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Population dynamics of *Carasobarbus luteus* in Shadegan International Wetland, Iran

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Abstract

Seasonal samplings were conducted over a year to study population dynamic of *Carasobarbus luteus* in Shadegan Wetland. Samples were collected from five sampling stations in Shadegan Wetland (Salmane, Rogabe, Khoroosi, Mahshahr and Atish) from April 2014 to March 2015. From total number of 1608 samples, 276 individuals were male and 1332 individuals were female. Length-weight relationship was $W=0.013L^{3.0124}$ ($R^2=0.92$) for males; and $W=0.0136L^{3.0117}$ ($R^2=0.91$) for females, showing an isometric growth pattern. Condition factor (K) was calculated to be 1.308±0.15 and 1.368±0.17 for the males and females, respectively, showing significant difference between the genders ($p<0.05$). Also, the results show that this species spawns in April-July with a long spawning period and sexual dormant period in autumn to early winter. Mean length at maturation was 161 and 174 mm for males and females specimens; whereas, weight of matured fish was 60 and 80 g for the males and females, respectively. Growth indices including L_∞, growth coefficient and t_0 were 305 and 301 mm, 0.67 and 0.55 per year and 0.23 and 0.29 for the males and females, respectively. Natural mortality, fishing mortality, total mortality, Munro Φ' and coefficient of exploitation were 1.22 and 1.02 per year, 1.61 and 1.45 per year, 2.83 and 2.47 per year, 2.79 and 2.72, and 0.57 and.59, respectively for the males and females.

Keywords: *Carasobarbus luteus*, Shadegan Wetland, Growth and fishing indices, Von-Bertalanffy equation

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Introduction

Population dynamics is one of the functional sub-divisions of population ecology and fundamentals of fish stock biology (Biswas, 1993). Population dynamic elements are fundamental of analytical models in the field of stock assessment, which provide important information about stocks' status (King, 2007). Estimation of length at maturation, spawning time, determination of fishing prohibition time and optimum length for catch is important information about a fish species. Population dynamics is related to sequential processes of regeneration and production, which are known as growth and mortality. Stocks' conservation is a global important key factor in sustainable exploitation of whole aquatic resources. Fisheries authorities focus on providing enough and assured food from natural resources considering the allowable exploitation (Jenning *et al*., 2000). Population dynamics is one functional sub-divisions of the population ecology and fundamentals of fish stock biology (Biswas, 1993). *Carasobarbus luteus* (Heckel, 1843) is a freshwater fish belonging to *Carasobarbus* sp. and Cyprinidae family. The maximum and average length of *C. luteus* is 38 and 23 cm, respectively (Ahmed, 1982; Borkenhagen, 2005). This species is found in the middle and lower parts of rivers, preferring standing waters near aquatic plants and algae (Coad, 2006). Increased demand for *C. luteus* has caused increased pressure on this species population (Hashemi *et al*., 2012); therefore, study on biological characteristics, population structure and growth factors are important for this species. With an area of 537700 ha (the area varies in different years), Shadegan Wetland encompasses about 34% of the total wetlands of Iran according to the Ramsar Convention (1971). Shadegan Wetland is located at 3°,17′-3°,48′ N and 48°,17′-48°,50′ E (Bogutskaya *et al*., 2008). The aim of this study was to estimate length at maturation and spawning time and to determine fishing prohibition time and optimum length for catch of *C. luteus*.

Materials and methods

Samplings were conducted seasonally over a year. Five sampling stations including Salmane (30°,40′N: 48°,28′E), Mahshahr (30°,52′N: 48°,30′E), Rogabe (30°,41′N: 48°,33′E), Khoroosi (30°,39′N: 48°,40′E) and Atish (30°,54′N: 48°,40′E) were selected in such a way to cover the whole wetland area (Fig. 1).

