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Growth parameters and mortality rate of *Neogobius caspius* (Eichwald, 1831) in southern part of the Caspian Sea (Teleostei: Gobiidae)

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Abstract: In the present work, due to the lack of information on population dynamics of the Caspian goby, *Neogobius caspius*, we aimed to investigate growth and mortality parameters of this species captured from the south part of the Caspian Sea (Mazandaran Province) during a year from April 2014 until March 2015. Growth and mortality rates were assessed using age calculation. By using least squared method, L_∞ and K of the specimens were 16.83 cm and 0.67 year^{-1} in female specimens and 17.76 cm and 0.83 year^{-1} in male specimens, respectively. Comparison of the growth curves resulted by likelihood ratio method showed a significant difference between two sexes (P<0.05). The maximum estimated age for female was 4.47 years old while 3.61 years old for male. According to Pauly's empirical equation, natural mortality rate was calculated 1.25 and 1.41 year^{-1} for female and male, respectively. Sex ratio (male: female) was 1: 1.14, indicating no significant difference (P>0.05). Based on the results presented here, the present investigation can be regarded as basis for future studies on the Caspian goby.

Keywords: Weight-length, Age-length, L_∞, Growth parameter, Age-weight.

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Introduction

Until now, 63 genera and 199 species according to Esmaeili et al. (2014) and 63 genera and 122 species according to Jouladeh-Roudbar et al. (2015) have been reported from the Caspian Sea basin that are allocated to 18 families, 16 orders and 2 classes, among which two families, Cyprinidae and Gobiidae have the most diverse fish species (See Esmaeili et al. 2014; Jouladeh-Roudbar et al. 2015). Some of the Caspian Sea fish species are exclusively habitant in this region and are not found in other parts of the world. In addition, near 40% of these fish have economically many exploitation capabilities. Hence, conservation of these species implying important characters of this unique environment is of great worth and specific strategies should be performed for their preservation.

Gobiidae, known as Gobies, plays an ecologically important role as predatory fish in an aqueous food chain. Gobies are the largest marine fish with over 1900 species and inhabit all types of water throughout the world (fresh, marine and brackish waters) (Nelson 2006; Freose & Pauly 2011). The well-represented species of Gobiidae in south part of the Caspian Sea Basin (Iranian waters) are considered as a major food item in the diet of Acipenseridae species (Holcik 1986; Kiabi et al. 1999; Naderi & Abdoli 2004; Abdoli & Naderi

2008). The prominent species of this family include duckbill pugolovka (*Anatirostrum profundorum* Berg, 1927); Caspian sand goby (*Neogobius pallasi* Berg, 1916); Caspian bighead goby (*Ponticola gorlap* Iljin, 1949); Caspian stellate tadpole-goby (*Benthophilus leobergius* Berg, 1949) and Caspian goby (*Neogobius caspius* Eichwald, 1831). The genus *Neogobius* currently consists of 4 species around the world (Froese & Pauly 2013). Although the family Gobiidae has many endemic species, few studies have been focused on these species inhabiting in the southern part of the Caspian Sea.

Identification and discrimination of population in marine fish species contribute with their population dynamics and corresponding management policies would be less validated without population identification. Hence, in studies pertaining to growth, survival, and reproduction rates, it is assumed that an independent population should be investigated (Haddon 2011). The biological and ecological study of different fish species in an aqueous ecosystem is of primary essentials to preserve their stocks. Population dynamic relates to the continually on-time replacement process of generation and its production which is actually referred to the growth and mortality. The study of growth and mortality parameters is regarded as a subunit of population ecology and the main foundation of fish stock biology (Biswas 1993). All the stock assessment methods are dealt with age composition data. The estimation of age and growth are the most important inputs in stock assessment models (Haddon 2011) which not only indicates the population differentiations but also implicates the habitat traits (Walter 2005).

Up to now, a few researchers have studied feeding regime and reproductive properties of gobies (Abbasi et al. 2009; Sarpanah Sarkohi et al. 2010). But little information has been published in local journals and no information, even their length and weight, has been recorded by comprehensive fishery database of Fishbase.

Considering the lack of investigation on growth parameters, mortality rate, population dynamics and stock assessment of the Caspian goby *Neogobius caspius*, the present work would be beneficial in determining the biological aspects of this species in coastal waters of Mazandaran Province, North of Iran (southern part of the Caspian Sea).

