Growth and reproduction of Bulatmai barbel *Luciobarbus capito* (Güldenstädt, 1773) in Gorganroud River of the Golestan Province- Northern Iran

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Abstract

Bulatmai barbel (*L. capito*) is found in upper parts of most rivers of southern Caspian basin. In order to determine age, growth and reproductive characteristics of this species, a total of 318 specimens was sampled using beach seine in the Gorganroud River - southeast Caspian Sea from May to September 2017. WLRs were found as $W=0.020TL^{2.74}$ for females, $W=0.016TL^{2.80}$ for males and $W = 0.234TL^{2.84}$ for sex combined, indicating negative allometric growth pattern for the species in the area. The age ranged from 0^+ to 8^+ in females and 0^+ to 7^+ in males. Three growth models were fit to the data set and the Akaike information criterion (AIC) indicated that there were clear differences between the fitting models that were ranked the highest based on AIC selection or AIC weights and those based on model's accuracy of length and growth parameter estimates. Considering AIC, $L_t=667.63*[1-e^{(-0.10*(t+0.14))}]$ and $L_t=621.11*[1-e^{(-0.11*(t+0.17))}]$ were best growth models for females and males respectively. The sex ratio was 1:2.38, highly unbalanced sex ratio. Considering GSI, the peak of reproduction was in May for both sexes. Absolute fecundity ranged from 1865.00 to 170940.00 with mean value of 26388.24, and relative fecundity had an average of 625.29. GSI and absolute fecundity related to fish size statically, while relationship between relative fecundity and egg diameter with fish size was no significant.

Keywords: *L. capito*, Growth, Akaike information criterion, Reproduction, Gorganroud River

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Introduction

Growth and reproduction traits are important to identify fish population and their habitat peculiarities. Study the biological characteristics of a species in the population level provides better understanding about ecological status of a species and additionally this kind of data is prerequisite for exploitation and conservation programs (Zivkov, 1996). Basic life history information is essential in the study and analysis of population performance and in both theoretical ecology and fisheries management (Wootton, 1998). Moreover, the study of biological traits is an important element of the overall description of a species, and this information is essential for the appreciation of the role of biodiversity in the functioning of ecosystems (Cooke *et al*., 2012).

The use of mathematical functions to represent the average growth of individuals in a population is a common practice that allows a simple representation of growth, permits the comparison of growth between species and populations, and enables incorporation of growth into models of population dynamics. The three-parameter von Bertalanffy growth function (VBGF) assumes annual growth to be equal to a constant proportion of the growth remaining before maximum length. In addition, Katsanevakis (2006) demonstrated that, if VBGF was not the best model for application to a data set, then its use would result in biased point estimation and false evaluation of accuracy. Other individual growth models include the Gompertz and logistic models, which contain inflection points to represent sequential acceleration and deceleration of individual growth (i.e. around age-at-maturity).

Barbs are considered one of important fishes which belongs to the true bony fishes (Teleostei) family Cyprinidae. The family has a large number of species, in the world have been reported more than 160 species that one of this family is Bulatai barbel (*L. capito*). The species has become extirpated from a large part of its range in the western Caspian, mainly due to the lack of spawning sites and pollution of the Rivers (IUCN, 2008). Overall, there is a continuing to decline due to expanding hydropower development, overfishing and strong ecological impacts on Rivers of the Caspian Sea basin (Freyhof and Kottelat, 2008).

In the case of native fishes, there is a general need to increase the knowledge of their biological traits because this information furnishes a necessary tool for conservation programs (Cooke *et al*., 2012), but such a data for fishes of the Gorganroud River are limited. Therefore, the present study aimed to reports growth and reproduction parameters of Bulatmai barbel (*L. capito*) from the Gorganroud River, a sub-basin of the Caspian Sea in the Golestan Provinces, Northern Iran.

Materials and methods

The Gorganroud River located in the Golestan Province originating from Golidagh Mountains and entering the Caspian Sea (Kiabi *et al*., 2000).

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Sampling was carried out in main drainage of the River, located in the east of Gonbad Kavous county, samples collected using beach seine with mesh diameter is 2.5 m, length of 10 m and height of 1.5 m from May to September 2017 (Fig. 1).

Figure 1: *L. capito* caught in Gorganroud River in September 2017 (photo given by authors).

The collected samples were immediately preserved in 10 % buffered formalin and transported to the laboratory for subsequent analyses. The lengths measured to the nearest 0.1 mm and weight to the nearest 0.01 gr. Age determined by scales and opercula and validated by two persons. The growth pattern was determined by least squar's method using the equation lnW=ln a+b lnTL.