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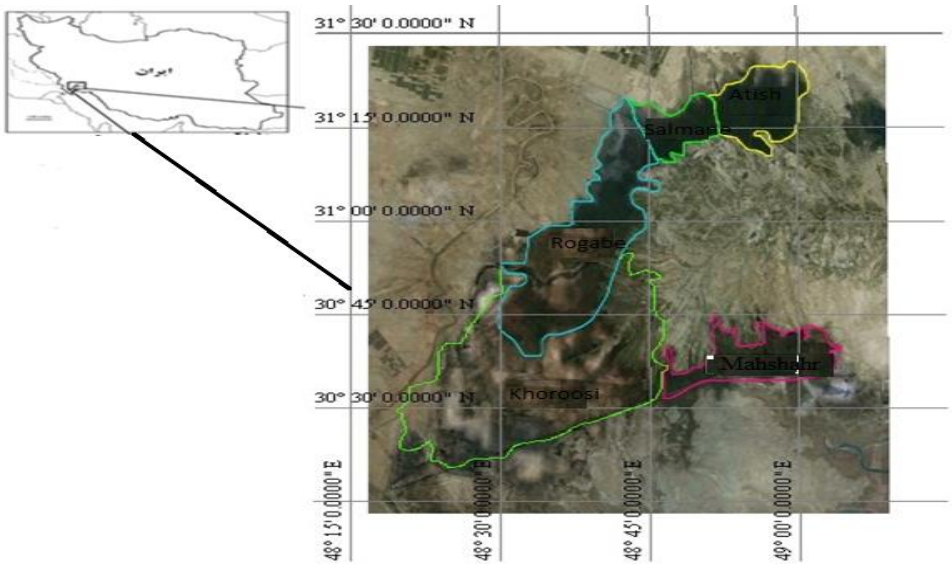

Figure 1: Five sampling stations in Shadegan Wetland.

Length-weight relationship

Measurement of fish length and weight along with the fish age provides useful information about the stock population structure, age of maturation, life span, mortality, growth and production. The following formula was used to calculate relationship between the fish total length and weight:

$W=aL^b$

Where, W was fish weight (g), L was fish length (cm), "a" was constant coefficient, and "b" was the equation power.

The following formula was used to find significant differences between the calculated "b" and B-3 for a fish with similar growth:

$t = [(SdX)/(SdYy)] \times [\,|\, b-3 \,|\, / (\sqrt{}\, (1-r^2)] \times [\sqrt{}\, (n-2)]$

Where SdX is standard deviation of fork length natural log, SdY is standard deviation of weight natural log, "b" is slope, r^2 is coefficient of determination and "n" is sample size (Zar, 1996). Condition factor or quality factor was calculated to investigate trend of the fish condition over the year, using the following formula (Beckman, 1984):

$K= W\times10^2/L^3$

Where "W" was the fish weight (g) and "L" was total length (cm).

Sexual maturation stages were determined both macroscopically and microscopically (7-stage key) and stages higher than 4 were considered as matured (Biswas, 1993; Sparre and Venema, 1998; King, 2007).

Fishes are matured just after reaching a certain size; therefore, length-maturation relationship is as useful as length-age relationship (King, 2007).

Logistic model and $Y=1/(1+\exp(-a-bX))$ equation were used to estimate length at the first maturation; where, "Y" is the proportion of matured males and females to whole fish within a same length class, "X" is total length (cm) and "a" and "b" are constant coefficients (Biswas, 1993; Sparre and Venema, 1998; King, 2007). Calculation of length-age relationship is important in fish growth study. All analytical methods for stock

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assessment, population dynamic and fish management are based on this information (Sparre and Venema, 1998). Infinite length (L_∞) is defined as the maximum length that the fish of a stock are able reach to. There are several methods to estimate L_∞ (Sparre and Venema, 1998), which Powell-Wetherall graph in the present study.

Calculation of K with Shepherd method

Similar to L_∞, K is one of the Von-Bertalanffy equation growth parameters. After calculation of L_∞, K is calculated using FiSAT software (Gayanilo *et al*., 2003). The shepherd program of FiSAT software estimates the K curve best fitted on longitudinal histograms (Pauly *et al*., 1998).

Growth performance index

Munro Φ' test is used to compare growth indices in the studied area (Pauly, 1984):

$\Phi' = \text{Log}(K) + 2\text{Log}(L_\infty)$

Where L_∞ is infinite length, K is growth coefficient and Φ' is growth index.

t_0 calculation

The optimum T_0 is calculated according to experimental formula of Pauly (Froese and Binohlan, 2000):

$\text{Log}(-t_0) = -0.3922 - 0.2752\ \text{Log}(L_\infty) - 1.038\ \text{Log}(K)$

Total mortality (Z)

Coefficient of total mortality is calculated using the method of longitudinal frequency to catch curve conversion. In this method, total mortality is calculated using growth parameters and conversion of length mode of each longitudinal class to relative age. Proportion of fish number in each longitudinal class is calculated monthly (Gayanilo *et al*., 2003).