Material and Methods

A total of 101 specimens of the Caspian goby (male=54 and female=47) were randomly sampled from southern part of the Caspian Sea. The beach seines with mesh size 30 and 33 mm was used for sampling from April 2014 to March 2015. Biometric characteristics including length and weight were measured and sexes were determined. Total length was measured for estimating growth and mortality parameters to the nearest millimeter using a digital ruler. For determination of age composition in each specimen, about 5-6 scales were randomly isolated from the forefront of dorsal fin (above the lateral line), placed in NaOH solution (8%) for one hour and then rinsed thoroughly under tap water. Thereafter, the washed-up scales from each individual were then fixed by two glass slides and were read under a dissecting microscope (using transmitted light) by two experts to ensure that an agreement in interpreting the banding pattern was achieved. The Sturges's formula was used to determine the age class:

$$R = (Max\text{-}Min) + 1$$

$$K = 1 + 3.322 \log (n)$$

$$C = \frac{R}{K}$$

Where n: the number of samples, K: the number of bins, and C: the class interval. Two-sample Kolmogrov-Smirnov test was used to determine whether size composition of individuals significantly differed between male and female.

The length-weight relationship was estimated by total length (cm) and total weight (g) according to the following equation (Mendes et al. 2004; Froese 2006):

$$W = \alpha L^b$$

Where W is weight (g), α: the intercept, L: total length and b: the slope.

The L_∞ and K were obtained by Gulland & Holt plot (Gulland & Holt 1959) using the following equation:

$$\frac{\Delta L}{\Delta t} = a + b * \bar{L}(t)$$

$$K = -b$$

$$L_\infty = -a/b$$

Where ΔL/Δt is growth rate as dependent variable and $\bar{L}(t)$ is mean length over the corresponding year as an independent variable (Sparre & Venema 1998). Von-Bertallanffy growth equation given by Sparre & Venema (1998) is as follows:

$$L_t = L_\infty(1 - \exp(-K)(t - t_0))$$

Where L_t is the average length at age t, L_∞: asymptotic length and t_0 is the hypothetical age when the size of fish is zero. The best regression parameters were obtained by minimizing the errors in residuals for finding the optimal values of L_∞, k and t_0 (Haddon 2011) as the following:

$$SSQ = \sum (X_O - X_e)^2$$

$$SSQ = \sum (Y - (a + bX)^2$$

Where SSQ is the sum of square; X_O: the observed value and X_e: the expected value. t_0 was calculated by the Pauly's equation (Pauly 1980):

$$\log -(t_0) = -0.3922 - 0.2752 log L_\infty - 1.038 log K$$

T_{max} is the maximum age (Pauly 1983) and determined as the following:

$$T_{max} = \frac{3}{K}$$

The weight-age relationship was fitted by the following equation (Haddon 2011):

$$\widehat{w}_t = w_\infty \left[1 - e^{-k[t-t_0]}\right]^b$$

Where w_∞ is the asymptotic weight and b: the slope in length-weight relationship. The following formula was used to estimate w_∞:

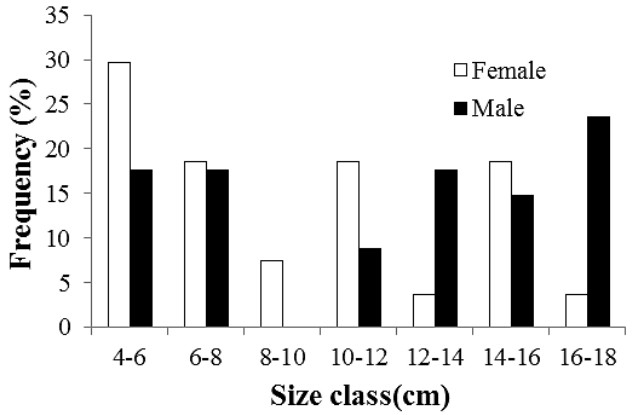

Fig.1. Total length-frequency distribution plot in males and females of *Neogobius caspius* captured from southern part of the Caspian Sea.

$$W_\infty = aL_\infty^b$$

Where W_∞ is the asymptotic weight and b: the slope in length-weight relationship. The following formula was used to estimate W_∞:

Growth performance index was measured by the following equation (Gayanilo & Pauly 1997):

$$\phi = \log K + 2 log L_\infty$$

The likelihood ratio test was used to compare growth curves between male and female by the following equation (Haddon 2011):

$$X_K^2 = -N \times Ln\left[\frac{\sum RSS_i}{RSS_P}\right] = -N \times Ln\left(\frac{RSS_\Omega}{RSS_\omega}\right)$$

Where k is the degrees of freedom, N: total number of observations from both curves combined, RSS_Ω: total sum of squared residuals derived from fitting both curves separately and $RSS\omega$: total sum of squared residuals derived from fitting curves with one of the hypothesized constraints.

