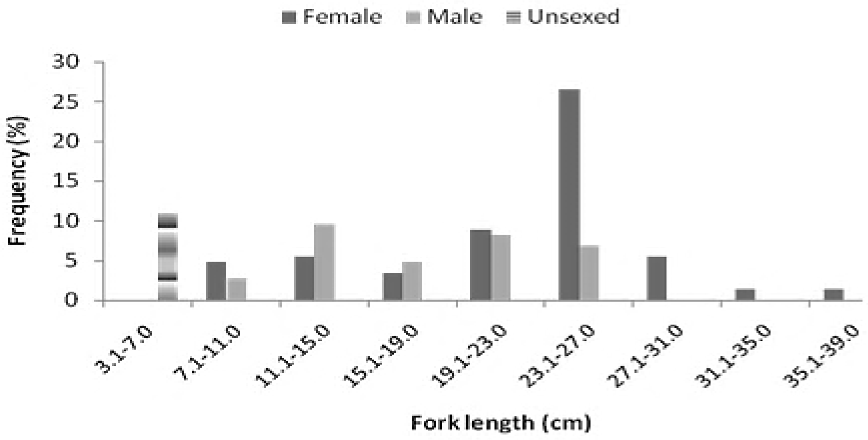

Figure 1: Fork length frequency of *Capoeta damascina* from Geshlagh Reservoir.

The mean length at which 50% of individuals were sexually matured was found to be at 12.35 cm for males and 15.14 cm for females. The equation was $p=1 / (1+ e^{(-0.19 (L-12.35))})$ for males and $p=1 / (1+ e^{(-0.424 (L-15.14))})$ for females. The age classes at these lengths were approximately 1 for males and 2 for females.

Reproductive cycle and spawning season were determined by monitoring the monthly GSI calculated for males and females matured individuals (Fig. 4a). Gonadosomatic index of both sexes was the least in August and September and then rose gradually from these months to reach maximum levels in June. In August ovaries of mature individuals were at stage II; while, during September to December most of them were at stage III. The ovaries were at stage IV from January to April and during May to July they were at stages V and VI (Fig. 4a). Therefore, the spawning of *C. damascina* occurs between May and July in the Gheshlagh Reservoir. During these months, water temperature ranged between 16 and 22°C and the mean day length ranged from 14-14.5 hours (Fig. 4b). While all individuals of age class 0 were found to be immature, the youngest male and female sexually matured were seen at age classes of 1 and 2, respectively.

The mean ova diameter was measured based on the maturity stages (Table 4). Oocyte diameter was not measured at the stage I, due to the very small size of ova. The oocyte diameters significantly increased by 2.7 times at gravid and spawning gonad stages than maturity virgin stage. Fecundity increased with increasing age and gonad weight. Fecundity ranged from 1551 to 20523 per fish and the highest fecundity was found in five year old samples (Table 5). The relationships between fecundity-body weight, fecundity-fork length, fecundity-gonad weight and fecundity-fish age were determined as $F_e = 50.35 (W)^{0.9}$, $F_e = 1.07 (L)^{2.68}$, $F_e = 2280 (W_g)^{0.39}$, $F_e = 2564 (T)^{0.78}$, respectively (Table 6).