Coefficient of natural mortality (M)

Natural mortality is defined as that caused by factors other than fishing. These factors include hunting by other animals, food deprivation, global climate change stresses, diseases and aging. Pauly experimental formula was used to calculate coefficient of natural mortality (M) in the present study:

$\text{Ln}(L_\infty) = 0.0152 - 0.279\ \text{Ln}(L_\infty) + 0.6543\ \text{Ln}(K) + 0.463\ \text{Ln}(T)$

Where M is annual coefficient of natural mortality, L_∞ is infinite length (cm), K is curve parameter of Von-Bertalanffy growth equation and T is the mean ambient temperature (King, 2007). Coefficient of fishing mortality (F) is calculated from total mortality and natural mortality using the following formula:

$F = Z - M$

Coefficient of exploitation calculation (E)

Coefficient of exploitation is calculated using this formula: E=F/Z. If E is lower than 0.5, the stock is underexploited. If the stock is overexploited, the value of E would be higher than 0.5. In fact, the E value is optimum when fishing mortality is equal to natural mortality; so that E =0.5 (King, 2007).

Production/biomass ratio or population production (P/B)

Production/biomass or population production (specific production) is

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calculated using this formula P/B = $2.64W_{mat}^{-0.35}$; where W_{mat} is fish weight at maturation (Randall and Minns, 2000).

Virtual model of population analysis

Virtual model of population analysis and cohort analysis are obtained using FiSAT program. The value of L_∞, K, M, F, a (constant) and b (power) are used as inputs for the model. t_0 is considered zero. VPA functional methods have been determined by Pauly (Pauly, 1984). These analyses were conducted in SPSS, Minitab and FiSATII software.

Results

This study was conducted in Shadegan Wetland and a total number of 1608 fish were sampled that underwent biometry. 276 samples were male and 1332 samples were female. Mean length (length range) in the males was 161±28 (110-222) mm, whereas it was 174±38 (95-280) mm in the females. Mean weight (weight range) in the males was 60±31 (15-175) g, whereas it was 80±39 (15-370) g in the females. Mean length (length range) of whole samples was 217±58 (95-280) mm, whereas mean weight (weight range) of whole samples was 164±120 (15-370) g. Data classification was performed with 20 mm intervals. Longitudinal classes and frequencies of *C. luteus* are presented in Table 1. The maximum and minimum longitudinal frequencies are 155-175 (25.37%) and 95-115 (0%) for the males and 175-195 (41.42%) and 275-295 (0.07%), respectively (Table 1).

Table 1. Longitudinal classification and frequency percentage of longitudinal classes of *Carasobarbus luteus* in Shadegan Wetland in 2014-2015.

Longitudinal classification(mm)	Frequency (%) male	Frequency (%) female
95-115	1.12	0.43
115-135	11.57	3.76
135-155	25.37	13.86
155-175	35.82	40.82
175-195	22.01	28.03
195-215	2.99	8.06
215-235	1.12	3.01
235-255	0	1.39
255-275	0	0.53
275-295	0	0.11

Length-weight relationship was $W=0.013L^{3.0124}$ ($R^2=0.92$) for males; $W=0.0136L^{3.0117}$ ($R^2=0.91$) for females (Fig. 2). The value of standard error was low (<0.5), so that keeps the b value within isometric growth range. There was no significant difference between the calculated b and expected B (=3) values. The value of b in the fish length-weight relationship was near 3, which is due to their isometric growth. The minimum and maximum condition factors in the males and females were observed in May and January. Condition factor (K) was calculated to be 1.308±0.15 and 1.368±0.17 for the males and females, respectively, showing significant difference between the genders (p<0.05). Overall, the males had lower condition factor than females and the maximum and minimum values were observed in winter and spring.

