Iranian Journal of Fisheries Sciences 17(1)194-207 2018
DOI: 10.22092/IJFS.2018.115610

Age, growth and spawning season of *Luciobarbus esocinus* Heckel, 1843 in Gamasiab River, Iran

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Received: April 2016 Accepted: July 2016

Abstract

In the current paper reproductive strategy and growth rates of *Luciobarbus esocinus* were investigated from 2010 to 2012, in Gamasiab River, Kermanshah, Iran. Samples were collected seasonally by gillnet and electro-fisher device. Sex ratio was evaluated from 162 individuals and the percentage of male and female individuals were 54.76% and 45.24% respectively. Age structure was distributed between I and V and most frequency numbers for males and females belonged to II and IV age group, respectively. Length-weight relationship was computed as $W=8E\text{-}05TL^{2.6546}$ for all individuals. Mean total length and weight was 333.82±13.10 mm and 297.67±4.85 g for males, and 371.5±21.17 mm and 307.85±7.64 g for females. The von-Bertalanffy growth models of *L. esocinus* were described as $Lt =357.14\times[1\text{-}e^{(-0.77\times (t -0.090))}]$ for males, $Lt =367.02\times[1\text{-}e^{(-0.78\times (t -0.094))}]$ for females and $Lt =363.57\times[1\text{-}e^{(-0.76\times (t -0.087))}]$for both sexes. Results indicated that growth factors were highly similar in spring, summer and winter. CDA analysis revealed that the total and gonad weight are the main factors in discriminant analysis. The highest GSI values were found in spring for females and winter for males, however, it decreased rapidly after spring in females. Maximum growth rates were observed in early ages (I-II) and depleted with ages. K value and $L\infty$ were determined as 0.77±0.09 Y^{-1} and 357.14±10.38 mm for males and 0.78±0.24 Y^{-1} and 367.02±24.15 mm for females, respectively. In conclusion this study provided basic information for stock assessment and management of *L. esocinus* in Gamsiab Reservoir.

Keywords: Life-history styles, Reproduction, Mangar, Iranian inland waters

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Introduction

For all living organisms, the passage of time is accompanied by growth, maturity and death (Watson, 1967), with much of the energy derived from food being used for body maintenance, activity, and reproduction. One of the most important aspects of the life history of fishes, including their stock assessment, is the computation of growth rates based on age estimation and reproduction biology (Sparre and Venema, 1998). *Luciobarbus esocinus* is member of the Cyprinidae that has spread along the Euphrates and Tigris rivers in Turkey, Syria, Iran and Iraq (Kuru, 1979; Dartay and Duman, 2006; Dartay *et al.*, 2010; Coad, 2014; Dartay and Duman, 2014). This species was previously known as *Barbus esocinus* and has been recently revised as *L. sesocinus* (Fricke *et al*., 2007).

L. esocinus is a Freshwater, benthopelagic and tropical species with a maximum length of 230 cm total length and 140 kg weight (Coad, 2014; Frose and Pauly, 2014). The Gamasiab River is one of the head branches of the Karkheh River Basin (11,459 km^2 area), which is located in the Hamadan and Kermanshah Provinces of Iran (Keshavarz *et al.*, 2012). *L. esocinus* is native to the Gamasiab River, where it is caught with different gear for commercial purposes. Although various studies have been conducted on the biological aspects of *L. esocinus* in other parts of the world (Ali and Tomas, 2009; Zulfu Coban *et al.*, 2012; Dartay and Gul, 2014) there is limited data for this species in the region and information about its population biology remains scarce. In addition there are limited data on growth rate for this species in Fishbase (Frose and Pauly, 2014).

The study of growth in fish involves the determination of body size as a function of age. This is fundamental to stock assessment methods, which rely ultimately on age composition data (Sparre and Venema, 1998). Also, knowledge of fish age characteristics is necessary for the development of management and/or conservation plans. However, despite size being generally associated with age, there is large variation for most fish species (Helfman *et al*., 1997). The aim of this study is therefore to provide basic data on the growth and reproduction biology of *L. esocinus*. It is expected that the present findings will ultimately be useful in the management, conservation programmers and aquaculture activities for this species in Gamasiab River.

