Iranian Journal of Fisheries Sciences
http:doi.org/ 10.22092/ijfs.2024.131125 2024, 23(2) 349-358

Short Communication

Some morphometric traits, condition factor, and growth indices of *Caridina fossarum* Heller, 1862 (Caridea: Atyidae), endemic to Iran

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Keywords: Growth, Decapoda, freshwater shrimp, condition factor index

Received: May 2023 Accepted: July 2023 Published: March 2024

Introduction

The bionomic studies on the representatives of the family Atyidae from Iranian lotic and lentic habitats are lacking at all and the available published information is focused on taxonomic investigations and zoogeographical distribution of *Caridina fossarum* Heller, 1862, *Caridina babaulti* Bouvier, 1981 and *Atyaephyra desmarestii* (Millet, 1831) (Heller, 1862; Gorgin, 1996; Karami and Gorgin, 2000). Up to now, only the biological traits of the species reproduction are well known (Zare *et al.*, 2011). Along with the study of reproduction, morphometrics and relative growth of the species remain crucial studies to describe completely their life history, population dynamics and productivity. Moreover, the length-weight relationships (LWR) and length-length relationships (LLR) have been applied for basic uses in the assessment of fisheries stocks and populations (Ricker, 1968). The length-weight and length-length relationships are important in stock assessment modeling, especially in the estimation of biomass or stock weight from growth equations (Pauly, 1993; Avsar, 1998; Moutopoulos and Stergiou, 2002). Furthermore, by studying LWR and LLR, crop biomass can be estimated (Morey *et al.*, 2003) and conclusions on seasonal variations in species growth can be tracked (Richter *et al.*, 2000). Finally, certain mathematical parameters of the LWR, as the condition factor, are usually influenced by the age, sex, season, and maturity stages of the species (Anyanwu *et al.*, 2007).

The aim of this study is to determine the main morphometric features of *C. fossarum* population from Ghomp-Atashkedeh spring, as well as to estimate the exact relationships of carapace length to body length, the condition factor and to describe the relative growth and mortality which have not been available for this species so far.

Materials and methods

The sampling area is located in the natural spring Ghomp-Atashkadeh (Fasa City, Fars, Iran). Monthly samples of *C. fossarum* were collected from April 2007 to March 2008. At the laboratory, the sex was determined through stereoscopic inspection of a second pair of pleopods, by recording the presence or the absence of the appendix masculina. For each specimen, five morphometric measurements were made: total length (TL), body length (BL), carapace length (CL), rostrum length (RL) and 6th pleon segment length (SSL). Body lengths' measurements were made by using a digital caliper (±0.01 mm). The total wet weight (TW) of animals was estimated to the nearest 0.01 g using an electronic balance. Two morphometric relationships, carapace length versus total length (CL versus TL), and carapace length versus weight (TL versus W), for females and males were calculated separately using the power functions $TL=aCL^b$ and $W=aTL^b$, respectively (Tidu *et al.*, 2004). The parameters of the equations were estimated by least-square regression following logarithmic transformation. Before regression analysis of log TL on log CL and log TL on log W, log–log plots of length-length and length-weight values were performed for visual inspection of outliers. The condition factor index (CF), which describes the condition of a population was estimated according to the equation given by Le Cren (1951).

Growth was described using the von Bertalanffy growth function (VBGF) (Pauly and Gaschutz, 1979). The natural mortality, life span and t_o were estimated by Pauly method (1980). To compare the growth performance of the shrimps, Pauly and Munro (1984) equation was used as:

$$\varphi = 2\log_{10}L\infty + \log_{10}K$$

Results and Discussion

The mean, range, standard deviation (SD), and coefficient variation (CV) of morphologic measurements of *C. fossarum* are summarized in Table 1. The average sizes of males were significantly smaller than those in females ($p<0.05$). So, the growth rate of males was much lower than the growth rate of females. Nevertheless, proportions of morphological characteristics to carapace length in males were significantly higher than those in females ($p<0.05$). No difference was detected between the ratio of RL/CL of both sexes ($p>0.05$).

Table 1: Inter-sex comparison of morphological characteristics of *Caridina fossarum*.

