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Reproductive biology of the large scale barb, *Capoeta aculeata* (Valenciennes, 1844) in Gizehrud River, Tigris basin, Iran

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Abstract. *Capoeta aculeata* (Valenciennes, 1844) is native to Iran and little is known about its biology. Some biological characteristics of this species were examined in 120 male and 257 female specimens collected monthly from the Gizehrud River of Lorestan Province (Tigris basin, Iran) during July 2014-June 2015. The maximum age of the specimens, based on scale reading, was 6^+ years for both males and females. The most frequent age group was 4^+ in both sexes. Fork length ranged from 12.2 to 20.8 cm (17.4±1.2SD) and weight ranged between 32–188 g (93.6±21.8SD). Sex ratio was 1M:2.1F. Based on macroscopic gonad observation, maturation cycle consisted of four stages: Developing, spawning, regressing and regeneration phases. The GSI index indicated that reproduction of *C. aculeata* in Gizehrud occurred between April and May, with the highest value average of 6.37 for males and 11.91 for females in May. Oocyte diameters ranged from 0.57 to 1.88 mm, with a mean value of 0.87 mm. Absolute fecundity ranged between 3000 and 19500 (8300±3400) eggs. Absolute fecundity and fish size (fork length and total weight) were moderately correlated. Relative fecundity varied from 50 to 140 (80±20) eggs per gram of total body weight. This fish is a synchronous spawner.

Key words: Cyprinidae, egg diameter, fecundity, hepatosomatic, gonadosomatic.

Introduction

Cyprinids with more than 120 species are the largest fish family in freshwaters of Iran. The genus *Capoeta* with 12 species is one of the most important native groups in Iran. The large scale scraper, *Capoeta aculeata* (Valenciennes, 1844), is a cyprinid fish widely distributed in Iranian basins including Tigris (Karun and Karkheh rivers), Fars, Isfahan, Kavir, Kerman and Namak (Keivany et al. 2016, Esmaeili et al. 2017). There are several works on the biology of *C. damascina* (Khalaf 1987, Stoumboudi et al. 1993, Soofiani & Asadollah 2010, Asadollah et al. 2011, Siami et al. 2017), *C. fusca* (Patimar & Mohammadzadeh 2010), *C. trutta* (Patimar et al. 2011, Poria et al. 2014a,b] and *C. capoeta* (Abdoli et al. 2008, Patimar et al. 2009). However, the reproductive biology of *C. capoeta* is not well documented, partly because of its low density and lack of commercial importance, nevertheless, it is consumed by locals.

Success of reproduction depends on normal gonadal development stimulated by favorable environmental conditions (Fernández-Delgado & Rossomanno 1997, Hoenig & Hewitt 2005). Hence, the aim of this study was to investigate the reproductive biology and gonadal development of *C. capoeta* in Gizehrud River a tributary of Karkheh River (Tigris basin). The results of this study could be used for management purposes of this species.

Materials and Methods

Gizehrud River is a tributary of Karkheh River in Tigris basin of Iran. Monthly samples were collected from July 2014 to June 2015 by a cast nets (2 cm mesh size). Some environmental factors including water temperature, pH, conductivity (EC) and total dissolved solids (TDS) of water were measured and recorded by a HANNA water quality measuring instrument model HI98129. Fish samples were anesthetized in 1% clove oil, fixed in 10% neutralized formalin and transported to the laboratory for further examination. In the laboratory standard (SL), fork (FL) and total lengths (TL) were measured to the nearest 0.1 mm and total weight to the nearest 0.01 g and gonads weight to the nearest 0.001 g. For the age determination, scales and sagittal otoliths were taken out and age reading was carried out through microscopic examination of annuli by three people and coincided readings were recorded to validate the ageing (Biswas 1993, Hoenig & Hewitt 2005, Nyeste et al. 2017).

The spawning period was determined by identifying monthly changes in the gonadosomatic (GSI) index. The GSI was calculated using the following equation (Biswas 1993).

GSI= (gonad weight/fish weight)×100

Brown-Peterson et al. (2011) was followed for studying the ovary stages. The ovaries of ripe females at maturity stage III were used to estimate the absolute and relative fecundities. Ovaries were removed, weighed and then placed in Gilson's fluid for two days to harden the eggs and dissolve ovarian membranes. Absolute fecundity was estimated using the gravimetric method as follows (West 1990):

F= Gonad weight×Egg number in the subsample/Subsample weight

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

Relative fecundity= absolute fecundity/total weight

Mean egg diameter was examined by measuring 100-200 eggs (oocytes from anterior, middle and posterior parts of each ovary) every month. Measurements were made to the nearest 0.01 mm under a microscope with an ocular micrometer. The HSI was calculated using the following equation (Biswas 1993). Where W_H= Liver weight and W_b= body weight.

