Some biological parameters of Silver Crucian carp, *Carassius auratus*, in the international wetlands of Alma-Gol and Ala-Gol (Golestan Province, Iran)

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Abstract

In the present study, age, growth and reproduction of *Carassius auratus* were investigated in the Alma-Gol and Ala-Gol (northern Iran) from September 2000 to August 2002. Among the total of 1450 specimens, the estimated ages ranged from 0^+ to 8^+ years. *C. auratus* showed an allometric growth, negatively in Alma-Gol and positively in Ala-Gol. The von Bertalanffy growth curves were fitted to mean total lengths at age, resulted as $L_{tmales}=183.33(1-e^{-0.31(t+1.05)})$ and $L_{tfemale}=245.66(1-e^{-0.19(t+1.21)})$ for Alma-Gol population and $L_{tmale}=224.79(1-e^{-0.24(t+0.83)})$ and $L_{tfemale}=242.80(1-e^{-0.23(t+0.80)})$ for Ala-Gol population. The value of ϕ' index varied from 9.25 to 9.51. The unbalanced sex ratio of males to females was 1:10 and 1:12.7 in Alma-Gol and Ala-Gol, respectively. The reproductive period for this species in these particular areas was February, March and April and the maximum recorded GSI was 2.19 and 2.17 for males and 10.37 and 10.49 for females in Alma-Gol and Ala-Gol, respectively. The linear relationship between absolute fecundity and total weight was more suitable for expressing the fecundity-weight relationship for both populations as estimated: $Fec._{Alma-Gol}= 4120.56+ 62.62W$ and $Fec._{Ala-Gol}= 3832.83+ 68.67W$.

Keywords: *Carassius auratus*, Biology, Wetland, Golestan, Iran

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Introduction

Uncertainty about life history patterns of non-indigenous species in the protected areas such as wetlands poses a risk for sustainable management and protection measures. The basic biological data on non-indigenous species provide an insight into the life history patterns of these species that could be used in conservation programs (Mack *et al.*, 2000). Silver crucian carp, *Carassius auratus* of the family Cyprinidae, is a cyprinid species that is wide-spread in fresh and brackish waters of south Caspian regions (Abdoli, 1999; Coad & Abdoli, 1993). Despite the wide distribution of *C. auratus* in this basin, knowledge on the life history parameters of the fish is limited. The only reference available on the biology of this species in the south Caspian basin is that of Seyyad-Bourani *et al.* (2001) who studied the population dynamics of silver crucian carp in Anzali Lagoon (south-west Caspian Sea). To our knowledge no study on *C. auratus* has been published for the international wetlands of Golestan province. In these areas, *C. auratus* is considered to be one of the most common non-indigenous invasive species (Patimar, 2008). The low economic importance of this fish resulted to paucity of information about it.

Within different habitats, silver crucian carp populations are subject to a variety of environmental conditions. Since, Mann *et al.* (1984) demonstrated strong influence of the local environment on life history traits of fishes; several studies have reported variability in population traits as phenotypic expressions in fishes, both within and between populations (Eliot, 1994; Mazzoni & Iglesias-Rios, 2002; Kume *et al.* 2003). In either case, in order to utilize and manage widely distributed species properly, it is necessary to treat them at population level. Therefore, in order to clarify population-based life history parameters, our objective was to determine the age, growth parameters and reproduction traits of *C. auratus* in the wetlands. Furthermore, the results were discussed using the available data on this species in the south Caspian Basin from different habitats to test whether the growth and reproductive traits of the silver crucian carp vary among habitats.

Material and methods

The study was carried out in the international wetlands of Alma-Gol (37°, 25′N and 54°, 38′E) and Ala-Gol (37°, 20′N and 54°, 35′E). The wetlands in a type of semi isolated lakes are located in the northern part of Iran in the Turkmen step near boundary of Turkmenistan (Fig. 1). The lakes have a connection with Atrak River seasonally. To the west, Ala-Gol is connected to the Caspian Sea by a narrow agricultural channel. The fish fauna of the wetlands consists of 10 species, in which cyprinids are dominated.