In this equation *W* is weight in gr, *TL* total length in mm, *b* regression slope and *a* the regression intercept (Le Cren, 1951; Ricker, 1975; Froese, 2006; Froese *et al*., 2011). Growth pattern (isometric or allometric) confirmed by using Pauli's t-test:

$$t = \frac{sd(\ln TL)}{sd\ (\ln W)} \times \frac{|b-3|}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Condition factor (CF) and instantaneous growth rate (G) calculated using the following equations:

$CF = (W\ .\ TL^{b}) \times 100$

$G = (Lnw_{t+1} - Lnw_{t}) / \Delta T$

The von Bertalanffy growth model (VBGF) as $L_i = L_\infty(1-e^{-k(t-t0)}$ determined using Ford- walford plot: $L_{(t+\Delta T)} = a + bL_t$. In this equation, K and L_∞ are $L_\infty = \frac{a}{1-b}$, $k = \frac{-Lnb}{\Delta t}$. Additionally, t_0 and φ' calculated based on $t_0 = t + Log_e \frac{1}{k}\frac{(L\infty - Lt)}{L\infty}$, φ'=Ln k+2 Ln L_∞ (Pauly and Monroo, 1984).

A multi-model, information theoretic approach (AIC MMI) was taken to modelling growth (Burnham and Anderson, 2001). This method has recently been proposed as an improvement on a priori use of the von Bertalanffy growth function (Katsanevakis, 2006; Katsanevakis and Maravelias, 2008; Thorson and Simpfendorfer, 2009). A set of Three candidate models g_i (i =1–3) was chosen based on Thorson and Simpfendorfer (2009) (Table 1). These included a 3 parameter version of the von Bertalanffy model (VBGF), the Gompertz model and the logistic model. The method of least squares was used to fit model and best-fit parameter estimates. Model performance was evaluated using Akaike's Information Criteria (AIC). The small sample, bias adjustment form of AIC was calculated as:

$$AIC_c = AIC + \frac{2K(K+1)}{n-K-1}$$

Where K is the total number of estimated parameters+1 for variance ($\acute{O}^2$), n is the samples size, and AIC=n log ($\acute{O}^2$)+2 K. Variance was calculated as $\acute{O}^2 = RSS.n$ where *RSS* is the sum of the squared residuals.

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Table 1: Set of growth models uses for multi-model inference, fllowing Thorson and Simpfendorfer (2009).

	Model	Parameters	Growth function
g1	von Bertalanffy	3	$L(t)= \beta_2+(\beta_{1-} \beta_2)(1-\exp(-\beta_3 t))$
g2	Gompertz	3	$L(t)= \beta_1 \exp(- \beta_2 \exp(-\beta_3 t))$
g3	Logistic	3	$L(t)= \beta_1\beta_2 \exp(\beta_3 t)/(\beta_1+ \beta_2(\exp(\beta_3 t)-1))$

Equations for growth models used to simulate population data, with error terms listed and length in centimeters. The only parameter with a common value between all models was β_1 which represented the L_∞ (L-infinity), β_2 asymptotic length (L_0) and β_3 the growth parameters (K), but all other parameter values were not directly comparable.

In order to investigate reproductive characteristics, gonadosomatic index (GSI), absolute and relative fecundities and Oocyte diameter determined for the studied population. Additionally, correlation between these reproductive indices and fish size (age, length and weight) calculated.

All analysis have been done by Excell$_{2015}$ and SPSS$_{22}$.

Results

A total of 318 specimens were caught during the study period, including 94 males (29.56%) and 224 Females (70.44 %). The overall ratio was dominated by females, with a significant difference from 1:1 (sex ratio 1:2.38; χ^2 = 138.68, p<0.05).

The distribution of the length ranged from 12 to 390 mm. The weight of the samples ranged from 1.00 g to 732.65 g (Table 2).

Table 2: Mean length (mm) and weight (g) of *L. capito* in Gorganroud River-Southeastern Caspian Sea.

Location	Genus	Number of specimens	TL±S.D	Min-Max	TW±S.D	Min-Max
Gorganroud River	Female	224	155.69±54.67	13-390	48.70±75.98	732.65-1.00
	Male	94	115.59±85.28	12-340	43.38±82.37	1.00-354.37
	population	318	148.88±62.63	12-390	47.55±77.08	1.00-732.65

Mean length and weight of different age groups are given in Table 3. It was obvious that the maximum length annual increment recorded between 2^+ and 3^+ and 6^+ and 7^+ age groups.

Length frequency distribution of the fish (Fig. 2) indicated that the most frequent size classes in the samples were 131-180 mm for females, while in males the length groups, 30-80 mm and 131-180 mm had high abundance. Age frequency showed that the most frequent ages in the fish were 2^+ in both species (Fig. 3).

Length-weight relationship of the male was $w=0.016\times L^{2.80}$ and of the female $w=0.020\times L^{2.74}$. The regressions on data were highly significant (p<0.05), the b showed negative allometric growth pattern in both males and females (Figs. 4 & 5).

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Table 3: *L. capito* mean length (mm) and weight (g) in different age groups in Gorganroud River-Southeastern Caspian Sea.