Results

On the whole, mean total length for female and male were measured 9.44±0.774 and 11.57±0.778cm, respectively. The smallest and the largest total length of the captured fish were 5.1 and 28.5cm, respectively. Weights of fish specimens ranged from 1.53 to 373.07g. A remarkable difference was also observed in abundance distribution of total length between male and female specimens (Fig. 1).

Table 1. Descriptive statistics of total length and LW relationship parameters in males and females of *Neogobius caspius* captured from southern part of the Caspian Sea.

	Total Length (cm)			*LWR* parameters and statistics				
Gender	N	Min	Max	*a*	CL 95% (a)	*B*	95% CL (*b*)	r^2
Female	47	4.93	16.4	0.0136	0.0074-0.0245	3.024	2.753-3.294	0.955
Male	54	5.5	15.7	0.0191	0.0175-0.0284	2.852	2.768-2.920	0.978

n: sample size, Min: minimum, Max: maximum, *a* and *b*: constant parameters in the equation $W = aL^b$, CL 95%: confidence limits, r^2: correlation coefficient

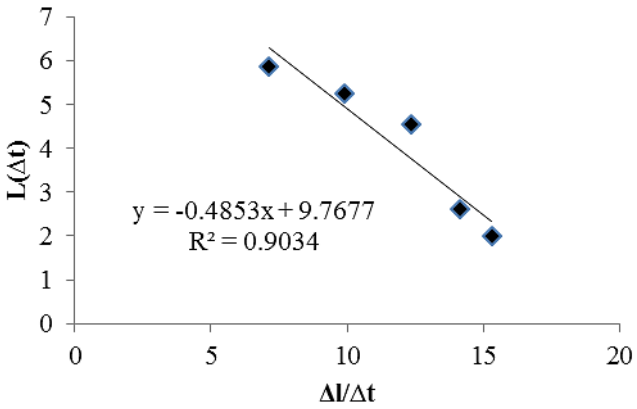

Fig.2. Gulland and Holt plot for estimation of L∞ and k in females of *Neogobius caspius* captured from southern part of the Caspian Sea.

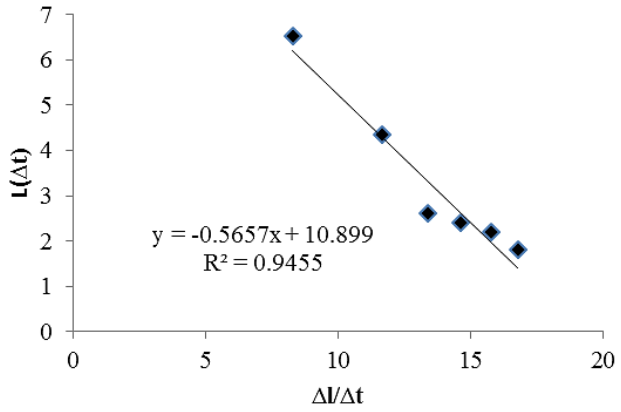

Fig.3. Gulland and Holt plot for estimation of L∞ and k in males of *Neogobius caspius* captured from southern part of the Caspian Sea.

Sample size, total length ranges and length-weight relationships parameters for males and females are presented in Table 1.

In this study, L_∞ and *K* were estimated according to the method described by Gulland & Holt (1959) (Figs. 2 and 3).

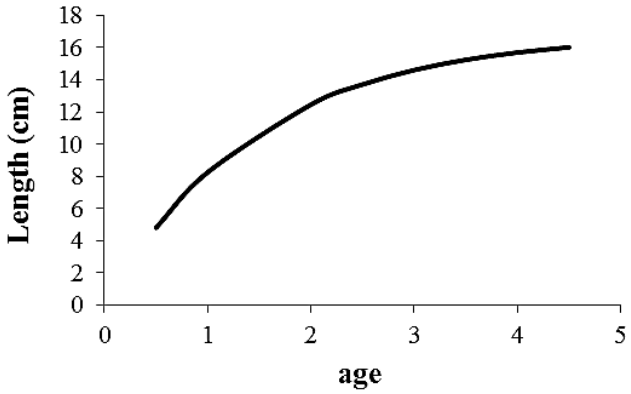

Fig.4. Length-age relationship in females of *Neogobius caspius* followed by least squares fitting.