$HSI= (W_H/W_b)*100$

After normality test, t-test was used for comparisons of two means and one-way ANOVA followed by Duncan posthoc test at 95% confidence level for multiple comparison of means. Chi square test was used for comparing the sex ratio. Statistical analyses were performed in SPSS 20 and Excel 2016 computer programs.

Results

Physico-chemical properties of the water

The mean values±SD and ranges for water temperature, pH, electric conductivity (EC) and total dissolved substances (TDS) are indicated in Table 1. The temperature ranged between 8°C in January and 21°C in August. The pH was almost stable between 8 and 9 with the lowest in October and the highest in March. The lowest EC was 490 µs in April-May and the highest 830 µs in July. The TDS is almost half of

the EC and both follow the same trend.

Age and sex ratio

All the 377 fish examined were mature, among which 120 (30%) were males and 257 (70%) females. The overall sex ratio of males to females was 1M:2.1F and Chi-square analysis showed a significant difference from the 1:1 ratio (χ^2 = 12.64, P<0.05). The fork length ranged from 12.2 to 20.6 (16.97±1.20SD) cm and weight from 32–152 (83.82±20.40 g in males. The fork length ranged from 14 to 21 (17.65±1.14) cm and weight from 47–188 (98.1±20.98) g in females (Table 2). Age of the specimens ranged between 3^+ and 6^+ years for both sexes. Although older fish may have been existed in the river, they were not caught because of net mesh sizes and natural obstacles.

Reproduction

Assessment of the main spawning period of *C. aculeata* in Gizehrud River was based on the GSI (Fig. 1), analysis of seasonal development in mean egg diameter (Table 3), and direct observation of the gonads. Significant differences were found in the males and females GSI and egg diameter (p<0.05) in different months. The highest GSI value for both sexes occurred in May-June (Fig. 1). Thus, the reproductive period for this species in this particular environment is from April to June when GSI is considerably higher and the water temperature was between 15°C and 20°C, pH between 8 and 8.5 and the EC at its lowest range (490-730 µs). Significant differences were also found in the males and females HSI (p<0.05) in different months. The highest HSI value for both sexes occurred in December at the lowest temperature (8-9°C) and the lowest in May at temperatures of 16-17°C (Fig. 2).

Table 1. Physico-chemical parameters of water in Gizehrud River in 2014-2015.

	Min-Max	Mean±SD
Temperature (°C)	8-21	15±4
pH	8-9	8.3±0.3
EC (µs)	490-830	610±120
TDS (mg/l)	240-410	300±60

The mean±SD of the absolute fecundity of 43 females, determined during the spawning period, was 3000-19500 (8300±3400) egg and relative fecundity was 80±20 egg/g body weight. The Fecundity-age (F= 2409.9 x–1072.1, r^2=0.25), fecundity-length (F= 1543.5FL–18886, r^2=0.39) and fecundity weight (F= 100.39W–1893.1, r^2=0.54) relationships were not highly correlated (Figs. 3-5).

The Mean egg diameter was significantly different during the year (P<0.05). The highest mean egg diameter (1.88±0.058 mm) was observed in May-June and the lowest in September (0.54±0.19 mm) (Fig. 2). The highest egg diameter was observed in June (1.88 mm).

The gonad development of adult *C. aculeata* is categorized in four stages following Brown-Peterson et al. (2011) which has been accepted by many researchers as the standard procedure (e.g., Abaszadeh et al. 2013, Dopeikar et al. 2015, Keivany et al. 2017, 2020, Siami et al. 2017, Keivany et al. 2018, Ghafouri et al. 2019, Keivany and Kamaloo 2021, Kiani et al. 2021) (Table 4).

Table 2. Number of specimens and mean±SD of fork length (FL) and weight in *Capoeta aculeata* caught from Gizehrud River in different months (2014-2015).