Location	Age	Female		Male	
		TW±S.D	TL±S.D	TW±S.D	TL±S.D
Gorganroud River	0^+	1.01±0.01	15.92±2.35	1.02±0.06	14.83±2.89
	1^+	8.76±10.13	86.17±21.90	6.12±9.22	76.87±21.88
	2^+	32.52±2.86	144.05±9.99	32.44±2.79	143.13±10.93
	3^+	46.45±5.58	176.04±11.52	45.39±7.19	173.20±15.27
	4^+	60.21±0.09	201.63±10.74	60.005±0.00	200.00±0.00
	5^+	213.59±16.07	272.00±13.04	185.24±0.00	255.00±0.00
	6^+	273.64±22.64	320.00±8.16	281.73±34.27	315.00±21.21
	7^+	358.58±4.79	360.00±0.00	341.97±17.54	355.00±7.07
	8^+	709.31±33.01	380.00±14.14	-	-

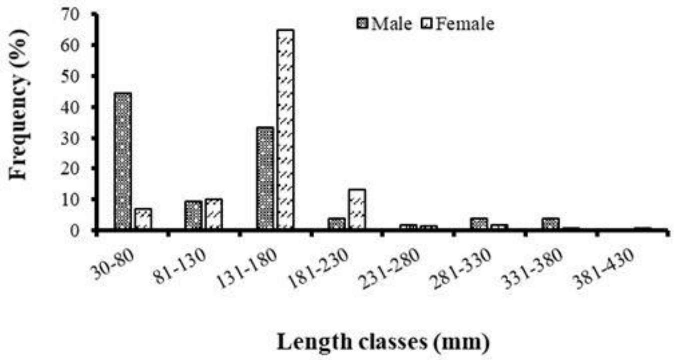

Figure 2: Length frequency distribution for *L. capito* in Gorganroud River-Southeastern Caspian Sea.

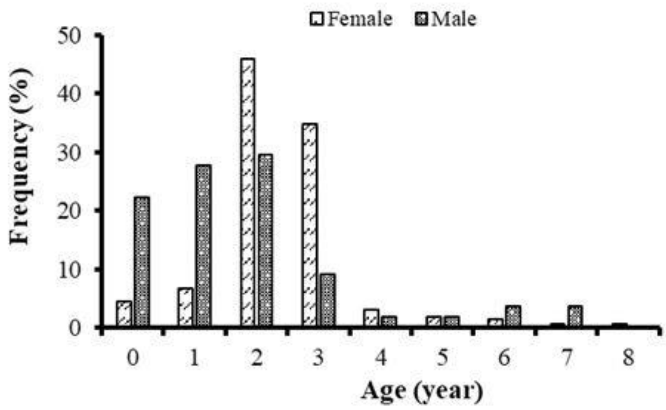

Figure 3: *L. capito* age frequency in Gorganroud River-Southeastern Caspian Sea.

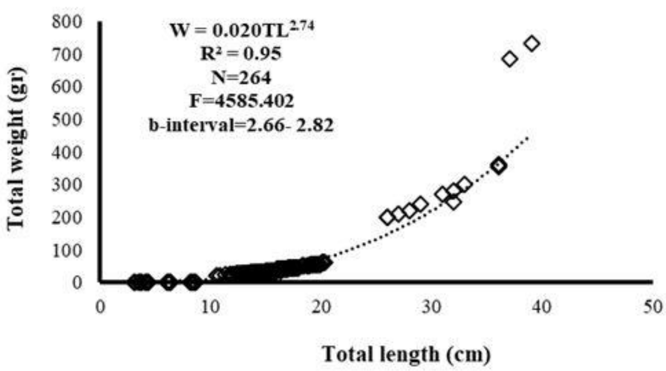

Figure 4: *L. capito* Females length-weight relationship in Gorganroud River-Southeastern Caspian Sea.

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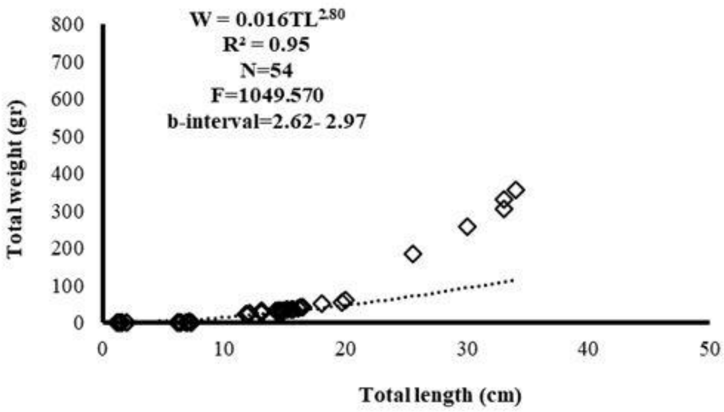

Figure 5: *L. capito* Males length-weight relationship in Gorganroud River-Southeastern Caspian Sea.

Growth rate for different ages are shown in Figure 6. Maximum growth rates were observed in early ages (1^+-2^+ years).

