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Reproductive characteristics of Siahmahi, *Capoeta damascina* (Family: Cyprinidae) in Beheshtabad River, Tigris basin

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Abstract A total of 426 specimens of Mesopotamian barb (Siahmahi) *Capoeta damascina* (Cyprinidae) were caught by gillnets (1–6 cm mesh sizes) from Beheshtabad River, Chaharmahal and Bakhtiari Province from May 2013 to June 2014. Fish specimens were anesthetized in 1% clove oil solution, fixed in 10% buffered formalin and transported to the laboratory for further analyses. Fork lengths of the sampled fish ranged from 8.94 cm to 42.45 (23.32±6.53SD) cm and total weight from 10.3 to 1255.5 (242.5±213.4) g. Based on scale readings, the maximum age was found to be 7^+ years for males and 8^+ for females. Six reproductive characteristics, viz: sex ratio, Gonadosomatic Index (GSI), Hepatosomatic Index (HSI), relative fecundity, absolute fecundity and ova diameter were determined. The smallest mature male and female were 11.2 and 18.5 cm in fork length respectively. Sex ratio was 1M:0.7F. The GSI showed that spawning occurred from March to June. Oocyte diameters ranged from 0.57 to 2.48 (1.30±0.41) mm. Absolute fecundity ranged between 2260 and 51770 (15360±12030) eggs. Absolute fecundity and fish size (fork length and total weight) were highly correlated. Relative fecundity varied from 11 to 65 (33±12) eggs per gram of total body weight. The average hepatosomatic index was 2.25 ± 0.05 and the highest value was observed in March (3.05 ± 0.31).

Keywords: *Capoeta damascina*, Cyprinidae, Fecundity, Gonadosomatic index, Ova diameter, Sex ratio

INTRODUCTION

The cyprinid fish, Siahmahi or Mesopotamian barb, *Capoeta damascina* (Valenciennes, 1842), is a very abundant native fish in Iran (Keivany et al. 2016) and other countries in Middle East such as southern and eastern parts of Turkey, the eastern Mediterranean coast of Syria, Lebanon and coastal rivers of Palestine (Khalaf 1987; Krupp and Schneider 1989; Stoumboudi et al. 1993; Fishelson et al. 1996; Schöter et al. 2009). Like salmons, *C. damascina* is a strong counter-current swimmer, capable of jumping very strongly and rapidly (Fishelson et al. 1996). Although morphometrics, parasites, scale structure, age, growth and reproduction characteristics of the mesopotamian barb in the Middle East waters have been studied extensively (Khalaf 1987; Stoumboudi et al. 1993; Fishelson et al. 1996; Abdoli & Mostafavi 2009; Soofiani & Asadollah 2010; Asadollah et al. 2011; Jalali & Miar 2011; Samaee & Patzner 2011; Marammazi et al. 2014; Razavipour et al. 2015a, b; Asadollah et al. 2017), little is known on reproduction of this fish in Karun River basin such as Beheshtabad River, where Mesopotamian barb is mainly caught for consumption.

The aim of this study was to determine reproductive characteristics of *C. damascina* including: sex ratio, length and age at first maturity, Gonadosomatic and Hepatosomatic Indices, ovum diameter, absolute fecundity and relative fecundity in Beheshtabad River, a tributary of Karun river in Tigris basin of Chaharmahal-va-Bakhtiari province, Iran, to provide the basic data for its management and conservation in this basin.

MATERIAL AND METHODS

Beheshtabad River is located approximately 40 km southwest of the city of Shahrekord (32˚01′50″N; 50˚37′45″E). Monthly samples were collected from May 2013 to June 2014 to determine some environmental factors including water temperature, pH, conductivity (EC) and total dissolved solid (TDS) of water using a HANNA water quality measuring instrument (model HI 98129).