Material and methods

Sampling was carried out in the middle of each season from 2010 to 2012 in the Gamasiab River (34°25'05.4"N 47°30'16.3"E), Kermanshah, Iran (2 years and 8 seasons). Sampling was performed randomly through the Gamasiab River (from start to the end) and in total, 162 fish were caught with gillnets of various mesh sizes (30 to 140 mm stretched mesh) and electro-fisher device (200-300 DC voltage, Model HT-2000 Electro-Fishing Unit).

Seasonal samples merged together for further studies. Fish scales were used to determine age of specimens (Bagenal and Tesch, 1987). In addition, sex determination was done by opening the abdominal region and examination of the gonads. For each sample, total length (TL), total weight (TW) and gonad weight (GW) was measured, separately. TL was measured to the nearest 0.1 mm and W was determined with 0.01 g accuracy. In order to calculate Gonadosomatic Index (GSI) and Condition Factor (CF) the following equations were used (Biswas, 1993):

GSI= [Gonad weight/ (Body weight–Gonad weight)]×100
CF= [(Body weight–Gonad weight)/Fish length^3]×10^5

Specific growth rate was determined by following equation (Biswas, 1993):
G= (Ln Body weight$_2$ – Ln Body weight$_1$)/ΔT (Time 1- Time 2)
G= (Ln Body Length$_2$ – Ln Body Length$_1$)/ΔT (Time 1- Time 2)

Von Bertalanffy Growth Function was investigated by following equation (Sparre and Venema, 1992; Nikolsky, 1969):

$L_t = L\infty \times [1-e^{(-k\times(t-to))}]$

Where "L∞" is ultimate length, "K" is the growth rate and "t_0" is the asymptotic length at which growth is zero.

Length-Weight relationship, $W=aL^b$ (Froese, 2006) was converted into its logarithmic expression: ln W=ln a + b ln L. In this formula W is weight (gram) and L is total length of the fish (mm). Statistical t-test expressed to demonstrate the significant differences between obtained b-values and isometric value (b=3) bye following formula (Sokal and Rohlf, 1987):

$$t_s = \frac{b-3}{s_b}$$

Where t_s was the t-test value; b was the slope of curve and S_b was the standard error of the slope. Analysis of Length at age data were performed by FiSAT II software (Version 1.2.2, FAO-ICLARM Stock Assessment Tools) as explained in details by Gayanilo *et al.* (1996). Canonical discriminant analysis (CDA) was performed by R statistical package (version 3.1.3). Similarity Percentages (SIMPER) and Multi-Dimensional Scaling (MDS) analysis was carried out by PRIMER 5 software to assess similarities between growth factors in seasons.

Results

Distribution of age and sex

In this study, 162 individuals (92 males and 70 females) of *L. esocinus* were caught in Gamasiab River. Male-female rate was found as 54.76% for males and 45.24% for females, although the Chi-square test showed no significant differences between sex ratios. Five age groups were identified in this study of

which the highest numbers for males and females belonged to the II and IV age group, respectively (Table 1).

Table 1: Growth parameters of *Lucioabrbus esocinus* population in Gamsiab Reservoir, Iran (2010-2012).

Sex	L∞ (mm)	K (1/Year)	T_0 (mm)
Male	357.14±10.38	0.77±0.09	0.090
Female	367.02±24.15	0.78±0.24	0.094
All individual	363.57±16.12	0.76±0.15	0.087

Growth

Growth parameters were calculated by analysis of length at age data and represented in Table 2. Based on growth parameters, the von Bertalanffy growth models of *L. esocinus* were described as $L_t=357.14*[1-e^{(-0.77*(t-.090))}]$ for males, $L_t=367.02*[1-e^{(-0.78*(t\ -0.094))}]$ for females and $L_t=363.57*[1-e^{(-0.76*(t-0.087))}]$ for both sexes. Growth graph according to von Bertalanffy equation are shown in Fig. 3. Maximum growth rates were observed in early ages (I-II years) and had depletion with ages (Table 3). Minimum and maximum of length for this species was 200-389mm for males and 194-422 mm for females (Figs.1,2). The distribution of weight was 101-612 g for males and 80-772 g for females. Length frequency distribution of the fish (Fig.4) indicated that the most frequent size classes in the samples were 250-340 mm for males while females had two cohorts in 200-250 mm and 310-400 mm.