	Sex	Range (mm)	Mean ± SD	CV		Sex	Range (mm)	Mean ± SD	CV
TL	M	11.8-24.5	18.22±2.54b	14	TL/CL	M	3.1-5.6	4.28±0.45a	11
	F	10.7-29.3	20.60±3.12a	15		F	2.9-5.5	4.22±0.38b	9
BL	M	9.6-20.7	14.94±2.08b	14	BL/CL	M	2.5-4.8	3.52±0.36a	10
	F	9-26.5	16.94±2.61a	15		F	2.5-4.6	3.47±0.29b	9
CL	M	1.3-5.1	4.27±0.70b	21	RL/CL	M	0.3-1.1	0.77±0.15a	20
	F	1.1-7.3	4.91±0.82a	25		F	0.3-1.3	0.79±0.15a	20
RL	M	2.4-6.2	3.27±0.68b	16	SSL/CL	M	0.2-0.7	0.45±0.07a	17
	F	2.2-7.2	4.88±0.97a	17		F	0.3-0.7	0.43±0.07b	16
SSL	M	1.1-2.7	1.89±o.28b	15					
	F	1.2-3.4	2.11±0.41a	20					

*The dissimilar letter indicates differences significantly among characteristics mean.
(TL: total length, BL: body length, CL: carapace length, RL: rostrum length, SSL: 6th pleon segment length, M: male, F: female)

In this paper, both of growth and size structure of a population of *C. fossarum* are studied for the first time. The only previously available data were on other species in the genus (Yam and Dudgeon 2005; Leuven *et al.,* 2008). On average, females of *C. fossarum* were significantly larger and heavier than males, so females attain larger body sizes compared to males of the same age. The differences in mean weight and length among sexes indicate the existence of sex dimorphism with respect to size in *C. fossarum*, as has been reported in other penaeid shrimps (Cha *et al.,* 2004; Puspitasari *et al.,* 2013; Bortolini *et al.,* 2019). Although the consequence of this sexual dimorphism has not yet been revealed, several hypotheses about this phenomenon have been proposed. Kim (2005) reported that the growth rate of the male *Palaemon gravieri* is significantly lower than that of the female; this may indicate a reduction in the male's energy investment in growth and a decrease in their risk of predation. In *Sclerocrangon boreas*, the earlier onset of sexual maturity in the male than in the female is suggested to contribute to the male's smaller body size (Sainte-Marie *et al.,* 2006). However, the relationship between the growth and sexual maturity of male *C. fossarum* remains unknown and needs to be examined in the future. An individual's fecundity of female *T. curvirostris* increases exponentially with body size (Cha *et al.,* 2004). Therefore, the large body size of female *T. curvirostris* may be an adaptation to increase egg production. However, in contrast to these reports Mossolin and Bueno (2003), Fransozo *et al*. (2004) Mantelatto & Barbosa (2005) observed that males reached a greater total length than females as a function of the differences in growth rates and patterns of population structure between sexes. In *M. brasiliense*, dimorphism may be related to domination males over females, as well pre-adult males, with larger body size during the copulation process.

The size frequency distribution was normal (KS= 0.139) for either sex, with a peak of occurrence in the size classes 5, 6 and 7 (4.0-5.5 mm). Males and females presented unimodal distribution with the absence of length class (6.5-7.5 mm) for males and peaks of occurrence in the size classes 4, 5 and 6 (3.5-5 mm) for males and 7^{th} size class (5.0-5.5 mm) for females (Fig. 1).

Size frequency distribution revealed a greater abundance of males in the first size classes and a larger number of females in the final classes. The high increase in number of individuals starting from the 4th class characterizes a marked recruitment of males measuring 3.5 to 4 mm CL, indicating an early preparation for reproduction compared to females.

Only the females fished in spring and summer (>20°C) presented a slope that was not different from 1, but the regression slopes for females was significantly smaller from 1 in Autumn and Winter (<20°C); for males, the slopes were significantly smaller than 1 in both seasons (Table 2). The slopes in the inter-sex comparisons were significantly different in spring and summer (>20°C) (Table 3). The slopes in the inter-sex comparisons were significantly different in females. However, the inter-sex comparisons in males showed that there were no significant differences in both slopes and elevations.