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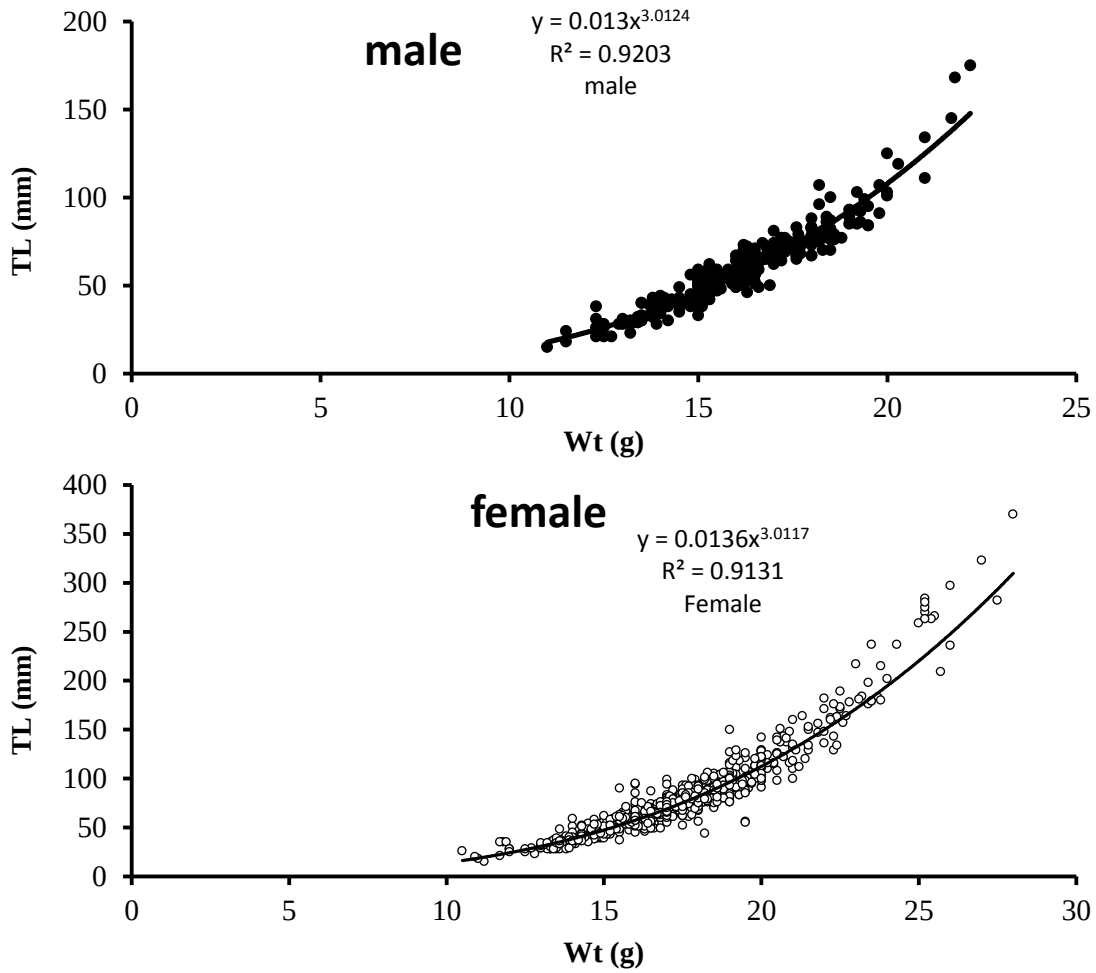

Figure 2: Length-weight relationship in male (A) and female (B) *Carasobarbus luteus* in Shadegan Wetland.

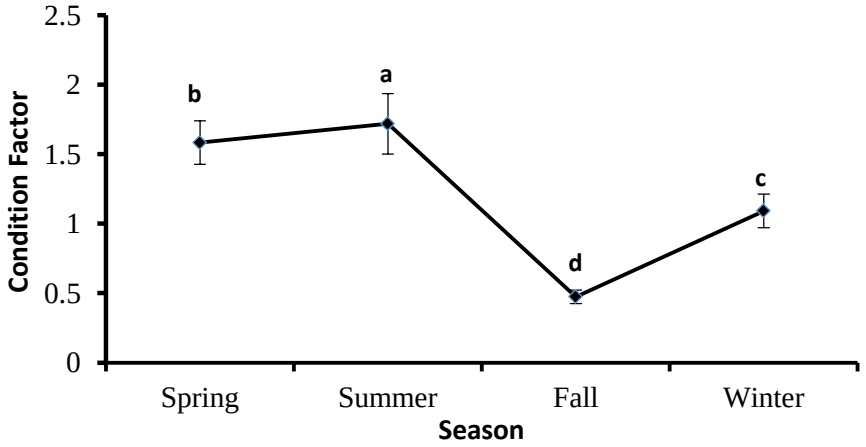

Figure 3: Condition factor in different seasons in Shadegan Wetland.