A total of 1450 specimens were collected in the study area on a monthly basis from September 2000 to August 2002. Sampling was performed using the gill-nets with various mesh-sizes (14, 16, 20, 22, 24, 28, 32, 36, 40, 45mm). Fresh specimens were examined in the laboratory. Total length was measured to nearest 1mm.

Total weight, weight of ovary and its sub-samples used in the gravimetric method of fecundity determination, were recorded by an electronic analytical balance (±0.01g). 5-10 scales removed from a standard position (second row of scales just under the front edge of dorsal fin) from right side of the body (Mann, 1973). Scales were mounted on glass slides and reviewed for growth annuli using a binocular microscope under reflected light at magnification of 10-25. Growth annuli from each glass slide were counted three times, each time by a different person. Scales showing no clear banding patterns on and on which readings disagreed, were rejected. The relationship between the total length and total weight were determined by fitting the data to a potential relationship $W = aL^b$, where W is the weight in grams, L the size in centimeters, *a* and *b* are the parameters to be estimated; *b* being the coefficient of allometry (Ricker, 1975). The adopted growth model was the specialized von Bertalanffy growth function and the parameters were estimated using the method of Ford-Walford (Everhart & Youngs, 1975) and phi-prime (ϕ') was used to study overall growth performance (Munro & Pauly, 1983): $\phi' = \text{LnK}+2\text{LnL}\infty$.

Sex was determined by examination of the gonad tissue either with eye or with the aid of a binocular (25-40×). The number of fixed eggs (in Gilson's fluid to facilitate the separation of eggs) was estimated by the gravimetric method (Bagenal & Tesch, 1978). To determine the number of eggs, pieces were removed approximately 0.10g each, from the anterior, medial and posterior positions of both ovarian lobes. The pieces were weighed and the eggs in them counted under a binocular microscope. The number of eggs in each female, absolute fecundity, was calculated as the proportion of eggs in the sample to the weight of the whole ovary. To calculate the fecundity, ovaries recognized as IV or V stage were used. The stage of gonad maturity was determined visually following the Nikolsky scale (1963). Gonadosomatic index (GSI %) = (gonad weight/total body weight)×100 was calculated for each fish and all values were averaged for each sampling date.

The comparison between the average values of GSI for seasons and for sexes was carried out by analysis of variance (ANOVA). An analysis of co-variance (ANCOVA) was performed to test significance differences in growth pattern, lengths-at-age, weight–length relationship and fecundity between Alma-Gol and Ala-Gol silver crucian carp. Differences in sex ratios between populations of wetlands were analyzed by chi-square tests. Statistical analyses were performed with SPSS 11.5 software package.