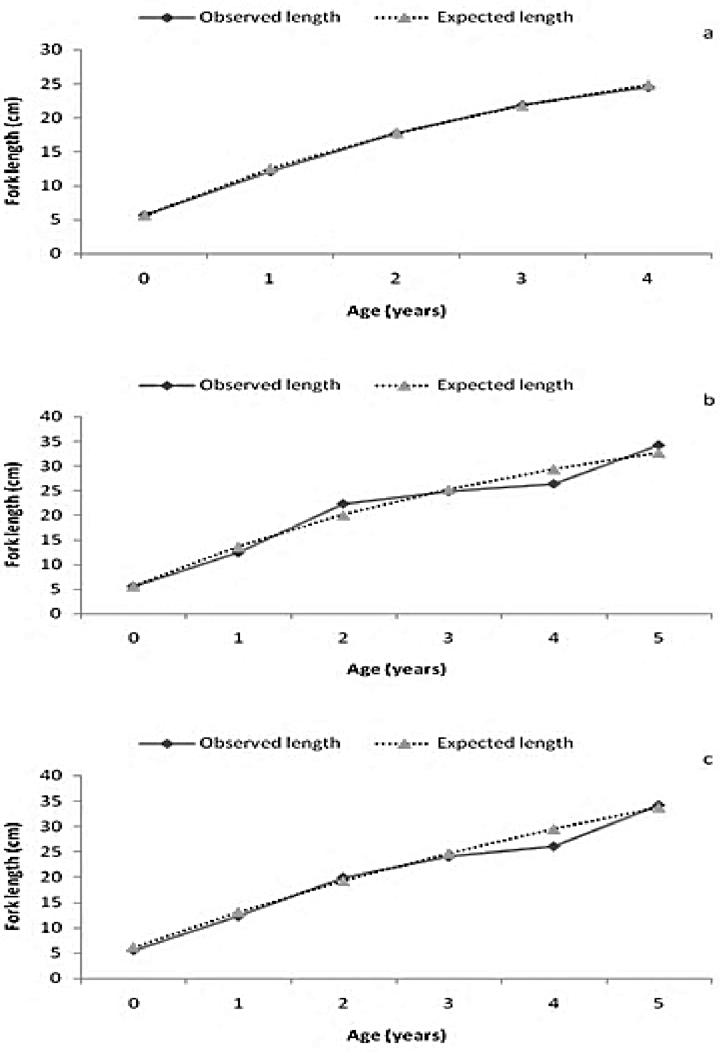

Figure 2: Observed lengths at age data and expected von Bertalanffy growth curves for males plus unsexed (a) females plus unsexed (b) and whole samples (c) of *Capoeta damascina* from Gheshlagh Reservoir.

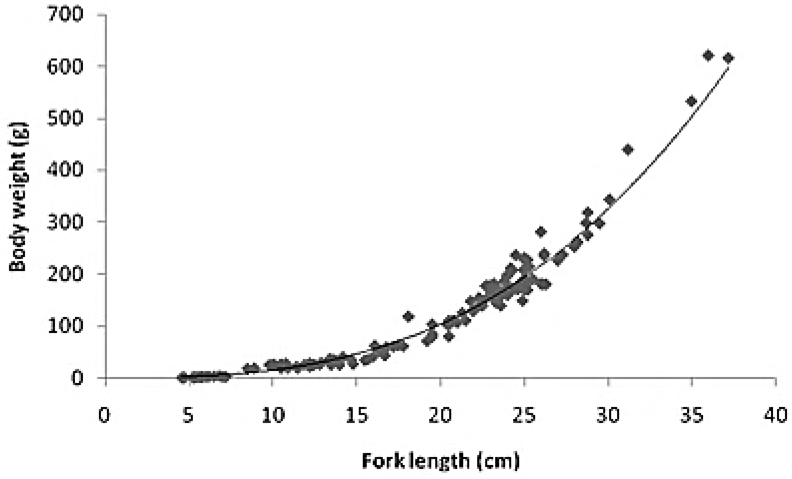

Figure 3: The length-weight relationship of combined sexes of *Capoeta damascina* from Gheshlagh Reservoir.

Table 4: The mean ova diameter of *Capoeta damascina* in different stages of maturity from Gheshlagh Reservoir.

Stages of maturity	Sample size	Ova diameter (mm) (Mean ± SE)*
Maturity virgin or resting adult (II)	12	0.63 ± 0.08^a
Developing (III)	25	1.08 ± 0.04^b
Developed (IV)	17	1.31 ± 0.03^c
Gravid (V)	5	1.70 ± 0.04^d
Spawning (VI)	10	1.75 ± 0.10^d

[*] Values followed by different letters indicate a significant difference between stages of maturity ($p<0.05$).

Table 5: Fecundity and gonad weights of *Capoeta damascina* at different age classes from Gheshlagh Reservoir.