Specimens were caught by gillnets of 1–6 cm mesh sizes (30m long, 1.5m depth). Fish samples were anesthetized with 1% clove oil, fixed in 10% buffered formalin and transported to the laboratory for further analyses. In the laboratory, fork length (FL) was measured to the nearest 0.1 mm and total weight and weight of gonads were measured to the nearest 0.01 g. For the age determination, scales were taken from above the lateral line below the anterior part of the dorsal fin. Each scale was cleaned with 5% KOH. After preparing the scale, age reading was carried out through microscopic examination of annuli (Biswas 1993). To validate the ageing, each scale was read by three people and coincided readings were recorded.

The spawning period was determined by identifying monthly changes in the gonadosomatic (GSI) and hepatosomatic index (HSI). The GSI and HSI were calculated using the following equations (Biswas 1993; Nikolsky 1963).

$$GSI = \frac{\text{Weight of gonad}}{\text{Total weight of fish}} \times 100$$

$$HSI = \frac{\text{Weight of liver}}{\text{Total weight of fish}} \times 100$$

For the estimation of absolute and relative fecundities, the ovaries of ripe females at maturity stage III and above were used (Brown-Peterson et al. 2011). Ovaries were removed, weighed and then placed in Gilson′s fluid for two days to harden eggs and dissolve ovarian membranes. Absolute fecundity (F) was estimated using the gravimetric method as follows (Wootton 1998):

$$F = \text{Gonad weight} \times \frac{\text{Egg number in the sub sample}}{\text{Sub sample weight}}$$

The relative fecundity (Bagenal and Tesch 1978) was calculated as:

$$\text{Relative fecundity} = \frac{F}{\text{Total body weight}}$$

Mean egg diameter was examined by measuring 30 eggs (10 oocytes from anterior, middle and posterior parts of each ovary). Measurements were made to the nearest 0.01 mm under a microscope with an ocular micrometer. Comparisons of GSI and HIS values during the year, ova diameter and fecundity in different ages were carried out by analysis of variance (ANOVA). Overall sex ratio was assessed using the Chi-square test incorporating Yate's correction for continuity (Sokal and Rholf 2012). All the comparisons were performed at 95% confidence level using SPSS 19 and Excel 2010 software.

RESULTS

Physicochemical properties of the water

The mean values ± SD and range for water temperature, pH, conductivity (EC) and total dissolved substances (TDS) are indicated in Table 1.

Table 1 Changes in some environmental factors of Beheshtabad River water during May 2013-June 2014.

Factor	Mean ± SD	Range
Water temperature (˚C)	12.47 ± 4.7	3.2-19.7
pH	8.6 ± 0.37	7.9-9.4
EC (µs cm^{-1})	690.5 ± 158.5	504-982
TDS (mg L^{-1})	343.3 ± 81.95	25-495

Length frequency and sex ratio

Amongst the 426 fish examined, 241(56%) were male, 169 (40%) female and 16 (4%) undetermined. The fork length ranged from 8.94 to 42.95 (23.32 ± 6.53 SD) cm and weight ranged from 10.3–1255.5 (242.59 ± 213.5) g. The majority of fishes were in the range of 19.10-23.00 cm for males and 23.10-27.00 cm for females (Table 2). The maximum age of the population based on scale reading was 7^+ years for males and 8^+ years for females. The overall sex ratio of males to females was 1M:0.7F and Chi-square analysis showed a significant difference from the 1:1 ratio ($\chi^2 = 12.295$, $P < 0.001$).

The smallest mature males and females were in the 11.1-15 and 15.1–19 cm length classes, respectively (The smallest mature male was 11.19 cm and the smallest mature female was 18.50 cm in fork length) (Table 2). The mean age at first maturity of *C. damascina* for males was ≤ 2 years (all specimens at age 2^+ (100%) were mature), and the age at first maturity for females was 3^+ years.