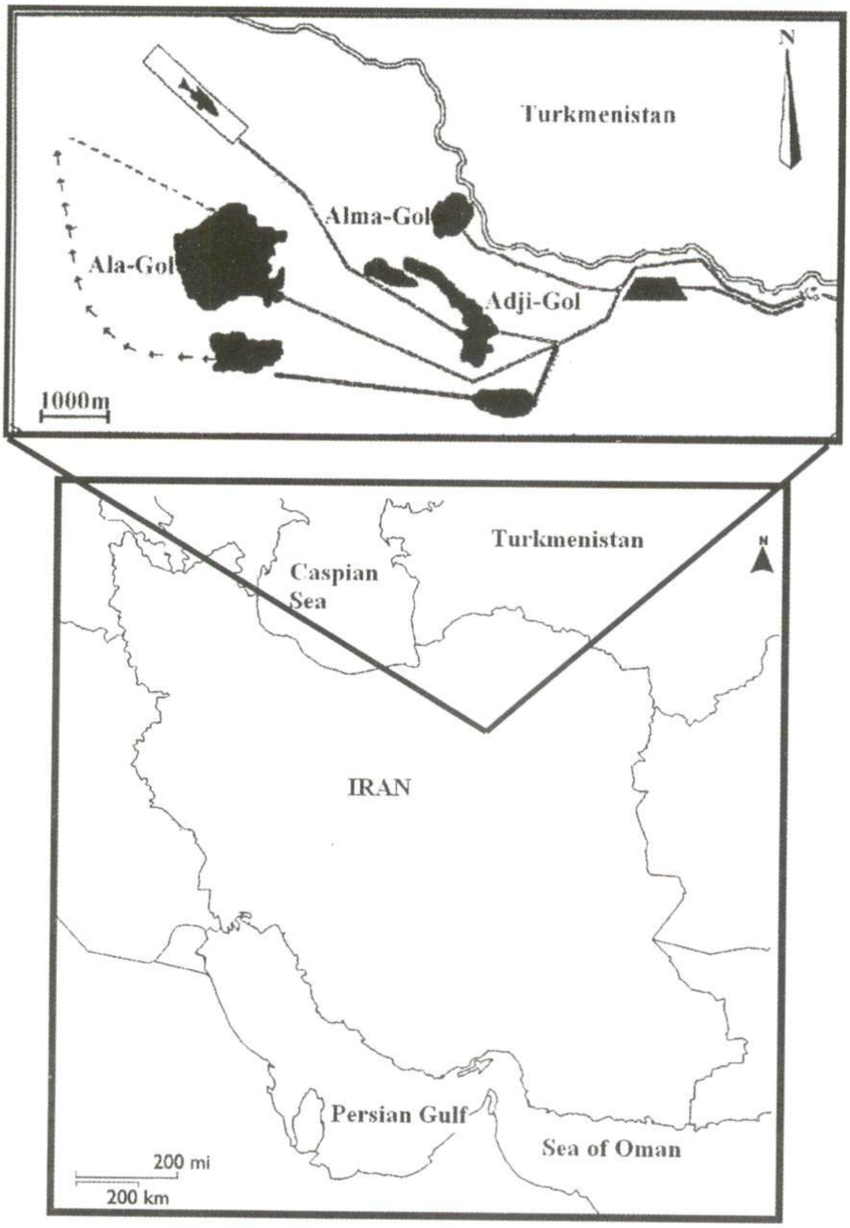

Figure 1: Location of Alma-Gol and Ala-Gol wetlands in the south Caspian, Iran

Results

The number of suitable specimens for age class determination was 96.99% of total number (99 males, 1106 females, 245 immature, 0^+ age group), and 3.10% (n=45) of total scales were omitted and rejected from the analysis as were considered unreadable. Scale reading showed that the maximum age of the studied fish was 8^+ years in both lakes. Individuals of both populations attained over 50% of their maximum observed size in age 2^+ years, and the growth of both populations in length decreases rapidly with age, with growth in length much reduced in age classes beyond age 5^+.

In both populations, there was significant difference between sexes in lengths-at-age (ANCOVA, $P<0.05$), being longer in females than in males, Also, an ANCOVA showed that there were no significant differences among males and females between wetlands (ANCOVA, P>0.05) (Tables 1 & 2).

The weight-length relationship in the different sexes varied significantly (ANCOVA, P<0.05), indicating different growth models (Table 3).

The parameters of the von Bertalanffy growth curves were fitted to mean total lengths at age for each sex, separately and the results were as $L_{tmales}=183.33\ (1-e^{-0.31(t+1.05)})$ and $L_{tfemale}=245.66\ (1-e^{-0.19(t+1.21)})$ for Alma-Gol population and $L_{tmale}=224.79\ (1-e^{-0.24(t+0.83)})$ and $L_{tfemale} = 242.80(1-e^{0.23(t+0.80)})$ for population from Ala-Gol. The value of the growth performance index (ϕ') was 9.35 and 9.51 for females and 9.25 and 9.40 for males in Alma-Gol and Ala-Gol, respectively. The theoretical asymptotic lengths were realistic as the largest specimens caught during this study had length less than calculated L_∞s for both sexes of populations.