Age class	Sample size	Fecundity (Mean ± SE)*	Gonad weight (g) (Mean ± SE)*
2	18	5314.60 ± 666.33^a	6.10 ± 0.55^a
3	25	6151.60 ± 512.22^a	13.28 ± 1.86^a
4	11	8057.90 ± 916.56^a	26.08 ± 4.69^{ab}
5	3	13730.00 ± 4752.17^b	48.00 ± 22.15^c

[*] Values followed by different letters indicate a significant difference between stages of maturity for each variable ($p<0.05$).

Table 6: The relationship between fecundity (F_e) and fork length (L), body weight (W), gonad weight (W_g) and age (T) of *Capoeta damascina* from Gheshlagh Reservoir.

Relationship	a	b	r square	*p*-value
$F_e - W$	50.35	0.90	0.62	< 0.001
$F_e - L$	1.07	2.68	0.61	< 0.001
$F_e - W_q$	2280	0.39	0.41	< 0.001
$F_e - T$	2564	0.78	0.18	<0.001

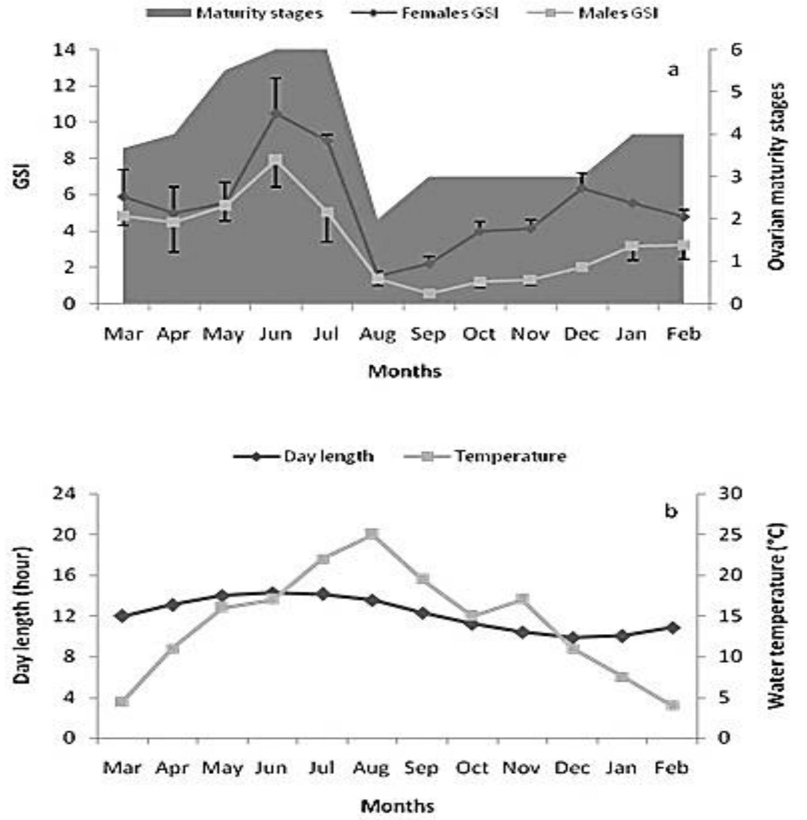

Figure 4: Monthly changes of males and females GSI and maturity stages of ovarian of *Capoeta damascina* (a), and variation of water temperature and day length in the studied area (b).

Discussion

The overall sex ratio was female biased and differs from the ratio of 1:1. Similar males to females sex ratios were reported for *C. damascina* from different geographic locations; Lake Kinneret, 1:1.7 (Stoumboudi *et al.,* 1993); Hanna Wetland, 1: 2.2 (Soofiani and Asadollah, 2010) and Zayandeh-Roud River, 1: 1.57 (Asadollah *et al.,* 2011). Although the overall expected sex ratio in many species is 1:1, but this ratio could be affected by some natural and environmental factors (reviewed by Bohlena and Ritterbusch, 2000). In Gheshlagh Reservoir, females were predominant in overall samples; but the sex ratio was not different between males and females in the early age classes (0, 1 and 2). After that and in the later age classes, the ratio deviated statistically from the ratio 1: 1. Our results showed that males attained maturity at a younger age than females (1 vs. 2). The data on age classes also revealed that males live less long than females due to their higher natural morality. Thus higher male mortality may be a possible reason for the female biased sex ratio in Gheshlagh Reservoir.