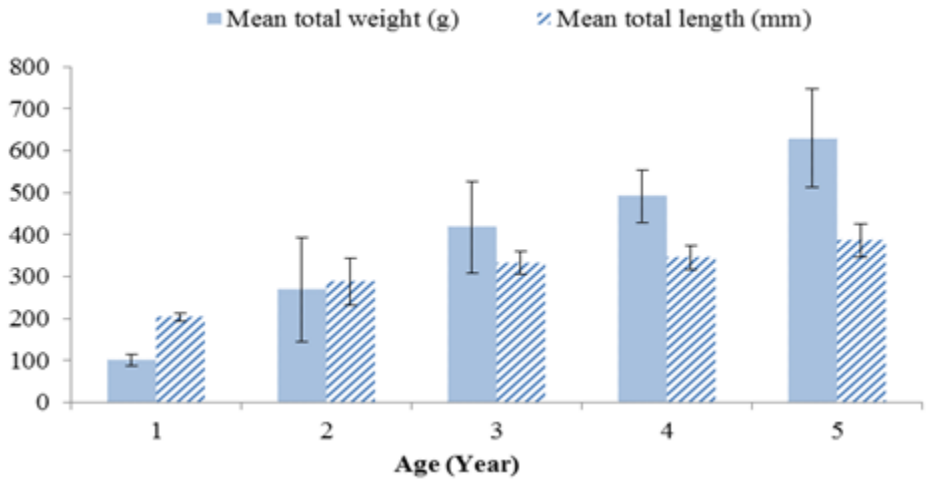

Figure 1: *Lucioabrbus esocinus* females mean length and weight in Gamasiab Reservoir (2010-2012).

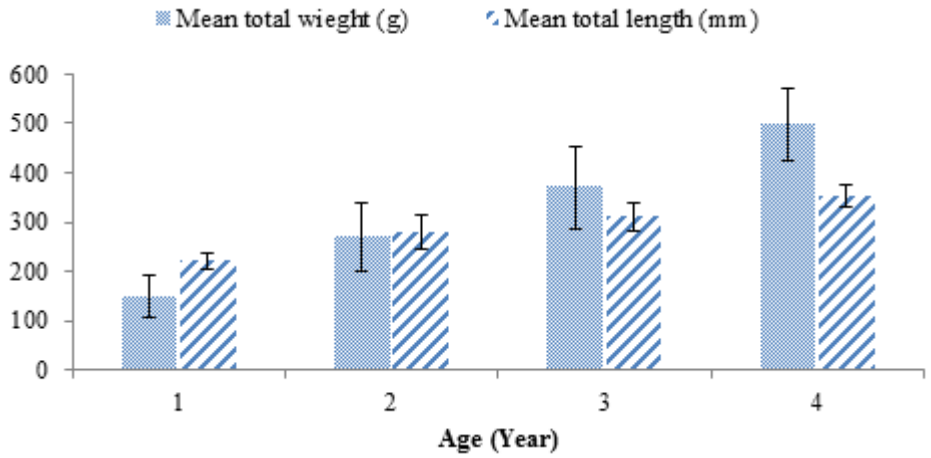

Figure 2: *Lucioabrbus esocinus* males Mean length and weight in Gamasiab Reservoir (2010-2012).