Table 1: Mean observed length (mm) and weight (g)-at-age in females from Alma-Gol and Ala-Gol wetlands, Iran

	Alma-Gol				Ala-Gol		
Age	number	TL±SD	W±SD	Age	number	TL±SD	W±SD
0^+	164	48.88±5.87	1.57±0.64	0^+	81	43.77±1.71	1.07±0.17
1^+	46	84.97±4.92	8.91±1.58	1^+	42	84.61±4.97	8.79±1.59
2^+	48	115.49±9.14	22.71±4.49	2^+	22	131.93±5.31	22.81±3.45
3^+	172	137.52±8.25	35.16±6.29	3^+	49	138.58±6.27	37.87±6.62
4^+	146	152.14±7.97	43.67±7.79	4^+	209	158.66±8.64	56.58±7.83
5^+	77	163.69±7.80	56.92±10.58	5^+	132	165.84±4.60	62.97±4.57
6^+	24	174.37±7.98	69.86±10.33	6^+	40	182.08±3.50	84.38±8.91
7^+	28	192.96±3.89	88.05±8.66	7^+	22	194.98±7.56	102.78±7.51
8^+	20	205.79±5.21	124.43±33.62	8^+	29	219.32±8.12	126.02±7.41

Table 2: Mean observed length (mm) and weight (g)-at-age in males from Alma-Gol and Ala-Gol wetlands, Iran

	Alma-Gol				Ala-Gol		
Age	Number	TL±SD	W±SD	Age	number	TL±SD	W±SD
0^+	164	48.88±5.87	1.57±0.64	0^+	81	43.77±1.71	1.07±0.17
1^+	6	81.83±9.32	8.25±3.16	1^+	10	80.30±3.24	7.49±.09
2^+	7	114.17±4.95	18.81±2.89	2^+	11	121.83±5.66	25.90±2.37
3^+	14	131.47±4.68	27.41±2.78	3^+	5	134.46±4.30	32.86±1.46
4^+	20	144.42±4.59	36.92±3.42	4^+	3	146.17±8.57	43.72±1.86
5^+	4	150.40±1.79	38.68±2.07	5^+	4	158.25±4.42	53.27±4.62
6^+	5	163.04±5.78	49.84±2.76	6^+	4	179.52±1.70	70.24±6.13
7^+	---	---	---	7^+	3	189.67±1.52	115.80±0.72
8^+	---	---	---	8^+	3	200.33±2.52	112.66±3.31

Table 3: Relative growth estimations (weight-length relationship) in *C. auratus* from Alma-Gol and Ala-Gol wetlands, Iran

Lake	Sex	a	b	Err.b	Significance	r^2	N
Alma-Gol	Female	$1.69*10^{-5}$	2.95	0.04	<0.05	0.97	561
Alma-Gol	Male	$2.81*10^{-5}$	2.83	0.02	<0.05	0.94	56
Ala-Gol	Female	$1.36*10^{-5}$	3.12	0.01	<0.05	0.99	545
Ala-Gol	Male	$1.08*10^{-5}$	3.05	0.03	<0.05	0.98	43

Table 4: Number and frequency (%) of males and females in Alma-Gol and Ala-Gol wetlands, Iran)

	Alma-Gol		Ala-Gol	
	Number	Frequency (%)	Number	Frequency (%)
Male	56	7.17	43	6.43
Female	561	71.83	545	81.46
χ^2	403.67*		428.59*	

*Significant (P<0.05)

Among sexed specimens, females were dominant in both wetlands (Table 4). The ratio of males to females was 1 to 10 and 1 to 12.7 in Alma-Gol and in Ala-Gol, respectively. 164 (21.00%) specimens in Alma-Gol and 81 (12.11%) specimens in Ala-Gol could not be differentiated sexually as they were immature 0^+ group, having a very thin and translucent gonads. The number of immature females present in the 1^+ class was significant (13.00% and 16.66% in Alma-Gol and Ala-Gol, respectively). There were no immature female in 2^+ and older classes in both lakes.