Age composition of *C. damascina* in the Gheshlagh Reservoir was different from those reported from Hanna Wetland (Soofiani and Asadollah, 2010) and Zayandeh-Roud River (Asadollah *et al.,* 2011). The age classes in our survey were 0-4 in the males and 0-5 in the females while this was reported as 0-6 and 1-7 in Hanna Wetland and 0-10 in Zayandeh-Roud River. Overfishing is generally accepted as a reason for the loss of large individuals, bringing down the average age and reducing the number of age classes in a spawning stock (Ottersen *et al.,* 2006; Brunel, 2010). This concept was also evident in Gheshlagh Reservoir. Although other reasons such as changes in water temperature and climate conditions (Ottersen *et al.,* 2006) plus temporal fluctuations of river discharge (Smith *et al.,* 2007) could have affected on this decrease, too.

The growth pattern of males and females were similar in the early life stage (0-1) based on their fork lengths and body weights, but thereafter females were longer and heavier than males. These differences could be due to onset of male sexual maturity which occurs at a lower age than in females. These could be explained by the bioenergetic theory; during fish sexual maturation, the allocation of energy is inclined to gonad development than somatic growth (Roff, 1983). This allocation takes place at later age in females and thus, they could grow more than males. The average asymptotic length (L_{inf}) was greater for females than males; however the relative growth coefficient (k) to reach those lengths was smaller for females than males. This is also confirming by growth performance indices of females which was found to be higher than of males in the Gheshlagh Reservoir. The same results were also reported for *C.*

damascina from Hanna Wetland (Soofiani and Asadollah, 2010) and also other species of the genus Capoeta (Turkmen *et al.,* 2002; Alp, 2005; Kalkan, 2008; Ozcan and Balik, 2009; Patimar and Farzi, 2011). This feature could be a sexual dimorphism in the genus Capoeta due to the fact that females grow faster and live longer than males (Weatherley, 1972; Turkamen *et al*, 2002). The comparison of estimated values of von Bertalanffy growth parameters from Gheshlagh Reservoir with those reported from Hanna Wetland (Soofiani and Asadollah, 2010) revealed smaller values for *C. damascina* population in Gheshlagh Reservoir (Table 2). On the other hand the maximum records of fork lengths and body weights of males and females were less than those reported for *C. damascina* from Hanna Wetland too (Soofiani and Asadollah, 2010). The differences in the largest records of length and weight between two populations could be a reason for this difference (Turkmen *et al*, 2002). Negative allometric growth was inferred from length-weight relationships of Gheshlagh population, while these relationships were reported as positive allometric growth from Hanna Wetland population. Several reasons could affect this relationship; nutritional status, environmental conditions, sexual maturity and genetic variations, all of which were not accounted for in the present study.