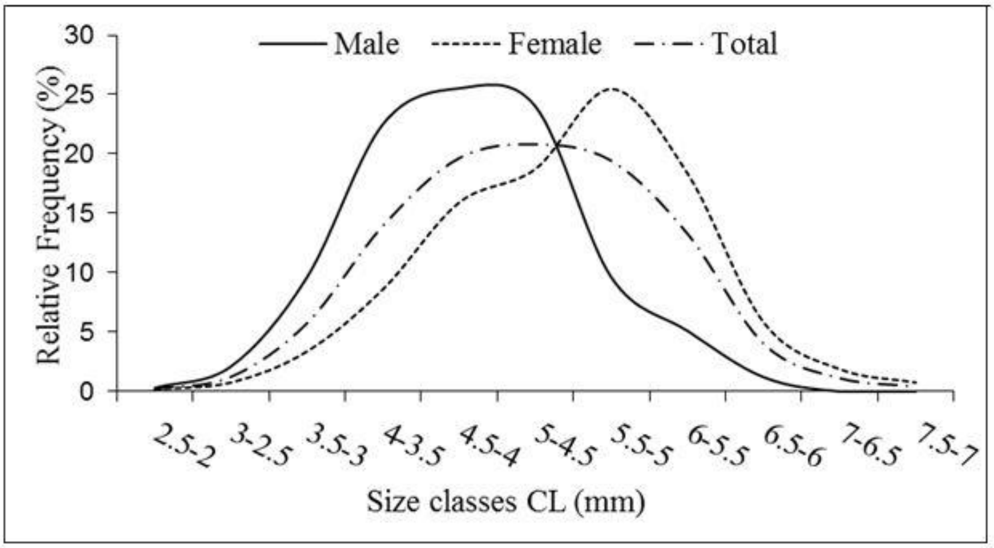

Figure 1: Size frequency distribution (CL = carapace length) of *Caridina fossarum* individuals (333 males and 533 females) collected in Ghomp-atashkehe spring in 2007-2008.

Table 2: Estimated parameters of CL vs. TL and W vs. TL relationships of *Caridina fossarum* in 2007-2008.

Season	CL vs. TL relationship					
	Group	**N**	**b (±S.E.$_{(b)}$)**	**a**	**r^2**	**A**
Spring and Summer (>20°C)	M	77	0.653 (±0.074)	6.772	0.510	na
	F	102	0.943 (±0.042)	4.468	0.833	i
Autumn and Winter (<20°C)	M	244	0.662 (±0.031)	7.036	0.651	na
	F	290	0.718 (±0.028)	6.795	0.691	na
	W vs. TL relationship					
Spring and Summer (>20°C)	M	76	2.220 (±0.148)	0.0002	0.754	na
	F	102	2.642 (±0.085)	0.00005	0.906	na
Autumn and Winter(<20°C)	M	242	2.111 (±0.086)	0.0002	0.713	na
	F	286	2.394 (±0.065)	0.00009	0.828	na

N, no specimens; a and b, intercept and slope of the relationships TL = aCL^b or W = aTL^b, respectively; M: Male; F: Female; S.E.$_{(b)}$, standard error of parameter b estimated at 95%; r^2, coefficient of determination. A= allometry: (i) isometry, (na) negative allometry.

Table 3: Inter-sex and intra-sex comparisons of the slope of the CL vs. TL and TL vs. W relationships (A: spring and summer; B: autumn and winter) in 2007-2008.

Compared relationships	**Difference between slopes**	
	CL vs. TL	**TL vs. W**
Females (A)/males (A)	$t > t_{0.05,170}=1.974$	$t > t_{0.05,500}=1.965$
Females (B)/males (B)	$t < t_{0.05,500}=1.965$	$t > t_{0.05,170}=1.974$
Females (A)/ Females (B)	$t > t_{0.05,400}=1.966$	$t > t_{0.05,400}=1.966$
males (A)/males (B)	$t < t_{0.05,300}=1.968$	$t < t_{0.05,300}=1.968$

(TL: total length, W: body weight, CL: carapace length)