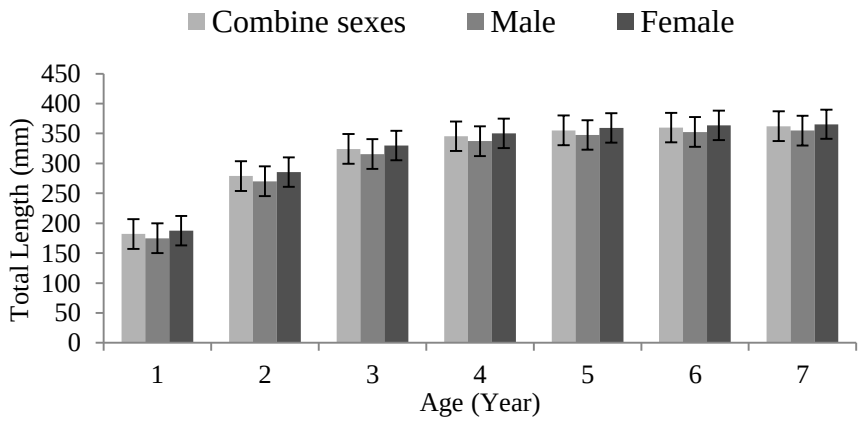

Figure 3: Von Bertalanffy growth graphs of *Luciobarbus esocinus* population in Gamsiab Reservoir, Iran (2010-2012).

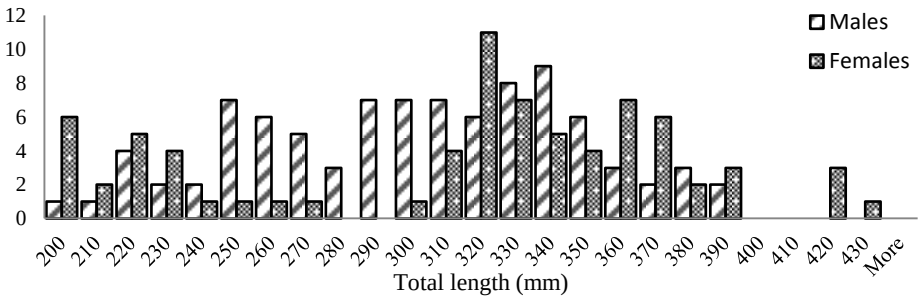

Figure 4: Length frequency distribution for *Luciobarbus esocinus* in Gamasiab Reservoir (2010-2012).

Table 2: *Lucioabrbus esocinus*. Number, Percentage and sex ratio at each sampling time (2010-2012).

Season	Males (n)	Females (n)	Females (%)	Sex ratio (M:F)	X^2	P
Spring	24	14	36.84	1:0.5	2.632	0.105
Summer	27	18	40	1:0.6	1.800	0.180
Autumn	22	19	46.34	1:0.8	0.220	0.639
Winter	19	25	56.81	1:1.3	0.818	0.366
Total	92	70	43.20	1:0.7	2.988	0.84

Table 3: Growth rates of *Lucioabrbus esocinus* population in Gamsiab Reservoir, Iran (2010-2012).

Sexes	Growth rate							
	I-II		II-III		III-IV		IV-V	
	Weight	Length	Weight	Length	Weight	Length	Weight	Length
Male	0.595	0.214	0.320	0.138	0.295	0.118	-	-
Female	1.017	0.355	0.395	0.111	0.171	0.063	0.247	0.111
Combine sexes	0.817	0.282	0.347	0.129	0.248	0.093	0.242	0.100

Gonadosomatic Index and Condition Factor

Results showed that highest level of GSI value was observed in spring for females and in winter for males and declined with a steep gradient in summer (Fig. 5). GSI value varied between 0.308 and 2.87% for males and 0.345 to 6.45% for females. Condition factor had the lowest value in spring for both sexes. Highest level of CF was in autumn for males and in winter for females (Fig. 6). CF value changed between 1.067 and 1.320 for males and between 0.942 and 1.286 for females. Based on GSI and CF values spawning season for *L. esocinus* was regarded as being in spring when CF was the lowest and GSI was the highest.