Frequency of different gonadal developmental stages was determined using the 7-stage key and is presented in Fig. 4. This figure shows that spawning of *C. luteus* occurs in April-July with a long spawning period and sexual dormant period in autumn to early winter.

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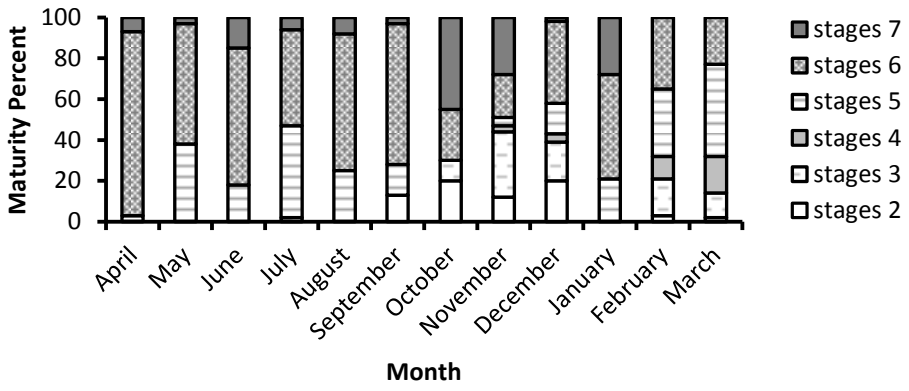

Figure 4: Spawning stages of *Carasobarbus luteus* in Shadegan Wetland.

LM_{50} curve (the length at which 50% of the fish are matured) was obtained according to the fish longitudinal classification and frequency of matured individuals in each class. Length at maturation was 152 and 139 mm for the males and females, respectively (150 mm for whole individuals); whereas, weight at maturation was 42 and 100 g, respectively. P/B was 0.71 and 0.52, and consumption to biomass ratio was 15.41 and 12.37 for the males and females, respectively.

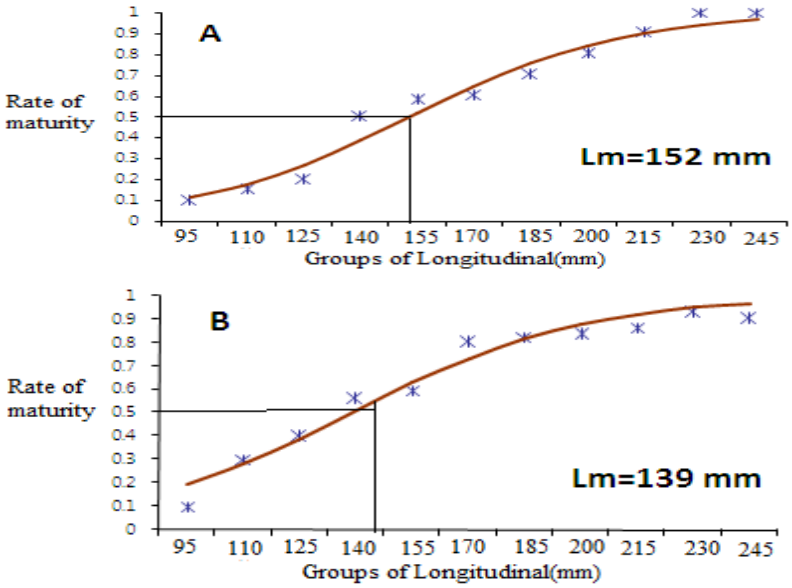

Figure 5: Length at maturation in male (A) and female (B) *Carasobarbus luteus* in Shadegan Wetland.

L_∞ was 305 and 310 mm, growth coefficient was 0.67 and 0.55 per year, and time for t_0 was -0.23 and -0.29 for the males and females, respectively (Fig. 6). Natural mortality was 1.22 and 1.02 per year, fishing mortality was 1.61 and 1.45 per year, total mortality was 2.83 and 2.47 per year, Munro Φ' was 2.79 and 2.72, and coefficient of exploitation was 0.57 and 0.59 per year in the males and females, respectively (Fig. 7).