Months	Sex	No.	Mean FL±SD (cm)	Mean Weight±SD (g)	Age
July	Male	6	17.63±0.92	96.85±15.49	4-5
	Female	24	17.42±1.12	93.49±16.01	3-4
August	Male	15	17.17±1.09	84.07±19.74	3-5
	Female	15	17.58±1.02	92.43±17.61	3-5
September	Male	10	17.37±1.03	84.30±14.21	3-5
	Female	22	18.12±0.82	98.18±15.15	3-5
October	Male	8	17.60±1.04	92.25±18.53	3-5
	Female	23	17.82±0.68	95.50±10.56	3-5
November	Male	8	16.76±0.70	82.25±8.53	3-5
	Female	24	17.83±1.16	98.17±17.08	3-6
December	Male	8	16.13±0.63	75.13±7.97	3-5
	Female	24	17.78±0.85	100.50±15.53	3-6
January	Male	11	17.11±0.88	79.22±10.97	3-6
	Female	21	17.18±0.65	85.97±07.55	3-4
February	Male	9	17.01±0.45	87.11±6.27	3-5
	Female	22	16.86±0.65	87.77±07.43	3-5
March	Male	12	16.56±0.82	74.92±11.65	4-5
	Female	20	17. 47±1.05	91.30±18.44	3-5
April	Male	12	17.03±0.59	90.25±10.17	3-5
	Female	20	18.09±1.07	106.70±16.39	3-6
May	Male	7	18.94±1.48	131.00±24.67	4-6
	Female	25	18.82±0.90	137.32±16.52	3-6
June	Male	14	15.59±1.35	58.85±12.33	3-6
	Female	17	16.51±1.77	77.98±22.40	3-6
All specimens	Male	120	16.97±1.20	83.82±20.40	3-6
	Female	257	17.65±1.14	98.10±20.98	3-6

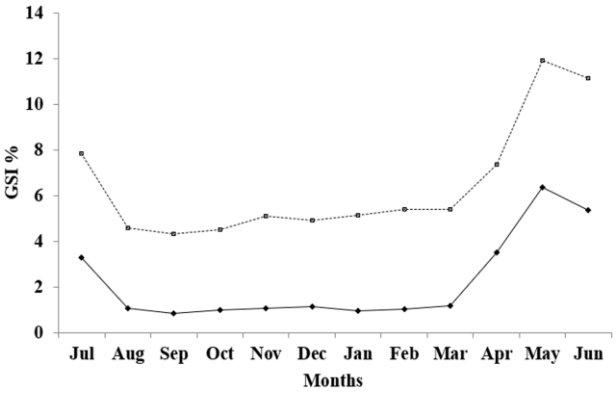

Figure 1. Mean monthly variations in GSI of male (dark line) and female (dash line) *Capoeta aculeata* in Gizehrud River in 2014-2015.

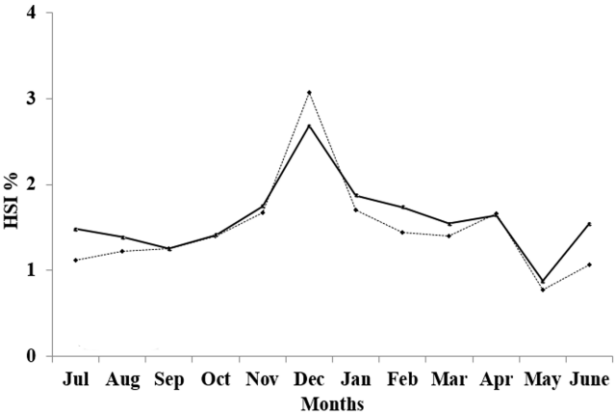

Figure 2. Mean monthly variations in HSI of male (dash line) and female (continuous line) of *Capoeta aculeata* in Gizehrud River in 2014-2015.

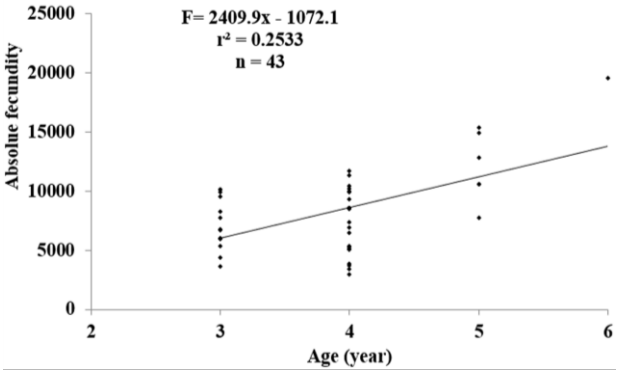

Figure 3. Fecundity-age relationship in *Capoeta aculeata* in Gizehrud River in 2014-2015.