The GSI was calculated for each sex, separately. Significant changes were obtained in the temporal variation of gonad activity (ANOVA, P<0.05). The GSI values of males were significantly lower than those of females (t-test, P>0.05). The maximum recorded values of GSI were 2.19 and 2.17 for males and 10.37 and 10.49 for females in Alma-Gol and Ala-Gol, respectively. The GSI of same sexes of both populations followed almost the same pattern (Fig. 2). The reproductive period for this species in these particular wetlands is thus February, March and April when GSI is considerably higher. It thereafter decreases in summer when the values were low, showing the resting period.

Fecundity was estimated from 285 (160 females from Alma-Gol and 125 females from Ala-Gol) mature females which ranged 45 to 210mm TL and were caught in spring 2001 and 2002. Absolute fecundity estimates ranged from 3165 to 13020, with a mean value of 6520.82±2469.14(SD) eggs in females of Alma-Gol and from 3641 to 12980, with a mean value of 6509.65±1924.22 (SD) eggs in females of Ala-Gol. Comparison of different regression models showed that the power regression is the most suitable model to describe the relation of absolute fecundity to total length. General relations of absolute fecundity to total length are given below:

Absolute $Fec._{Alma\text{-}Gol} = 2.17TL^{1.58}$ (R^2=0.63, F=25.32, P<0.05)

Absolute $Fec._{Ala\text{-}Gol} = 4.51TL^{1.44}$ (R^2=0.56, F=16.86, P<0.05)

Taking into account that the absolute fecundity could be associated with the total weight, we estimated the models of absolute fecundity-total weight relations in females of both populations, that described by the following equations:

Absolute $Fec._{Alma\text{-}Gol} = 4120.56+62.62W$ (R^2=0.74, F=35.53, P<0.05).

Absolute $Fec._{Alma\text{-}Gol}$= 4120.56+ 62.62W (R^2=0.74, F=35.53, P<0.05)

Absolute $Fec._{Ala\text{-}Gol}$= 3832.83+ 68.67W (R^2=0.78, F=39.89, P<0.05)

The regression analysis revealed that linear relationship between absolute fecundity and total weight is more suitable for expressing the F/W relationship for both populations of this species in these wetlands. ANCOVA, taking the fish length as a co-variate and the area as a factor, showed no significant differences in fecundity between two wetlands (P>0.05).