The age and length of which 50% of males and females attained their first sexual maturity were lower in Gheshlagh Reservoir population than those reported for age and length at first maturity of this species from Lake Kinneret (Stoumboudi *et al.,* 1993), Hanna Wetland (Soofiani and Asadollah, 2010) and Zayandeh-Rud River (Asadollah *et al.*, 2011). The fork length reported from Lake Kinneret population was above 25.0 cm of which all males and females were matured sexually. The spawning fork length and spawning age for males were reported as 13-40 cm and 2 years from Hanna Wetland, and as 13.3- 39.0 cm and 2 years from Zayande-Rud River. In females these parameters were reported as: 24.0-44.2 cm fork length and 4 years old from Hanna Wetland and as: 25.0-54.5 cm and 4 years old from Zayandeh-Rud River. In the other *Capoeta* species, *C. capoeta* (Sen *et al.*, 2008); *C. capoeta umbla* (Turkmen *et al.,* 2002) *C. tinca* (Ekmekçi and Ozeren, 2003); *C. trutta* (Duman, 2004; Oymak *et al.,* 2008), these parameters were found to be higher than in the Gheshlagh *C. damascina* population, however in *C. bergamae* (Ozcan and Balik, 2009) these measurements were found to be close to our findings in this study. Variation between species and the effect of some environmental factors were proposed to explain differences in the first spawning age and size (Turkmen *et al.,* 2002). However, our results showed a loss of large individuals of *C. damascina* in Gheshlagh Reservoir. This loss which was likely due to overexploitation, could serve as a selective factor to decrease size and age at maturity of *C. damascina* from Gheshlagh Reservoir than other populations. Ricker (1981) had showed that reducing of age and size at maturity of many populations of Pacific salmon (*O. kisutch* and *O. gorbuscha*) was related to fishery selection. Based on this study Ricker (1981) had argued this hypothesis; most fisheries tend to catch faster growing individuals of a stock and so, the larger individual in this stock will be eliminated and a greater proportion of slow growing individual will prevail, thus in this circumstance a gradual change in the heritable growth rate seems likely, which could result in slower growth cumulatively and also decrease in age and size (Ricker, 1981).

The spawning season of *C. damascina* based on males and females GSI fluctuations in Gheshlagh Reservoir occurred one month later than those reported from Hanna Wetland and Zayandeh-Roud River which peaked in May (Soofiani and Asadollah, 2010; Asadollah *et al.*, 2011). Moreover the Gheshlagh population showed more delay to reach the maximum GSI than those populations from Lake Kinneret (January-February) and Jordan River basin (January-April) (Stoumboudi *et al.*, 1993; Fishelson *et al.*, 1996). Variation between ecological factors of different regions could be the reason for those differences. The spawning of *C. damascina* in Gheshlagh Reservoir took place by increasing the day length and raising the water temperature. Photoperiod and temperature are known as ecological factors associated with maturation and spawning of freshwater and marine fishes in high latitudes (Lam, 1983). Comparison of our results with those from Lake Kinneret could easily reveal that *C. damascina* population of Lake Kinneret spawn with increasing day length but earlier than Gheshlagh Reservoir population, however water temperature at spawning season is similar for both populations which is achieved in the earlier months. It could be concluded that temperature has more effect on the variation of *C. damascina* spawning season.

The range of ova diameters in this study was close to the ranges reported for this species from Jordan River basin (0.04-1.80 mm) and Zayandeh-Roud River (0.81-1.81 mm) populations (Fishelson *et al.,* 1996; Asadollah *et al.*, 2011); however, the range of ova diameters at each stage of maturity were different from those reported at the Jordan River network and Zayandeh-Roud River. These differences could be due to the use of a morphological key to classify gonad development in our study instead of a histological classification key. The observed range of fecundity through the female samples was less than those reported for *C. damascina* from Hanna Wetland (2203-36763) and Zayandeh-Roud River (2523-72645) populations (Soofiani and Asadollah, 2010; Asadollah *et al.,* 2011). These differences could be due to the larger age classes that they used to calculate fecundity.

The significant relationships between fecundity and body weight, fork length, gonad weight and fish age were also reported for *C. damascina* (Soofiani and Asadollah, 2010; Asadollah *et al.,* 2011), *C. capoeta umbla* (Turkmen *et al.*, 2002) and *C. trutta* (Patimar and Farzi, 2011). Although significant relationships were established between fecundity and those variables, fecundity showed more correlation with body weight than other variables. It may be revealed that the body weight is more reliable to estimate fecundity of *C. damascina*.

In conclusion, the study of growth and reproductive biology of *C. damascina* population from Gheshlagh Reservoir revealed some differences with those reported from other populations in Persian Gulf basin and Euphrates basin. Some of these differences could be due to ecological and environmental features of the studied area. However, other differences could be due to overexploitation of this species in Gheshlagh Reservoir.

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