Thus, a common equation for the whole year can be obtained for males. From these equations, the growth rate of TL in relation to CL was calculated by means of the first derivate for both sexes in two seasons. As shown in Figure 2, the growth rate of TL in relation to CL in females was greater than males and constant (isometric growth) in spring and summer (> 20°C), while in males a decreasing rate (negative allometry) in each two seasons of the studied year was observed. In this study, negative allometry was obtained for males in all seasons while females showed it only in autumn and winter (<20°C) in the relationship CL versus TL, reflected in the decreasing growth rate of TL in relation to CL. Conversely, females in the breeding season have a constant (isometric) and larger TL growth rate than males. These differences in the growth pattern explain why females for the same CL have a larger TL than males. Thus, for an equal carapace size, females have also a greater abdomen, a feature which can be explained by its reproductive functions since it is the zone of egg attachment. On the other hand, this relationship in males due to its inter-season stability, as found in the present study, showed that it could not be affected by environmental factors. However, to confirm this hypothesis a larger temporal series is required. In the all-relationships TL versus W, the slopes were significantly smaller than 3 (negative allometry). The inter-sex comparisons showed in both seasons that there were significant differences in the slopes and elevations. The inter-sex comparisons showed in female sex that the slope in spring and summer was significantly greater than the slope obtained in autumn and winter (Table 3). Therefore, as expected, the growth rate of W in relation to CL for the female sex was greater in spring and summer (>20°C) (Fig. 3). The CL versus W relationship shows an inter-season variability for the female sex, but this relationship in males showed an inter-season stability.

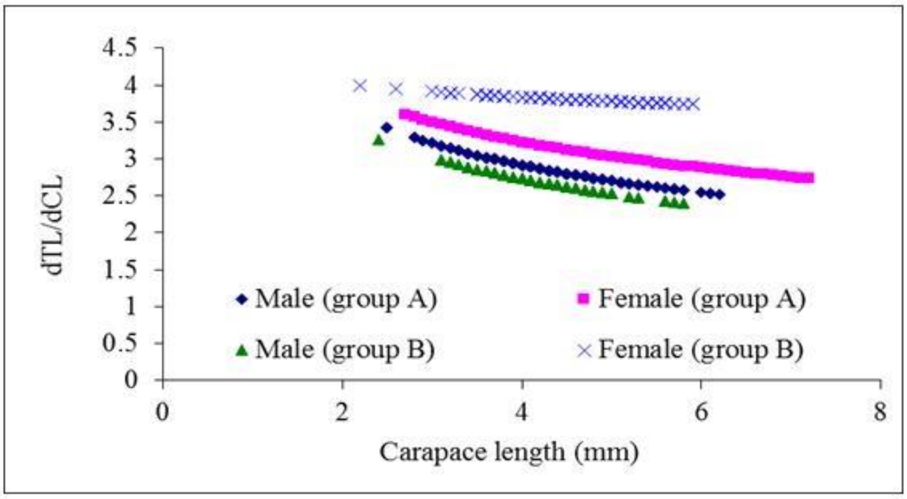

Figure 2: Growth rate of total length in relation to the carapace length (mm) in 2007-2008 (A: spring and summer; B: autumn and winter).

The beginning of spring onward was associated with a reduction of CF until the first month (July) of summer in both sexes. After that, except for september (a negligible increase of CF), a gradual decline in CF was observed, reaching the lowest value in February. The mean CF of female shrimps (1.56±0.33) was more than males (1.52±0.38) ($p>0.05$). The maximum value of mean CF was obtained in July for male (1.8±0.46) and female shrimps (1.93±0.36). On the other hand, male

(1.28±0.09) and female shrimps (1.28±0.13) showed a minimum value of mean CF in February. No significant variation was observed in mean CF during different months for male and female shrimps. Also, on seasonally based analyses, the maximum and minimum value means CF of both sexes were observed in summer and winter respectively (Fig. 4).

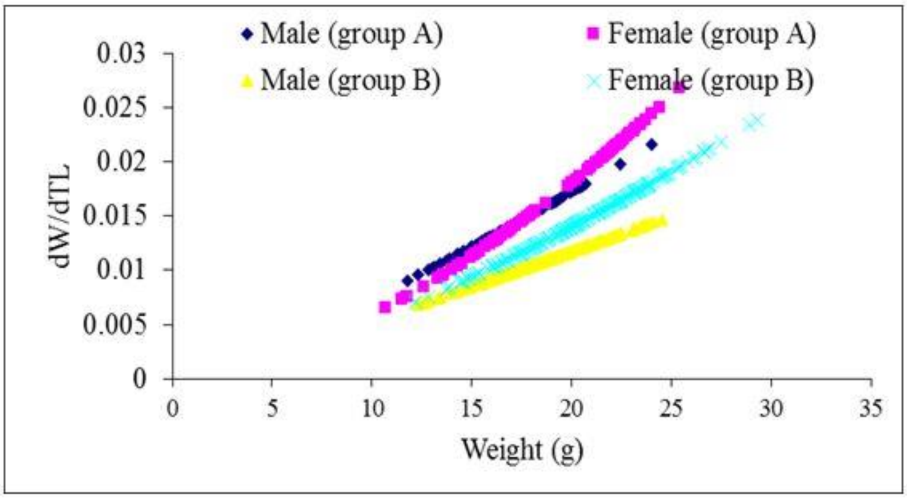

Figure 3: Growth rate of weight (g) in relation to the total length 2007-2008 (A: spring and summer; B: autumn and winter).