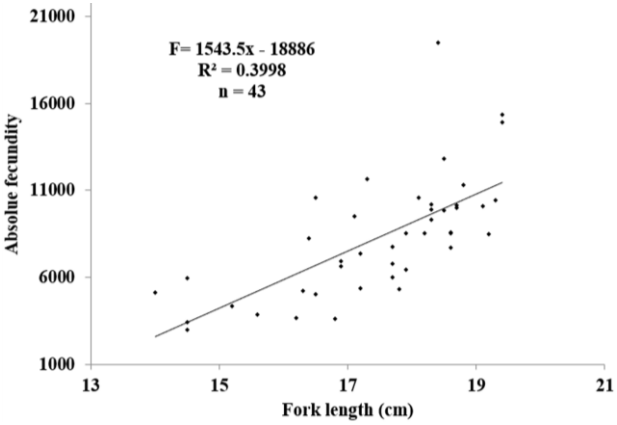

Figure 4. Fecundity-fork length relationship in *Capoeta aculeata* in Gizehrud River in 2014-2015.

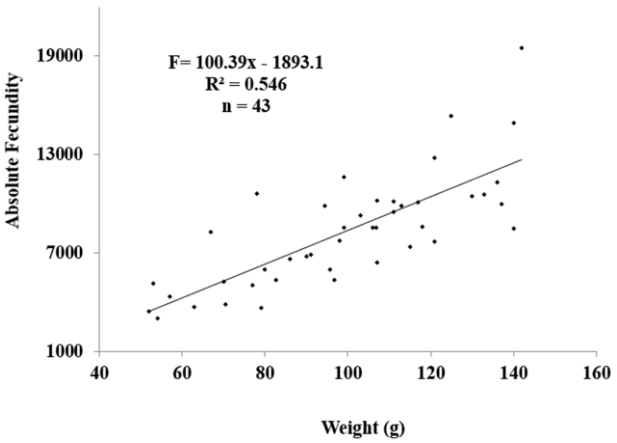

Figure 5. Fecundity-weight relationship in *Capoeta aculeata* in Gizehrud River in 2014-2015.

Table 3. Maturity stages and mean monthly variations in egg diameter of *Capoeta aculeata* in Gizehrud River in 2014-2015.

		Oocyte diameter	
Months	Maturity stage	Mean±SD	Min-Max
July	Regression	1.11±0.34	0.25-1.53
August	Regression	0.63±0.20	0.20-1.25
September	Regression	0.54±0.19	0.25-1.00
October	Regeneration	0.68±0.09	0.35-0.88
November	Regeneration	0.70±0.15	0.25-0.98
December	Developing	0.75±0.17	0.25-1.00
January	Developing	0.73±0.13	0.25-1.00
February	Developing	0.75±0.11	0.38-0.98
March	Developing	0.78±0.01	0.60-1.25
April	Spawning	0.93±0.13	0.45-1.10
May	Spawning	1.38±0.27	0.63-1.80
June	Spawn capable	1.50±0.34	0.50-1.88

Discussion

This is the first study on the reproductive biology of *Capoeta aculeata* in Tigris basin and also in its distribution range, so it is rather difficult to discuss the biology of the species. In this study, the maximum observed total length and weight of *C. aculeata* were 21 cm and 150 g in females, the maximum length and weight reported for this species is 37 cm and 695 g (Esmaeili et al. 2014, Froese & Pauly 2020). In general, the differences in the length of the fish could be due to differences in the fishing season, different geographic areas, biological and ecological conditions, or inter-species and intra-species variation by regions (Keivany et al. 2020, Keivany & Kamaloo 2021).

Sex ratio in this study was in favor of females. In other species like *C. damascina* different ratios have been reported (Asadollah et al. 2011, Khalaf 1987, Siami et al. 2017, Soofiani & Asadollah 2010). This might be due to the shorter life and earlier maturation of the males, sexual differences in growth, mortality rates, or reproductive energy costs or different be-

Table 4. Reproductive features of *Capoeta* spp. in different localities (numbers are rounded).

Species	Locality	Age at maturity	Sex ratio F:M	Relative fecundity	Absolute fecundity	Spawning Period	Reference
C. gracilis	Gorganrud River	-	1:1.9	68 (24-262)	2000 (600-16000)	April-May	Patimar et al. 2009
C. fusca	Shadmehr Qanat	2^+	1:2.4	133 (34-583)	5000 (500-23000)	May-June	Patimar and Mohamadzadeh 2010
C. trutta	Gamasiab River	-	1:0.5	51±3.6	7800 (1900- 17500)	June-July	Poria et al. 2014a
	Alvand River	-	1:0.7	37±2.38	15200 (3000-27000)	June-July	Poria et al. 2014b
	Mimeh River	1^+	1:1	70 (14-242)	7600±280	May-June	Patimar and Farzi 2011
C. damascina	Hanna Wetland	2^+ 3^+	1:1.5	-	(2000-37000)	May-June	Soofiani and Asadollah (2009)
	Zayandehrud River	2^+ 4^+	1:1.6	29±11.4	24800 (2500-73000)	May	Asadollah et al. 2011
	Beheshtabad River	2^+ 4^+	1:0.7	34±12.2	15400 (2300-51800)	May	Siami et al. (2017)
C. aculeata	Gizehrud River	3^+ 3^+	1:2	0.82±22	3000-19500 83003±400	May-June	Present study