Table 2 Stages of first sexual maturity of male and female *C. damascina* of different fork length groups

Length class (cm)	Male			Female		
	n	Number of mature	% mature	n	Number of mature	% mature
11–15	4	4	100[a]	6	0	0
15–19	66	66	100	9	1	11.1
19–23	105	105	100	37	19	51.4[a]
23–27	33	33	100	41	40	97.6
27–31	19	19	100	29	29	100
31–35	13	13	100	24	24	100
35–39	1	1	100	13	13	100
39-43	-	-	-	10	10	100

[a]Length (fork length) groups at the first maturity of male and female fish.

Gonadosomatic and hepatosomatic index

The average gonadosomatic index (GSI) of male and female fish was achieved as 3.92 ± 0.23 and 4.96 ±0.30, respectively, which were significantly different ($p<0.05$). The highest GSI values were observed in March and May, for males and females, respectively. The average hepatosomatic index was 2.25 ± 0.05 and the highest HSI values were observed in March (3.05 ± 0.31). The spawning season for *C. damscina* in Beheshtabad River, based on the GSI values, seasonal development of the ovary, direct observation of the gonads and also HSI values, was determined to commence in March (at 13.5-15.5˚C) and end in June (Figure 1).

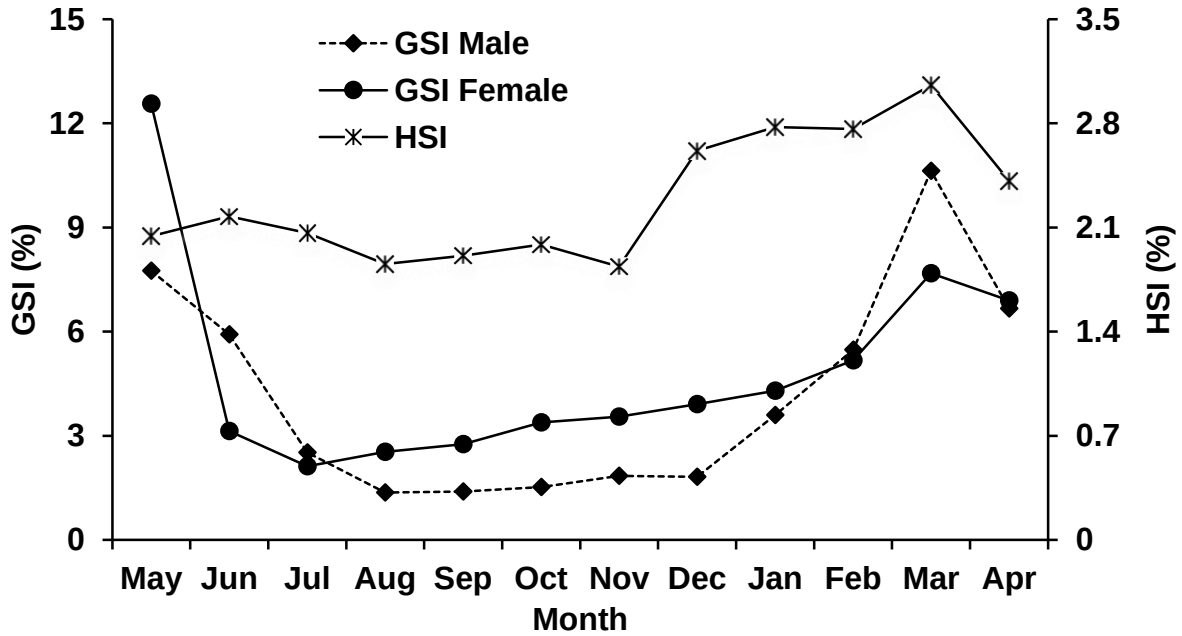

Fig. 1 Annual cycle of gonadosomatic (males, females) and hepatosomatic indices (both) for *C. damascina* in Beheshtabad River

Fecundity and oocyte diameters

Oocyte diameters ranged from 0.52 to 2.48 mm, with a mean value of 1.3 ± 0.41 (SD). The mean egg diameter reached its maximum size in May as 2.05 ± 0.12 mm, while its minimum size was measured in July as 0.84 ± 0.13 mm ($P<0.05$). Two types of eggs were found in the ovary; smaller than 0.6 mm and larger than 0.6 mm (Table 3).