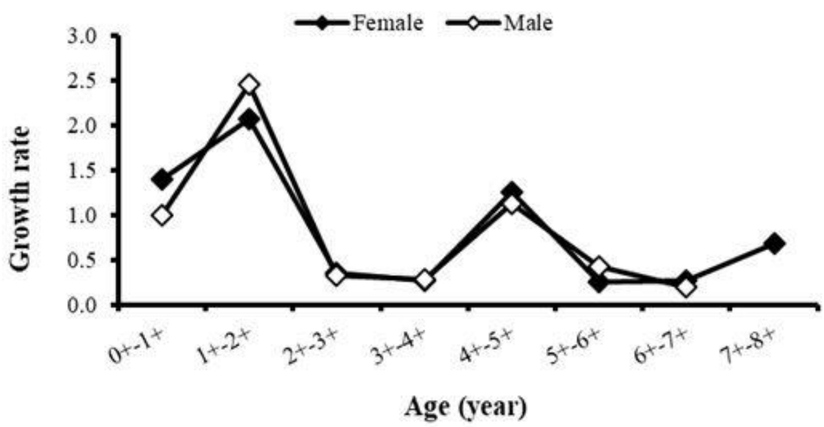

Figure 6: The growth rate for different ages in *L. capito* in Gorganroud River-Southeastern Caspian Sea.

The condition factor was calculated between 1.13–1.93 for males, and 1.92–2.31 for Females (Fig. 7).

Growth parameters analysis of length at age data represented in Table 4. Based on growth parameters, the von Bertalanffy growth models were described as Lt=621.11*[1-e (-0.11*(t+0.17))] for males, Lt=667.63*[1-e (-0.10*(t+0.14))] for females and Lt=692.75*[1-e (-0.10*(t+0.15))] for the population.

The growth performance index (φ') was found to be 10.74 for population, 10.66 and 10.70 for males and Females respectively.

Different L_∞ and k calculated for the fish using three methods for analyzing growth. Considering AICs, the logistic model had the smallest one. Additionally, the L_∞ of Gompertz model was almost as same as traditional method of Gulland-Holt plot's result. In each model analysis, females grew slower than males, but attained a larger asymptotic size.

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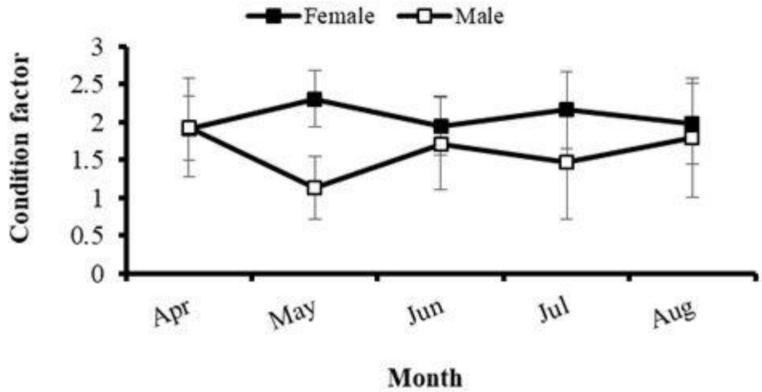

Figure 7: The condition factor of *L. capito* in different months in Gorganroud River-Southeastern Caspian Sea.

Table 4: Van Bertalanffy parameters of *L. capito* in three groups of male, Female and population in Gorganroud River-Southeastern Caspian Sea

Location	Genus	φ’	t_0	K	L_∞
Gorganroud River	Male	10.66	-0.17	0.11	621.11
	Female	10.70	-0.14	0.10	667.63
	Population	10.74	-0.15	0.10	692.75

GSI relationship with fish sizes (TL, TW and Age) represented in Figures 8-13. The relationships were significant statistically ($p<0.05$). The GSI reached its maximum value in May and gradually declined in June and August (Fig. 14). Based on GSI, reproductive activity of this species in Gorganroud River is between May and July (Table 5).

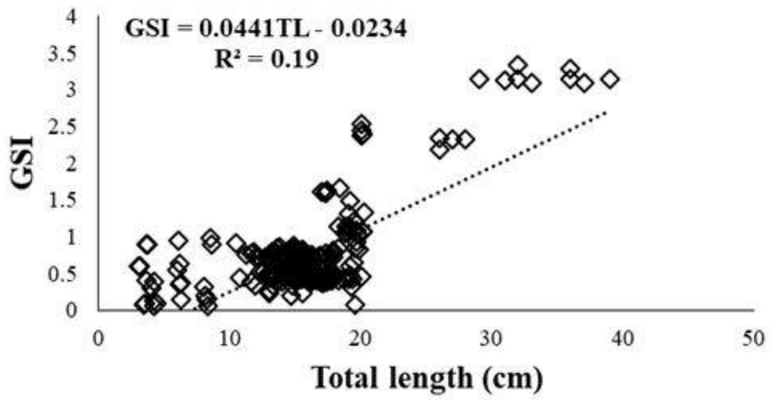

Figure 8: *L. capito* females length-GSI relationship in Gorganroud River-Southeastern Caspian Sea.