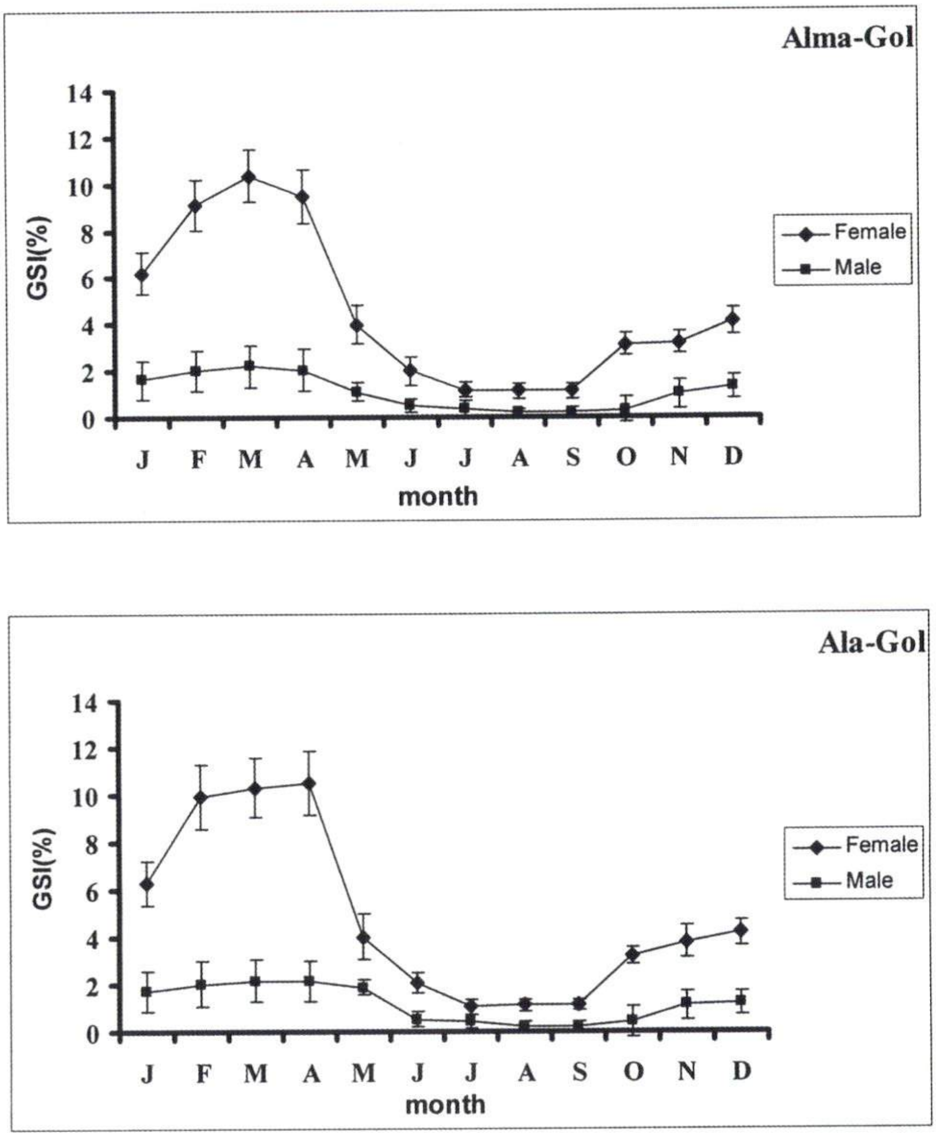

Figure 2: Monthly Gondosomatic Index (GSI %), mean value (±SD) for *C. auratus* in Alma-Gol (above) and Ala-Gol (below) wetlands, Iran

Discussion

The life-histories of several phylogenetically distinct freshwater fishes have been shown to vary greatly throughout their range (Mann *et al.* 1984, Lobon-Cervia *et al.* 1991 & 1996). The lifespan of the population in the studied wetlands was relatively long, with nine age groups being evident (maximum age-class: 8^+). This is different from the patterns observed in Anzali Lagoon where maximum observed age was 6+ (Sayyad-Bourani *et al.* 2001). The study area is wetland habitat with almost stable conditions, characteristics which might have determined the greater longevity. Differences obtained in age composition and longevity could be explained on the basis of the different exploitation patterns and/or ecological conditions. In this sense, while the *C. auratus* is not subject to commercial exploitation in the south Caspian Basin, environmental conditions seem to affect significantly the life history parameters of this species.

The exponents of total length-somatic weight relationship of *C. auratus*, estimated in the wetlands, showed that the somatic weight grows allometrically (Ricker, 1975) with the total length. Differences between males and females in the relationship of total length–weight can be explained by the differences in size distribution of the two sexes as a consequence of inter-sexual differences in growth, suggesting the convenience of using the appropriate estimate from those proposed for each group when calculating weights by sexes. The functional regression *b* value is directly related to the weight affected by ecological factors such as temperature, food supply, spawning conditions and habitat characteristics within a year (Ismen, 2005). Higher values in females than in males are apparently suggesting a different fish condition or fitness between sexes as consequence of different responses to habitat conditions.