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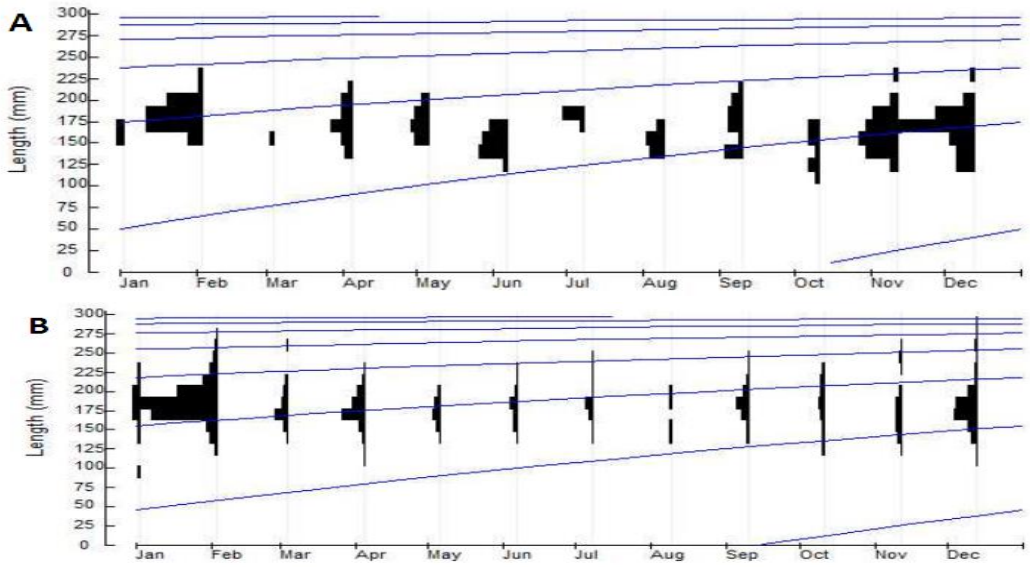

Figure 6: Growth coefficient of the male (A) and female (B) *Carasobarbus luteus* in Shadegan Wetland.

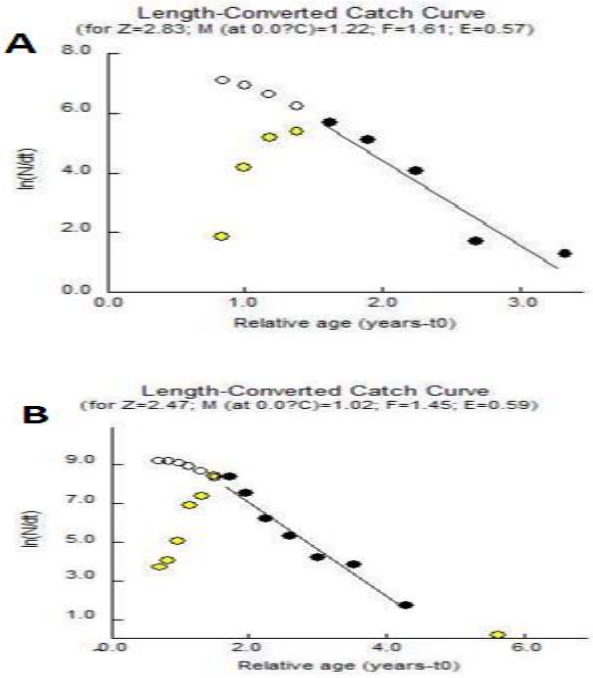

Figure 7: Catching curve obtained from longitudinal frequency data of the male (A) and female (B) *Carasobarbus luteus* in Shadegan Wetland.

Von-Bertalanffy equation for the male and female *C. luteus* population in 2015 was L_t=305 (1- exp (-0.67(t+0.23))) and L_t=310(1-exp(-0.55(t+0.29))), respectively. In this equation L_t is the fish fork length (mm) and t is the fish age (year).

Using the curve, length of *C. luteus* was calculated for each longitudinal class based on virtual population analysis. In males, probability of catch maximizes in longitudinal class of 20 cm and falls afterward. In females, probability of catch maximizes in longitudinal class of 18 cm and

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fluctuates afterward. Considering the virtual population analysis for either of the genders, survivorship falls and fishing mortality elevates along with increase in the fish length from 15 cm to higher values (Fig. 7).