The Minimum, maximum and mean of absolute fecundity were calculated as 1865.00, 170940.00 and 26388.24, and those of relative fecundity were 7.67, 3543.92 and 625.29 (eggs per kg body weight) respectively. The lowest and the highest fecundities were determined in May (30684.65±17587.93 eggs/female) and August (10446.20±12816.77 eggs/female), respectively. Absolute

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fecundity relationships with fish size (TL, TW and Age) are shown in Figures 15-17. The relationships were significant statistically ($p<0.05$), while relationships between relative fecundity and fish size (TL, TW, Age) was no significant ($p>0.05$).

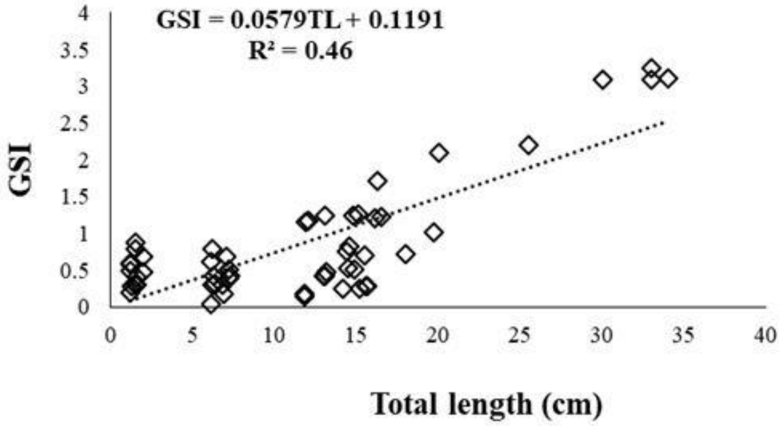

Figure 9: *L. capito* males length-GSI relationship in Gorganroud River-Southeastern Caspian Sea.

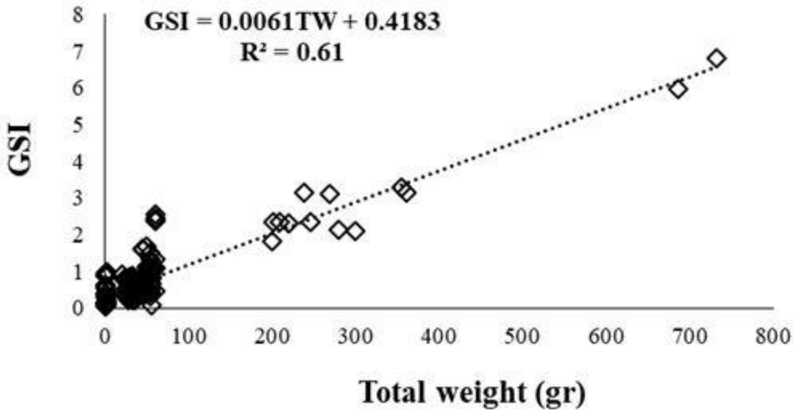

Figure 10: *L. capito* females weight-GSI relationship in Gorganroud River-Southeastern Caspian Sea.

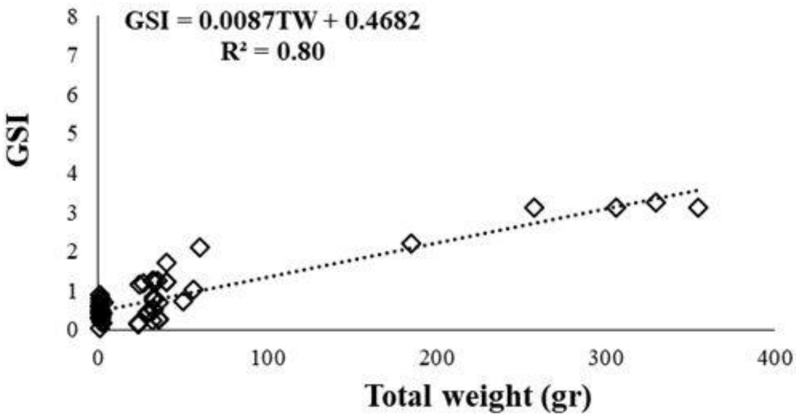

Figure 11: *L. capito* males weight -GSI relationship in Gorganroud River-Southeastern Caspian Sea.