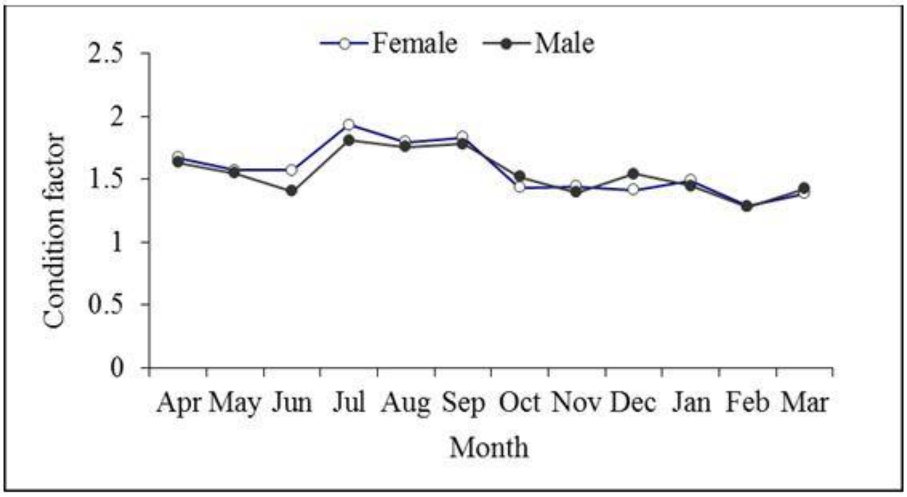

Figure 4: Relative condition factor of *Caridina fossarum* in different months in 2007-2008.

The higher value of condition factor in females can be due to larger size and gonad high weight of adult individuals (Pinheiro and Fiscarelli, 2009; Lira *et al.,* 2012). Based on the main breeding season of *C. fossarum* (April to August) (Zare *et al.*, 2011), the value of condition factor was high in spring and summer compared with autumn and winter which can be affected by increased gonad development in the reproduction period (Taddei *et al.*, 2017). On monthly-based analyses, decrease in the value of condition factor (except for July) was observed during the reproduction period. Increasing in the condition factor in July can be due to captured samples that energy stored in their hepatopancreas was restored to the maturity of the gonads or their reorganization after spawning (Naderi, 2017; Naderi *et al.,* 2018). In this study, the minimum value of condition factor was observed in winter (February). The one of reasons for this situation can be a high frequency of ecdysis (Pinheiro and Fiscarelli, 2009).

Results showed that female shrimps had higher L∞ and K values (L∞=6.62 mm, K=0.71 year^{-1}) compared to the values of males (L∞=6.1 mm, K=0.61 year^{-1}) which is similar to reporting for *Crangon crangon* (Oh *et al.,* 1999) and *Neocaridina denticulata denticulate* (Oh *et al.,* 2003). The parameter "t_o" was -0.39 years for males, and -0.32 years for females. The natural mortality was calculated 1.36 per year for both sexes. The maximum life span was estimated at 4.5 years for male and 3.9 for female shrimps. There were some differences in the growth performance index between two sexes, indicating that female shrimps grew faster and reached a larger size at age than males, as is also indicated by the growth performance indices (Φ') of 1.34 for males and 1.49 for females. This pattern of growth was similar to several studies for freshwater and marine decapods: *Caridina fernandoi* (De Silva and De Silva, 1989); *Palaemon paucidens* (Kim *et al.*, 2008); *Neocaridina denticulata denticulata* (Oh *et al.*, 2003); *Haliporoides sibogae* (Baelde, 1994); *Crangon crangon* (Oh *et al.,* 1999); *Palaemong ravier* (Kim, 2005); *Palaemon adspersus* (Bilgin *et al.*, 2009); *Ocypode rotundata* (Naderi, 2017; Naderi *et al.*, 2018).

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