Table 3 The monthly variations (mean ± SD) of egg diameter of *C. damascina* in Beheshtabad River

Month	Mean fork length ± SD (cm)	Mean egg diameter ±SD (mm)	Range
May	34.8 ± 0.9	2.05 ± 0.23	1.35-2.48
June	30.1 ± 4.4	0.92 ± 0.12	0.55-1.15
July	30.9 ± 3.0	0.84 ± 0.16	0.52-1.1
August	31.9 ± 3.2	1.23 ± 0.28	0.7-1.7
September	25.5 ± 1.4	1.10 ± 0.1	0.68-1.58
October	36.7 ± 4.6	1.13 ± 0.09	0.75-1.55
November	26.4 ± 1.5	1.20 ± 0.18	0.62-1.58
December	28.2 ± 5.3	1.10 ± 0.21	0.58-1.55
January	24.3 ± 0.5	1.19 ± 0.19	0.62-1.7
February	30.3 ± 3.4	1.39 ± .019	0.75-2.05
March	32.8 ± 4.6	1.43 ± 0.27	0.78-2.23
April	37.8 ± 4.1	1.92 ± 0.24	1.28-2.45

Absolute and relative fecundity in different ages for *C. damascina* in Beheshtabad River is reported in Table 4. The relationship between body weight (BW)-absolute fecundity (AF) (AF = 41.107 BW - 2468.8, $R^2 = 0.79$) and age (T)-absolute fecundity (AF=7056.1 T-24988, $R^2 = 0.62$) were highly correlated.

Table 4 Absolute and relative fecundity in different age groups of *C. damascina* in Beheshtabad River

Age	N	Body weight (g)	Fork length (cm)	Absolute fecundity (Number)		Relative fecundity (Number /g of body weight)	
		Mean ± SD	Mean ± SD	Mean ± SD	Range	Mean ± SD	Range
4^+	9	213.5±55.9	23.3±1.5	6873. 6±2393.4	2266-10135	32.5±10.6	14.6-49.2
5^+	5	261.2±75.3	25.6±2.8	6184.6±1962.5	3060-7993	24.1±6.9	14.1-31.6
6^+	7	487.7±178.6	30.9±4.1	14345.0±7411.3	3887-24644	29.6±12.9	12.0-44.9
7+	8	518.7±126.7	32.0±2.4	20994.1±7726.9	12718-36303	41.2±13.4	23.8-65.8
8^+	3	1030.3±220.1	40.2±2.2	43496.7±7689.4	36574-51773	43.1±8.7	33.6-50.7
Total	32	433.8±265.2	29.1± 5.8	15363.8±1224.1	2266-51773	33.7±12.4	12.0-65.8

DISCUSSION

The sex ratio of Mesopotamian barb in Beheshtabad River was 1M:0.7F. Gharache (2008) in a Qanat of southern Isfahan and Stoumboudi et al. (1993) in Jordan River reported similar results. This ratio for *C. damascina* in other areas were in favour of females (Mazaheri 2007; Soofiani and Asadollah 2010; Asadollah et al. 2011). Differences in sex ratio might be related to the interspecific differences in adapted population of a species to different ecological conditions, different in the date and time of capture, fishing gear, location, different growth rates and different mortalities in males and females, migration of mature fishes from the region and different behavior pattern in male and female fish (Qasim 1966; Fishelson et al. 1996; Keivany and Soofiani 2004; Soofiani et al. 2006; Asadollah et al. 2011; Keivany et al. 2012; Abaszadeh et al. 2013; Tabatabaei et al. 2014; Keivany and Daneshvar 2015).