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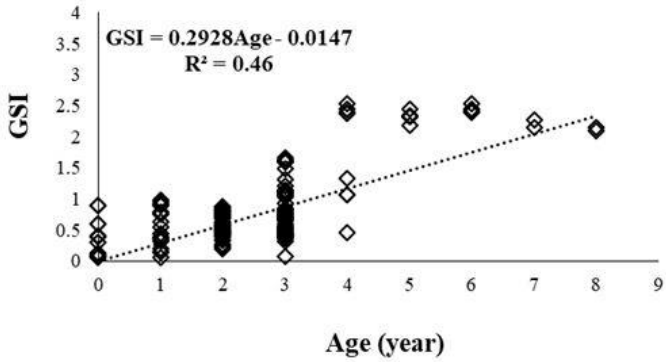

Figure 12: ***L. capito*** **females age-GSI relationship in Gorganroud River-Southeastern Caspian Sea.**

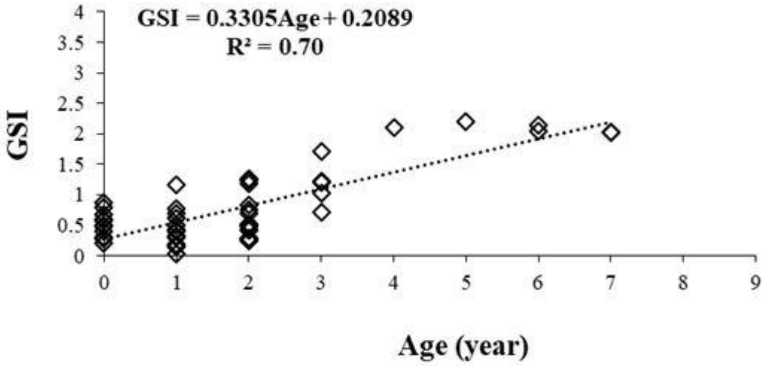

Figure 13: ***L. capito*** **males age-GSI relationship in Gorganroud River-Southeastern Caspian Sea.**

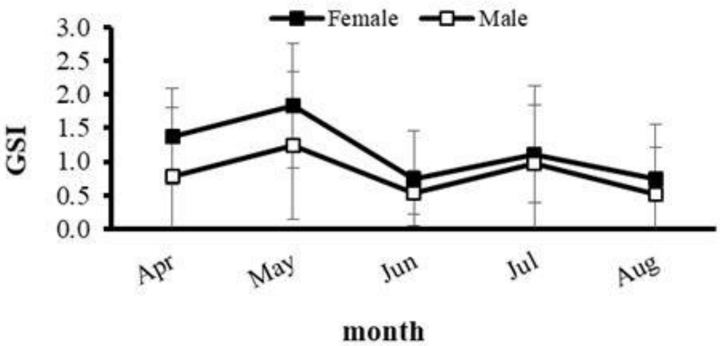

Figure 14: Seasonal changes in gonadosomatic index (GSI) of *L. capito* population on different months in Gorganroud River-Southeastern Caspian Sea.

Table 5: Results of the multi-model analysis of growth using three different values for Bulatmai barbel (*L. capito*) in Gorganroud River-Southeastern Caspian Sea

Model	Fitting					
	β_1 ~L∞ (cm)	β_3 ~K per year	β_2 ~L0 cm	σ^2	*RSS*	AIC
Females						
Gompertz	69.72	0.10	15	14.55	1906.50	67.74
Logistic	42.31	0.52	5.07	16.48	244.45	28.53
VBGF	104.27	0.06	23.51	11.22	1133.56	63.06
Males						
Gompertz	43.35	0.32	14	15.45	1726.96	89.42
Logistic	37.86	0.55	4.67	18.47	3070.85	55.43
VBGF	93.19	0.08	21.11	10.75	935.96	54.80

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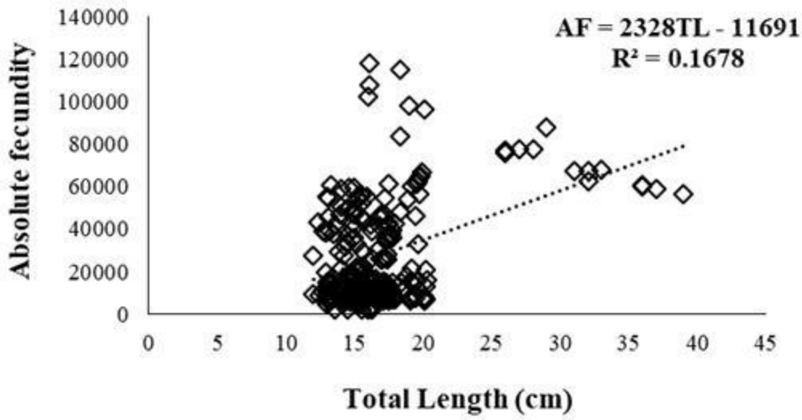

Figure 15: *L. capito* TL-Absolute fecundity relationship in Gorganroud River-Southeastern Caspian Sea.