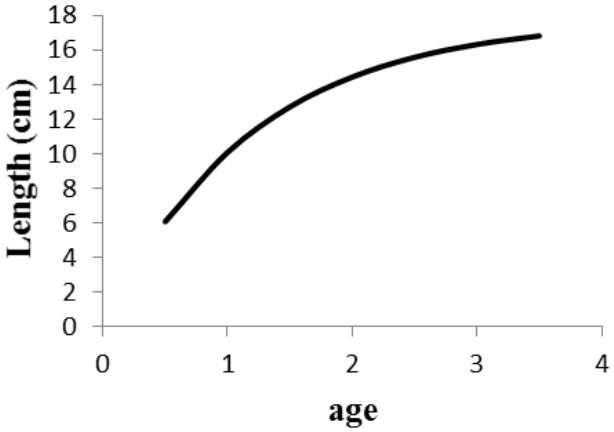

Fig.5. Length-age relationship for males of *Neogobius caspius* followed by least squares fitting.

By using the least squared method, best estimations of L_∞ and *K* were obtained for females (16.83cm and 0.67 $year^{-1}$, respectively) and males (17.76cm and 0.83 $year^{-1}$, respectively) of *Neogobius caspius* (Figs. 4 and 5).

Comparison of growth curves between male and female revealed a significant difference ($P<0.05$) (Fig. 6).

The maximum age for females and males of the

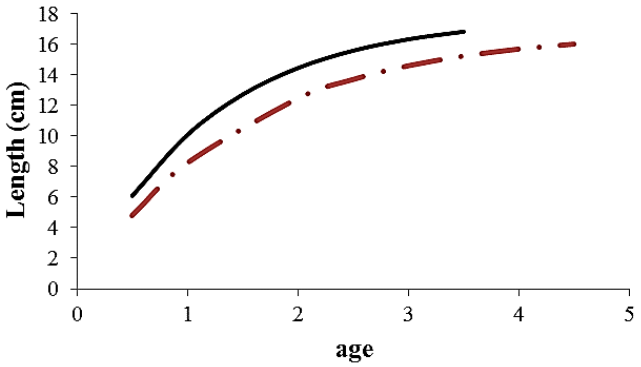

Fig.6. Comparison of growth curves between male and female of *Neogobius caspius* captured from southern part of the Caspian Sea.

fish was calculated 4.47 and 3.61 years old, respectively.

$$T_{max} = \frac{3}{0.67} = 4.74\ female$$

$$T_{max} = \frac{3}{0.83} = 3.61\ male$$

In addition, weight-age relationship was estimated in fish sampled in the present study (Fig. 7).

According to the empirical Pauly's formula, natural mortality rate of the Caspian goby in female and male were measured 1.25 year^{-1} and 1.41 year^{-1}, respectively. The value of growth performance index (ϕ) was estimated 2.28 and 2.42 for female and male, respectively. The sex ratio of male to female was 1:1.14 which showed no significant difference (P>0.05).

$$\phi = \log 0.67 + 2log16.83 = 2.28\ female$$
$$\phi = \log 0.83 + 2log17.76 = 2.42\ male$$

Discussion

As shown in the results section, parameter b in LWRs of *N. caspius* was within the acceptable range of 2.5-3.5 in all fish species (Froese 2006). In this case, a previous research by Abdoli et al. (2009) declared the similar range of *b* for other gobies (*Benthophilus leobergius* and *Ponticola gorlap*) in the southeastern Caspian Sea basin. They also found significantly different Length-weight relationships between sexes for *Ponticola gorlap*, *N. fluviatilis* (Pallas, 1814) and

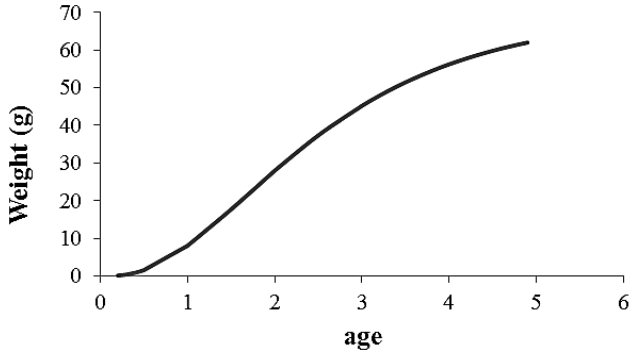

Fig.7. The weight-age relationship in the Caspian goby *Neogobius caspius*.