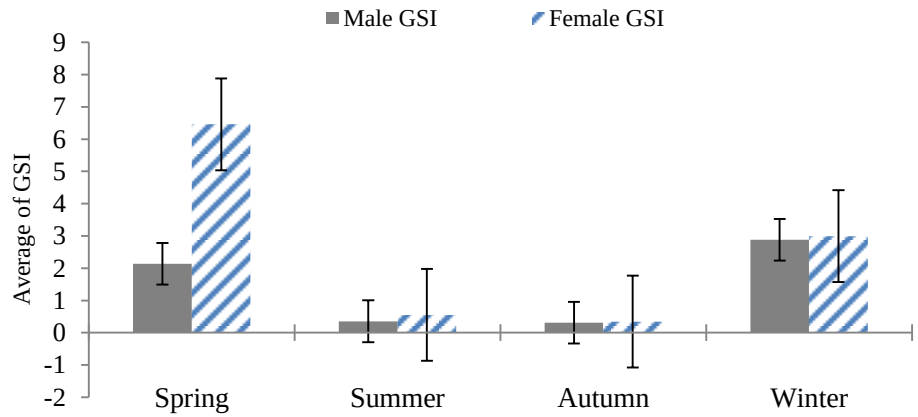

Figure 5: Seasonal changes in gonadosomatic index (GSI) of *Luciobarbus esocinus* population in Gamsiab Reservoir, Iran (2010-2012).

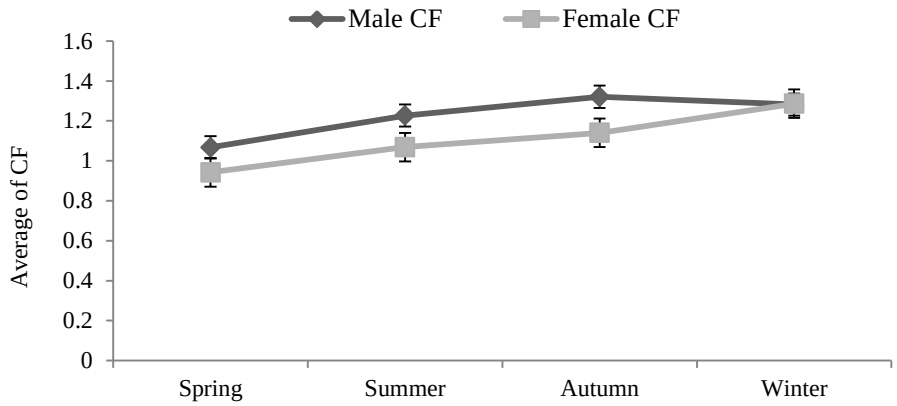

Figure 6: Seasonal changes in condition factors (CF) of *Luciobarbus esocinus* population in Gamsiab Reservoir, Iran (2010-2012).

Length-weight relationship

The length-weight relationships of the *L. esocinus* were estimated as $W=0.0004TL^{2.3959}$ for males, $W=3E\text{-}05TL^{2.81}$ for females and $W=8E\text{-}05TL^{2.6546}$ for both sexes (Fig.7). The *b* values for males, females and all individuals were estimated as 2.395, 2.81 and 2.65, respectively. According to the *b* value this species shows negative allometric growth in the both sexes.

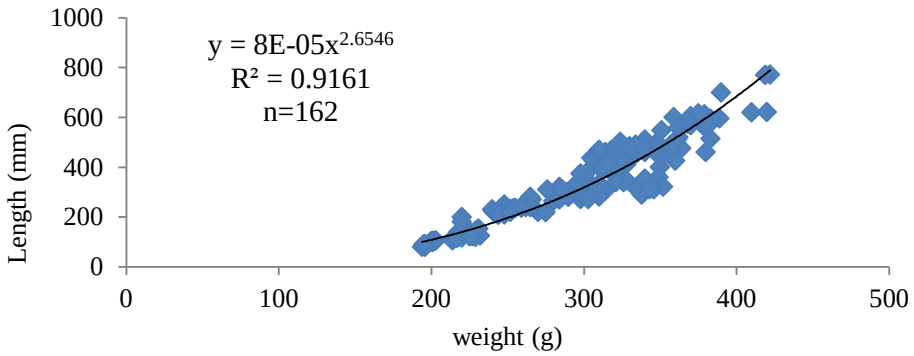

Figure 7: Length-weight relationship of *Luciobarbus esocinus* in Gamasiab Reservoir (2010-2012).