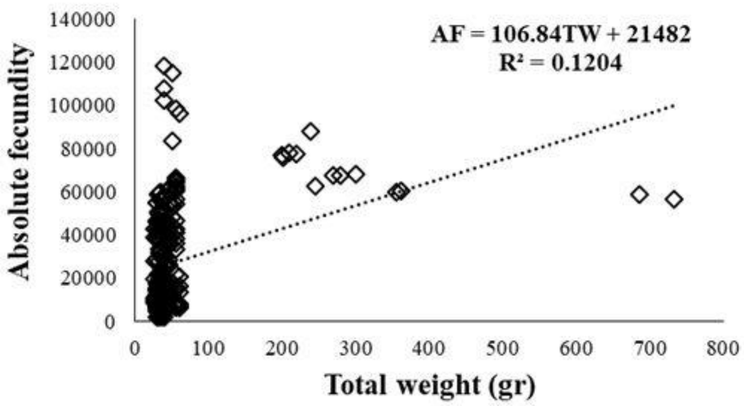

Figure 16: *L. capito* TW-Absolute fecundity relationship in Gorganroud River-Southeastern Caspian Sea.

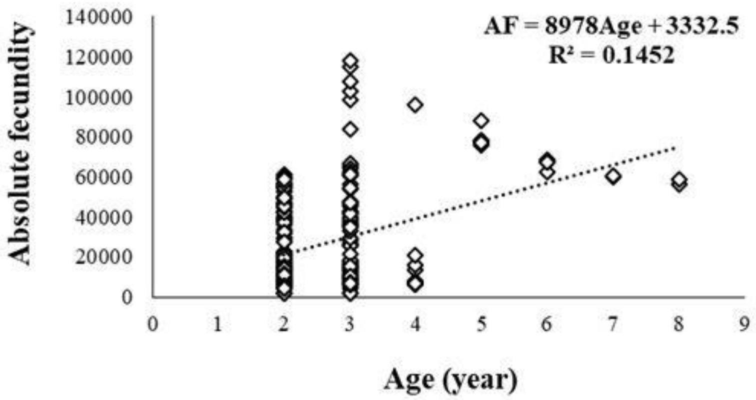

Figure 17: *L. capito* Age- Absolute fecundity relationship in Gorganroud River-Southeastern Caspian Sea.

The eggs diameter size was ranged from 0.058 to 0.088 mm, with average of 0.069 mm (Fig. 18). The mean Oocyte size reached its maximum value in May (0.071±0.02 mm), and its minimum value was observed in August (0.068±0.02 mm). Egg diameter relationships with fish size was no significant (p>0.05) (Table 6).

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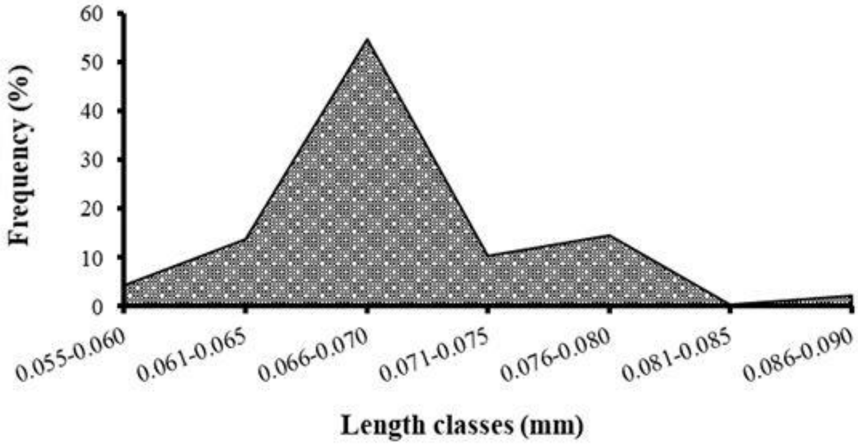

Figure 18: Frequency percent of oocytes on the *L. capito* in Gorganroud River-Southeastern Caspian Sea.

Table 6: Absolute and relative fecundity in species *L. capito* in Gorganroud River-Southeastern Caspian Sea.

Location	Age	Relative fecundity		Absolute fecundity	
		Mean ±SD	Min - Max	Mean ±SD	Min – Max
Gorganroud River	2+	2203.44±8502. 58	55.44-60440. 91	22834.07±20293. 23	1956.00-109324. 00
	3+	2278.83±7865. 53	46.59-42283. 86	29565.46±26854. 20	3655.00-118164. 00
	4+	361.90±507. 38	105.503-1599. 06	21780.88±30507. 91	6342.00-96161. 00
	5+	424.98±352. 91	38.98-778. 55	89754.40±75080. 07	7783.00-170940. 00
	6+	31.44±14. 71	22.80-53. 40	8783.25±4825. 73	6132.00-16017. 00
	7+	30.59±13. 88	20.77-40. 41	10935.00±4832. 37	7518.00-14352. 00
	8+	8.40±1. 02	7.67-9. 12	5940.59±449. 01	5623.00-6258. 00