Age of first sexual maturity in this study was $< 2^+$ for males and 3^+ years for females. Age at sexual maturity of *C. damascina* living in Iranian waters was reported as 2^+ and 4^+ for males and females (Soofiani and Asadollah 2010; Asadollah et al. 2011). In the present study, the smallest mature male and female fish were 11.5 and 18.5 cm, respectively. Study of reproductive cycle of this species in three rivers in

Lebanon showed that males of *C. damascina* reach maturity at 18 cm and the females at 20 cm (Khalaf 1987). Stoumboudi et al. (1993) also found that males in Lake Tiberias mature between 16 and 25 cm and females between 20 and 25 cm total length. Soofiani and Asadollah (2010) and Asadollah et al. (2011) reported the size at first maturity as 13.5 cm for males and 24-25 cm for females. Females, generally, attained maturity at an older age than males and generally, many other cyprinids fish males reach maturity at smaller sizes than females.

The spawning of *C. damascina* occured in May to June. The gonadosomatic index reached the highest value in March (10.63) for males and in May (12.57) for females. The reproduction period of this species was in March-June (Figure 1). In previous studies, it was recorded as May (Asadollah et al. 2011), May-June (Soofiani and Asadollah 2010) and April-June (Gharache 2008; Mazaheri 2007) (Table 5). Khalaf (1987) recorded that in Lebanese rivers the spawning of this species began in May and ended in June. However, according to Stoumboudi et al. (1993), *C. damascina* in the Jordan River spawned between January and March, depositing its eggs among gravel and pebbles in small streams. Egg diameter value was the highest in May (2.48 mm) and the smallest (0.84 mm) in July (Table 3). The highest ova diameter in Zayandehrud River (Asadollah et al. 2011) and Lebanese rivers (Khalaf 1987) have been recorded as 2.28 and 2.00 mm, a figure similar to that of the present study. The diameter of the ova depends on the size and species and individuals which belong to the same species may have ova of different sizes in different regions. The highest average HSI value was observed in March, coinciding with the highest value of GSI. Generally there is an inverse relationship between GSI and HSI; about a month before peaking the GSI, the HSI decreases due to consumption of the lipids for vitellogenesis, but in cases where feeding is continued during spawning, this trend is not observed (Wootton 1977; Abaszadeh et al. 2013). In *C. damascina*, the positive correlation between HIS and GSI may be due to the reason that feeding intensity remains unchanged during spawning.

In this study, the fecundity of *C. damascina* was found to vary between 2,266 and 51,773. The fecundity of *C. damascina* reported by other researchers (Gharache 2008; Khalaf 1987; Soofiani and Asadollah 2010; Asadollah et al. 2011) was between 2,073 and 72,645 eggs (Table 5). Differences in fecundity in these studies might be related to, amongst others, differences in sampling methods, frequency of spawning, egg size, population density and environmental factors (Nikolsky 1963; Bagenal 1978; Jonsson and Jonsson 1999).

Table 5 Comparison of fecundity and reproduction season in *C. damascina* in different regions AF – Absolute fecundity; RF – Relative fecundity

Study area	Sex ratio (M:F)	(AF)Mean ± SD (min - max)	(RF) Mean ± SD (min - max)	Reproductive period	References
Lebanese rivers	-	5138	-	May-June	Khalaf (1987)
Jordan River	1:0.6	-	-	January - March	Stoumboudi et al. (1993)
Zayandehrud River	1:2.8	-	-	April-May	Mazaheri (2007)
Qanat of Isfahan	1:0.7	9715 (1190–19 620)	339 (58–839)	April-May	Gharache (2008)
Daleki & Shahpour rivers	1:1.5	-	-	-	Abdoli and Mostavi (2009)
Hanna Wetland	2.2:1	(2023-36763)	-	May-June	Soofiani & Asadollah (2010)
Zayandehrud River	1:1.6	24811 (2523- 72645)	28.7±11.4	May	Asadollah et al. (2011)
Beheshtabad River	1:0.7	15363.84 ± 1224.1 (2266-51773)	33.73 ± 12.43 (11.96-65.82)	May	Present Study

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