Differentiation between growth factors in seasons

Results indicated that growth factors were highly similar in spring, summer and winter (Fig. 8). CDA analysis revealed that total weight and gonad weight are the main factors in discriminant analysis (Fig. 9). It should be noted that total weight was the most important factor due to its high contribution in dimension 1 in CDA analysis. In addition, SIMPER analysis showed that total weight was the most important factor contributing to similarity between seasons (Table 4). Furthermore, Table 4 demonstrated low dissimilarity (mean average 3 to 8 %) between growth factors in different seasons.

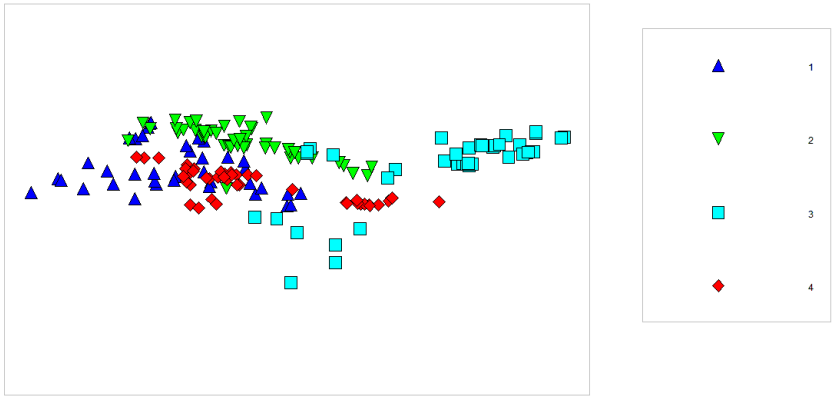

Figure 8: MDS analysis of growth factors between seasons. (1= spring, 2= summer, 3= autumn, 4= winter).

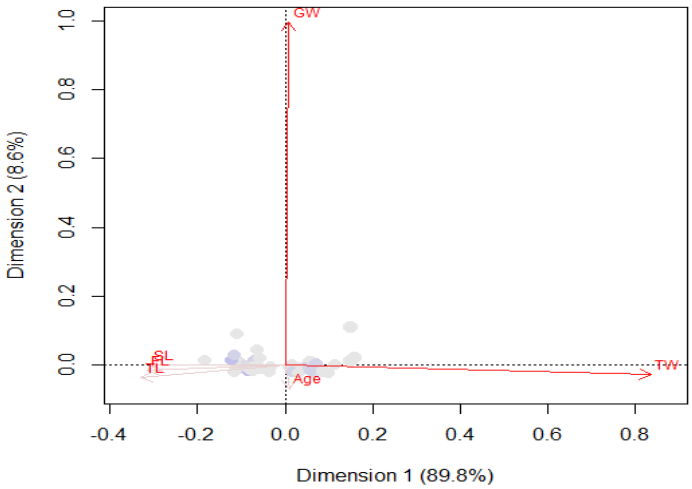

Figure 9: CDA analysis between growth factors. (GW= gonad weight, TL= total length, SL= standard length, FL= fork length, TW= total weight).

Table 4: Growth factors SIMPER analysis within and between seasons. (1= spring, 2= summer, 3= autumn, 4= winter).