haviors leading to an easier catch of one sex. Sex ratio varies considerably from species to species; but in the majority of them, it is close to one. However, subsequent changes in this ratio may be explained by a number of hypotheses, including differences in habitat preference, season, sampling errors, or selective mortality (Fernández-Delgado & Rossomanno 1997, Fishelson et al. 1996, Hoenig & Hewitt 2005, Hontela & Stacey 1990, Khalaf 1987, Pitcher & Hart 1982, Qasim 1966, Yancheva et al. 2020, Kiani et al. 2021). It is noted that in younger age classes, males were dominant and in older age classes females were dominant.

The GSI and HSI are used as biological indicators to determine the fish spawning season (Fishelson et al. 1996, Stoyanova et al. 2020). The HSI index for females is more important because the vitellogenesis is performed for egg production in the liver. Typically, in many fish species, at the peak of spawning, the GSI is at the highest and the HSI at the lowest level. Based on the obtained results in different months, the lowest value of HSI in females was in April-June, and the highest in December. Variation in the HSI might be contributed to the vitellogenesis in the liver. The monthly changes in HSI index were lower in males than females. The monthly variations in GSI were highly associated with the seasonality of maturity stages. An increase in the GSI of females was observed in April-June which peaked in May. A decrease in the GSI was observed from July to September. The GSI in males and females was coincided, increasing the reproduction success, however, it was lower in males, probably due to less energy investment by males (Buxton & Garratt 1990). Asadollah et al. (2011) reported similar figures for *C. damascina* from Zayandehrud River (Table 4).

The oocyte diameters frequency distribution of mature female exhibited a significant difference during the year. Increase in the mean egg diameter was observed from April to July with the highest being in May. The short period of spawning and the similar size of eggs indicate a synchronous spawner (Patimar et al. 2009, Pitcher & Hart 1982, Stoumboudi et al. 1993, Tomkiewicz et al. 2011). Similar figures were found in *C. damascina* (Asadollah et al. 2011, Siami et al 2017). The egg size could vary from population to another or even from year to year depending on temperature, available food, etc.

The absolute fecundity was lower than those reported for *C. damascina* in Beheshtabad River (Siami et al. 2017), but higher than Hanna Dam population (Poria et al. 2014b) and Zayandehrud River (Asadollah et al. 2011) (Table 4). The differences in fecundity found among species may reflect the differing environmental conditions of their habitat, food availability, size and age of the females and life history strategies (Lam 1983, Khalaf 1987). Additionally, it differs among populations of same species and does not remain constant from year to year (Pitcher & Hart 1982, Murua et al. 2003). Furthermore, the mean fecundity relative to total weight of this fish is lower than that given for some other related congeneric species. Fecundity in females was moderately correlated with total length and more with total weight.

The maximum diameter of the eggs and highest number of hydrated oocytes were observed in May-June, confirming the spawning peak occurred in May-June. Macroscopic development of the testes followed a trend similar to those of the ovaries and coincided with it, increasing the reproduction success (Bromage et al. 1992, Wootton 1984,1998). It could be concluded that *C. aculeata* is a synchronous spawner with a short period of reproduction which lasts from April to June and peaks in May.

The fish in stage I of maturity were not found among the specimens, since all the specimens were adults. Fish in stage II were found in October-December, stage III in January-March, stage IV April-June and stage V in July-September. In general, the rhythm of gonadal development depends on various external factors such as temperature, photoperiod, and social and behavioral factors such as visual, olfactory and auditory stimuli (Asadollah et al. 2011, Dopeikar et al. 2015, Ghanbahadur 2013, Grier 2012).

Based on GSI, HSI, egg diameter and visual condition of the gonads, it could be concluded that this species is a synchronous spawner (Rinchard and Kestemont 1996) with a moderate fecundity and a short period of reproduction which lasts from April to June and peaks in May.

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