There were differences in the parameters of the von Bertalanffy growth formula between sexes and populations. These differences can be attributed to differences in the size of the largest individuals sampled in each wetland. Considering that L_∞ value 30% higher than the observed maximum lengths (Garcia-Rodriguez *et al.*, 2005), the obtained results are reliable values. A trade-off between growth rate (k) and L-infinity (L_∞) is often found. Optimum ecological conditions cause a shift towards larger maximum size which in turn results larger L_∞ values (Dulcic et al., 2003). Comparison of k and L_∞ from the population in Anzali lagoon shows that the growth patterns were different; in Anzali lagoon the parameters were estimated as L_∞= 360mm, k=0.225 year^{-1} and ϕ'=10.28 (Sayyad-Bourani *et al.*, 2001). The growth performance (ϕ') is considered a useful tool for comparing the growth curves of different populations of the same species and/or of different species belonging to the same family (Sparre *et al.*, 1987). In the studied populations of the *C. auratus* from the South Caspian basin, ϕ' ranged from 9.34 to 10.28, indicating that the obtained ϕ'

of the *C. auratus* in both wetlands studied are very close to each other. These evidences confirm the reliability of the *C. auratus* growth curve, as the overall growth performance has minimum variance within the same species because it is independent of growth rates.

– In the wetlands of Alma-Gol and Ala-Gol, the overall sex ratio is unbalanced in favor of females, probably as a consequence of the gynogenesis even though the males had normally developing gonads. The observed sex ratio was unlike that found by Sayyad-Bourni *et al.* (2001) who proposed a male to female ratio of 1 to 148 in Anzali Lagoon. The predominance of females is common in *C. auratus* populations. It seems that the differences in sex are highly significant throughout its range distribution.

From maximum recorded GSI values, it is evident that the reproductive season of the *C. auratus* extends from February to April. Sayyad-Bourani *et al.* (2001) also reported a similar situation; according to them, the spawning period of this species occurs slightly earlier, from January to March in Anzali Lagoon. In comparison with other cyprinid species (Abdoli, 1999), *C .auratus* has an extended breeding season (~3 months) in south Caspian basin (Abdoli, 1999). This extended breeding time of populations may be interpreted as an increase of reproductive effort which, in turn, promotes a rapid increase in the number and distribution of *C. auratus* as a successful invasive species.

There is a widespread trend for fecundity in fishes to be positively correlated with length (Peters, 1983) because the amount of energy available for egg production and the body cavity accommodating the eggs increases with fish size (Jonsson & Jonsson, 1999). In the present study, the absolute fecundity of *C. auratus* was positively correlated to fish size (length and weight), larger females may be considered as a life history strategy *C. auratus* for supporting increased egg production in the wetlands. It has been suggested that variations in fecundity between and within freshwater fish populations is regulated by proximate environmental factors (Heins & Baker, 1987; Lobon-Cervia *et al.*, 1991) and the fecundity-body weight relationship can probably be used to discriminate between the different populations of the same species due to variable growth rates in different localities (Hotes *et al.*, 2000), but no data on fecundity-body weight relationship of other populations of this species are currently available from literature. According to our results, the correlation coefficient of the relationship between fecundity and fish weight was higher than that of the relationship between fecundity and total length. It is thus clear that the total weight gives a better correlation with reproductive capacity.

In conclusion, Life history characteristics of the *C. auratus* is important with respect to management of the species, under consideration point to being simple, easily adapted to its habitat and gynogenesis, which, in turn, may be interpreted an adaptive response that promotes a rapid increase in the number and distribution of this species. As described, it has been shown that the silver crucian carp life history parameters in south Caspian basin could be varied significantly among populations over the its range distribution. There are several possible explanations for the varied life history parameters. The variations relating to growth and reproduction may be interpreted as adaptation to local selective pressure and respond to environmental characteristics to improve fitness locally.

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