Factors*	Similarity % Contribution Within season				Dissimilarity % Contribution Comparing seasons				
	1	2	3	4	1 vs. 2	1 vs.3	1 vs.4	2 vs.3	3 vs.4
TW	26.45	25.74	26.53	25.24	26.45	37.10	31.78	42.89	28.82
TL	23.52	24.25	25.25	23.71	10.65	13.03	13.34	15.21	12.04
FL	22.26	23.40	24.48	22.70	12.49	13.29	13.88	12.82	11.13
SL	21.68	22.75	2.38	22.01	11.79	12.98	12.49	12.92	10.85
GW	--	--	--	--	34.76	21.54	24.95	13.72	32.25
Average	96.54	97.37	95.61	97.21	4.07	8.29	3.37	6.17	3.66

*GW= gonad weight, TL= total length, SL= standard length, FL= fork length, TW= total weight

Discussion

L.esocinus is a frequent species in the Gamasiab River but limited data on biological characteristics of this species is available. In this survey, value of GSI was found to be maximum in spring for both sexes and rapidly decreased in summer. 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). According to this indicator, the spawning period for this species in

Gamasiab River was determined as spring which is a short period. Zulfu Çoban *et al.* (2012) declared that *L. esocinus* has a rapid spawning period in March-April in the Keban Reservoir. In literature, the spawning season of *L. esocinus* is identical but the month varies, being April-May in Iraq (Al-Rudainy, 2008); March in the Turkish Tigris River (Unlu, 2006) and March in Iran and Iraq (Coad, 2014). Overall, results of the present study coincided with the findings on the spawning period in the geographic distribution of this species.

Biswas (1993) reported that the value of condition factor changes according to nutrition conditions, seasonal changes and reproduction activity of the fish. The condition factor for this species was in the lowest range for both sexes in spring, which confirms this. Results of condition factor showed that males were in a better condition than females (Fig. 5). It shows that males had better welfare conditions than females. The value of condition factor was varied between 0.942 and 1.32 for both sexes. Zulfu Çoban *et al.* (2012) reported condition factor from 0.528 to 1.863 for this species in the Keban Reservoir. They said CF increased until the age of 5 and declined after this age.

In the present study, the exponent *b* in the length-weight relationships for males, females and both sexes were calculated (b=2.395, b=2.81 and b=2.65), which suggests negative allometric growth for *L. esocinus* in the Gamasiab Reservoir. Similar studies in other parts of the distribution of *L. esocinus* reported *b* value for this species as 2.915 in Keban Dam Lake (Dartay and Gul, 2014), 3.218 in Keban Reservoir (Zulfu Çoban *et al.*, 2012), 3.017 in Lake Habbaniya and 3.085 in Lake Tharthar (Szypula *et al.*, 2001). Sampling gear may influence the size range covered and cause deviations from existing values for parameters "*a*" and "*b*". Furthermore, health, and sex certainly affect these parameters as well (Bagenal and Tesch, 1987; Froese, 2006; Gerami *et al.*, 2013). Differences in LWR parameters may represent spatial variation and different environmental conditions which influence such as local selective pressure on fish condition (Sparre *et al.*, 1989), due to the influence of water quality or food availability on fish growth (Mommsen, 1998). However, none of these parameters were considered in this study. This study represents new *b* value for this species. It seems that geographical location and associated environmental condition can significantly affect the value of *b* in *L. esocinus*. However, the negative allometric growth of *L. esocinus* in this study was identical with another population of this species in the Keban Dam Lake, Turkey (Dartay and Gul, 2014).

Five age groups were identified for this species in the Gamasiab River (Table 3). Age group II was dominant in males and IV in females. In addition, age group V was not observed in males.

Other findings for this species show I to X age groups in some reservoirs with IV as the dominant age group (Şen *et al*.1996; Zulfu Çoban *et al.*, 2012). It shows that this species has a long lifetime; however, environmental conditions in the Gamsiab River were not consistent with growth for this species. Although Mimeche *et al*. (2013) reported at least 14 age groups of *Luciobarbusc allensis* living in K'sob Stream, they did not catch any specimens younger than 3^{+} at the sampling site. This occurrence could have happened in our study from the Gamsiab Reservoir too. The long lifespan of the populations in the reservoir and the occurrence of younger specimens primarily in the streams are in agreement with the patterns observed in several cyprinid populations previously studied in watershed systems throughout the Mediterranean area (Enucina *et al*., 2006). However differences of age groups may be due to fishing methods, sample size, different years (Nikollsky, 1980) and spatial genetic variation between two populations.