Fig. 6. Virtual analysis of population obtained from longitudinal frequency data of the male (A) and female (B) *C. luteus* in Shadegan Wetland

Discussion

The biometry data show that the fish weight and length elevation reduces in higher ages and females usually have higher weight and length than males. Differences in length-weight relationships of *C. luteus* were reported from different geographical regions, which is due to variations in the condition of the regions. In Shadegan Wetland, higher weight was observed at same lengths in some stations, which may be related to nutritional conditions. Variation in length-weight relationships may be due to seasonal variations, environmental factors, fish physiological condition at sampling time, gender, gonad developmental stage and nutritional conditions in the environment (Yildirim *et al*., 2002). Trend of K data shows that the maximum and minimum values are observed in pre-spawning (winter) and spawning (spring), respectively, and the mean K values of the females were higher than those of the males. Generally, male and female populations have similar K value pattern. Variation of K values in different regions is related to several factors including population density, diseases, nutrition, spawning style, age and aquatic resource type (King, 2007). *C. luteus* spawns in Shadegan Wetland in spring, which is similar to what has been reported in Hoorolazim Wetland. Studies on sexual maturation stages and percentage of matured (*C.luteus* in Hoorolazim Wetland show that the highest number of matured fish is present in April. This suggests that percentage of the matured fish increases in late winter with temperature elevation, which finally spawn in the middle of spring (May and June), which is somehow in line with other studies. In the other regions, most *Barbus* sp. species spawn in late winter to early spring, and such a negligible difference in spawning time is related to environmental characteristics and water temperature (Dutta *et al*. 2012). Considering other studies on *C. luteus*, it seems that L_{∞} of this species is higher in Turkey and Syria than that in Iran and Iraq; in other words, L_{∞} is higher in cold water than in warm water. However, variation of L_{∞} and other growth indices in different regions may be due to quality and quantity of feeds and climatic conditions (Bartulovic *et a*l., 2004). Several factors can affect fish growth including age, gender, season, year, nutrition, physiological conditions, feed availability and reproduction cycle (Dutta *et al*. 2012). Population size of a species is dependent on survival and reproduction success and considering the constant fluctuation in environmental conditions, each species should adapt different conditions, otherwise cannot survive. Therefore, growth parameters of a

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species show fluctuations in different years and should be investigated in different times (Cengiz, 2012). Comparison of length at maturation of *C. luteus* between Shadegan and Hoorolazim Wetlands suggest that the Shadegan population matures earlier than the population in Hoorolazim. Length at maturation varies among different species depending on environmental conditions, life span and feed type; also, environmental factors directly affect age and length at maturation (Dutta *et al*., 2012). No systemic trend was observed in t_0 values in different sampling stations being -0.37 for the whole sampling satiations of Shadegan Wetland. Age at zero length varies in different regions depending on environmental factors and change in L_∞ and growth coefficient. Age at zero length elevates along with growth coefficient elevation and L_∞ demotion (Sparre and Venema, 1998). Φ' value ranges 2.3-2.93 being 2.3 (Hashemi *et al*., 2011) for Shadegan Wetland. Variations in ecological conditions and latitude may affect infinite length and growth coefficient, which in turn affect Φ', and even in a single region, variable values are observed at different time because of variation in environmental conditions (Sparre and Venema, 1998). Coefficient of exploitation (E) of this species was higher than 0.5; thus, the stock is overexploited. Coefficient of exploitation of higher than 0.5 along with higher fishing mortality compared to natural mortality show the stock is under overfishing pressure (King, 2007). Catching size quantity and environmental factors that affect the stock survival are the factors causing pressure on the stock (Mateus and Estupina, 2002). It seems that P/B or population production (specific production) of *C. luteus* is not high in Shadegan Wetland. P/B of inland water fish ranges from 0.2-3 and usually is higher in warm regions compared to cold regions. Population production (specific production) can indicate fish population growth potential in respect to habitat production capacity (Jenning *et al*., 2000). P/B is more important than production; because if P/B of different organisms of an ecosystem is available, production of a certain regions can be calculated and populations with different biomasses can be compared among different regions. Feed consumption rate (Q/B) of *C. luteus* is high, which was expected regarding the fact that this species is omnivorous. Palomares and Pauly (1999) reported that fishes with forked caudal fin have higher aspect ratio and consume more feed, which is in line with the present study. Virtual population analysis for each longitudinal class showed that catch probability for *C. luteus* increases along with the fish length elevation up to 18 cm (maximum fishing mortality) and fluctuates thereafter. Also, according to results it showed that females are more abundant and have higher fishing mortality than males.

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