Discussion

Based on data base, more 110 fish species have been identified in the South Caspian Sea and amongst them barbels or *barbus* are considered as important ones with a total four species inhabiting the area (Naderi and Abdoli, 2004). *L. capito* is considered as an endangered species (Esmaeili *et al.*, 2010). At present, very few individuals of the Caspian barbels are found in the basin due to overexploitation, climate changes, ecosystem disturbance and increase of pollution in the Caspian Sea (Daryanabard *et al*., 2009). The species recorded only in southern Caspian Sea in recent years, our study area is one of very limited distribution of the species in southeast Caspian Sea. The female-to-male ratio was significant different from the expected ratio of 1:1 in favour of females. Amouei *et al*., (2013) reported dominance of females (1:0.93) in a population from southern Caspian Sea. Generally, the sex ratio of fish populations of a species changed based on spawning season, life stage of the fish, spawning ground, and migration among distribution areas (Nikolskii, 1969; Bartulovic *et al*., 2004).

In this study, the maximum observed age was VIII for females, VII for males, the majority of specimens belonged to age group II for both sexes, which proved that the fish population is young. The age of species was between I and IV in the southern Caspian Sea-Guilan, Mazandaran and Golestan Provinces (Amouei *et al*., 2013), indicating that the species lives long in the studied area.

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Total length changes with age, the average of length are added by age increasing; the maximum slope of growth length were observed in the age group I and II and then decreased with age. The growth almost stopped in the age above (VII- VIII). These results were consistent by observations of Shajiee *et al*., (2002) who reported some biological characteristics of growth and reproduction of the species from Astara to Chaboksar County, southwest Caspian Sea- Guilan province. The mean of total weight changes measurably increased with age; this raise is greater before the maturation in somatic growth, while near or after the maturation related with gonad growth and sexual cell's (Shajiee *et al*., 2002).

The length-weight relationship in fish is of great importance in fishery assessments (Haimovici and Velasco, 2000). This relationship in conjunction with age data can give information on the stock composite, age at maturity, life span, mortality, growth and production. Furthermore, the relative robustness or degree of well-being of a fish expressed as the coefficient of condition (condition factor) is an important tool for the study of fish biology, mainly when the species lies at the base of the higher food web (Diaz *et al*., 2000; Lizama and Ambrósio, 2002). In the context of WLRs, the slop "*b*" provides valuable information on fish growth (Amouei *et al*., 2013). WLRs at age groups show that the weight is added exponentially than total length. On the basis of given WLRs equations, the growth type of both sexes was negative allometry. Froese (2006) expressed that the parameter *b* should normally range between 2.5 to 3.5, while Tesch (1971) reported values of *b* varies usually between 2 and 4. Shajiee *et al*. (2002) calculated the value of this parameter as 3.0823 for *Barbus capito*. The comparison shows that the allometry coefficient vary significantly among barbs.

The only available data on $L\infty$ and k of the studied species are that reported by Naderi Jolodar *et al.* (2018); L_∞=138.6 and k=0.1 year^{-1} for a population of *L. capito* inhabiting Shahid Rajaee Dam lake (Sari, Iran). Jawad (1975) reported L_∞=73.7 and k=0.3245 year^{-1} for *Luciobarbus esocinus* in Basrah region- Iraq. Barak (1983) calculated a value of 165 cm for L_∞ of *Barbus luteus*. Comparison of $L\infty$ values shows that the species *Barbus luteus* had a moderate values among *barbus* species. As other Cyprinid species, there was difference in L_∞ between males and females. This variation reflects inter-sexual difference of a population of the species.

Gonadosomatic index increases with the maturation of fish, being maximum during the period of peak maturity and declining after the spawning period (Parween *et al*., 1993). Based on GSI, reproductive activity of this species in Goganroud River is between May and July. Çoban *et al*. (2012) reported that the maximum values of GSI were observed in March, and then rapidly decreased in April for *Luciobarbus esocinus* living in Keban Reservoir-Turkey. Spawning period of this species

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in Keban Reservoir was determined in March-April and this species has a short spawning period. In previous studies, spawning period of *Luciobarbus esocinus* were reported in April-May in Keban Dam Lake-Turkey (Coban *et al*., 2012); in March in the Turkish Tigris River (Ünlü, 2006); in April-May in Iraq (Al-Rudainy, 2008); in March in Iran and Iraq (Coad, 2011). Comparison of spawning period of different barbs shows that the studied species has longer period that other barbs, a rare one in Cyprinid species.

There was no information on fecundity of this species in the data base. The observed values of absolute fecundity of this species were higher than other *barbus* species from southeast Caspian Sea. It can be concluded that reproduction investment of this species is much higher comparing that of *b. Lacerta*, *L. brachycephalus* inhabiting the area/basin. Consider relative fecundity, this parameter decreased with increasing fish size (length, weight, age). This implies that relative investment of energy in reproduction decrease in older sizes.

Generally, the provided information of this study is the first one for the species in the southern Caspian Sea which could be used in conservation program of this species and biodiversity of the area as well.

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