Male predominance of *L. esocinus* was in agreement with Zulfu Çoban *et al.* (2012) in the Keban Reservoir or other genus like *Labeo barbus* (Tiohue *et al.* 2013). Higher sex ratio of males in the samples may be due to the differential fishing factors related to seasons and schooling of fishes in the feeding and spawning grounds, or to selective fishing for the large fish, rather than reflecting a real population sex ratio (Tiogué *et al*., 2013). Deviation from a 1:1 sex ratio has been associated with various parameters, for example, sex reversal and hermaphrodism (Lehoday *et al.*, 1997; Kulmiye *et al.*, 2002) or different survival rates of males and females or spatial segregation of size-classes in each sex (Falahatimarvast *et al*., 2012). Growth coefficient (K) was estimated 0.77 Y^{-1} and 0.78 Y^{-1} for males and females respectively (Table 2) indicated that sex did not affect growth rate in *L. esocinus*, significantly. Zulfu Çoban *et al*. (2012) estimated growth coefficient for this species in Keban Reservoir as 0.031 for males and 0.038 for females. They also declared that L∞ was 225.621 cm for males and 234.378 cm for females. Szypula *et al*. (2001) estimated K for *Barbus grypus* as 0.094 in the Tharthar Lake. Also Hashemi *et al*. (2010) calculated K for *Arabibarbus grypus* as 0.27 in the Karoon River. Different values of L∞ and K might be associated with sampling error or variation in fishing intensity or environmental conditions. L∞ and K have reverse correlation and with decrement L∞, K increases (Sparre and Venema, 1998). The L∞ value of females was higher than males. The reason for this may be due to faster growth rate of females than males and longer lifetime (Weatherly, 1972). Results showed that *L. esocinus* in the Gamsiab River have higher K rate and lower L∞ in comparison with its counterpart in other parts and other *Barbus* genus. It seems that *L. esocinus*

can have various growth rates based on habitat and distribution. However, MDS analysis revealed that growth rates were similar in seasons and there was little dissimilarity between autumn with other seasons. Table 4 and Fig. 9 showed that gonad weight was one of the discriminant factors. Maximum GSI was found in winter and spring. This suggests that fishes grow fast in autumn to prepare themselves for spawning periods in late winter and early spring. This kind of spawning behavior was observed by Enucina and Grando-Lorencio (1997) for *Barbus sclateri* and they declared that juveniles, males and females of Sclater barbel exhibited a similar condition, nutrition and somatic energy cycle throughout the year, with active somatic energy accumulation from winter through spring while adults represented spawning behavior. In addition, Eliassen and Vahl (1982) declared that changes in energy are usually more than the seasonal weight variations. This phenomena consequently would affect growth and specially, total length of fishes (second important factor in CDA analysis in this study). However, seasonal variations encountered are more related to variations in food availability than to the reproduction cycle (Cambray and Bruton, 1984), but the effect of reproduction cycle on growth rate reduction is negligible.

Generally, this study indicated that *L. esocinus* in the Gamasiab Reservoir has spawning season and sex ratio, lower condition factor, L-W relationship b value, higher growth rate, $L\infty$ and lifetime similar to those of other Mangar populations in Euphrates River and reservoirs. According to IUCN Red List Status (CITES, 2013) this species is considered as Vulnerable (VU) and needs conservation programs to be applied to it. This study provided basic information on growth rate, condition factor and spawning season for this species in one of its major habitat and distribution places. The conclusions of this study remain, however, limited by the relatively low sampling period of one year only. Therefore longer sampling period (monthly sampling in several years) may depict a better picture of the results of this study in Gamasiab Reservoir. In addition, further studies could be conducted on the environmental conditions and habitat structure of this species in different seasons and changes in environmental food supply of Gamsiab River to find the best model for conservation programs.

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