N. melanostomus (Pallas, 1814). Not only these parameters (a and *b*) might be species-specific due to a wide range of affecting factors including environmental variations, physiological condition of the specimen at sampling time, sexuality, feeding rate, and fertility stages, but also they might differ among individuals of a given species (Froese 2006). Furthermore, this study provides the missing LWRs of the Caspian goby that will be useful for fishery biologists and managers in the Caspian Sea. As stated by an earlier research, *b* values range from 2.5 to 3.5 and the closer to 3, the more equal fish growth at all dimensions. In length-weight relationship, b depends on fish condition and the greater value of b in females than that of males might be attributed to their different body shapes as females' bodies are thicker than male's ones (Froese 2006).

In the present trail, length frequency distribution detected a significant difference between female and male (P<0.05). Results of growth curve comparison between sexes suggested a significant difference which might be a reason for the perceived significant difference in length frequency distribution. This situation is commonly observed in fishes migrating horizontally and spawners migrating into the coastal areas as well.

No significant difference was discovered in sex ratio between males and females. The sex ratio is species-specific and variations in the ratio depend on behavior, mortality rates, easier catching as well as periodically interruption of sexually mature forms

which vary between sexes at a given region (Abou-seedo & Dadzie 2004; Mirghiyasi et al. 2016).

L_∞ and K values were estimated in females (16.83cm and 0.67 year^{-1}, respectively) and males (17.76cm and 0.83 year^{-1}, respectively) of *N. caspius*. Based on K values calculated here, this species is not classified as a fast-growing fish (Jeninges et al. 2002). Commonly, L_∞ varies according to both sampling tools and environmental factors and hence, less and more fluctuations are also observed in K values. Moreover, growth parameters vary at different regions for a given species due to other environmental aspects like as dissolved oxygen, salinity, temperature and metabolism-affecting factors (Jones 1981; King 1995). Because of environmental variations, these parameters differ even in a given region (King 1995). Available food supply typically impacts on L_∞. Alterations in environmental temperature have a controlling effect on both k and L_∞ values and this is more likely that with increased water temperature, K value increases in a logarithmic trend while L_∞ decreases. However, this reduction is less than increased K value (Sparre & Venema 1998). All these factors along with stock population density, different pollutions and some changes in ecological behavior of animals can alter their growth rate, which might implicate the reason of observed significant difference in the calculated growth parameters in the present study.

Natural mortality rate of the Caspian goby was obtained 1.25 year^{-1} in female and 1.41 year^{-1} in male. In an animal community, natural mortality occurs most frequently by predator-prey relationships and less through the aging process (approximately 90% and 10%, respectively) (Niameimandi et al. 2003).

The value of growth performance index ϕ' was estimated 2.28 and 2.42 for female and male, respectively. Latitude differences and ecological changes can affect L_∞ and K which definitely make some variations in ϕ values. Therefore, owing to changes in environmental condition, as already mentioned earlier, ϕ values differ even in a given region (Sparre & Venema 1998).

Until now, there has been no study work on population dynamics of *N. caspius* and no information on this species is found in the international website of Fishbase (Froese & Pauly 2016). The results presented here can be considered as basis for further studies on this goby. Long-term monitoring of growth, mortality and feeding indices besides population dynamic models can help the scientists get a better understanding if a given species may be at the risk of extinction or not. Due to the lack of enough specimens of *N. caspius*, this study was encountered the limitation of sample size.

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مطالعه پارامترهای رشد و نرخ مرگ‌ومیر *Neogobius caspius* (Eichwald, 1831) در بخش جنوبی دریای خزر (ماهیان استخوانی: خانواده گاوماهیان)

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چکیده: به‌علت فقدان اطلاعات در خصوص پویایی جمعیت گاوماهی خزری (*Neogobius caspius*)، هدف از انجام این مطالعه بررسی پارامترهای رشد و مرگ‌ومیر این گونه طی یکسال نمونه‌برداری در بخش جنوبی دریای خزر (استان مازندران) از فروردین ۱۳۹۳ تا اسفند ۱۳۹۴ بود. نرخ رشد و مرگ‌ومیر از طریق تعیین سن فلس انجام شد. با استفاده از روش حداقل مربعات، میزان L_∞ و K برای جنس ماده به ترتیب ۱۶/۸۳ سانتی‌متر و ۰/۶۷ در سال و برای جنس نر به ترتیب ۱۷/۷۶ سانتی‌متر و ۰/۸۳ در سال به‌دست آمد. مقایسه منحنی رشد با استفاده از روش نسبت درست نمایی نشان داد که بین دو جنس نر و ماده تفاوت معنی‌داری وجود دارد. بیشینه سن ماهی برای جنس ماده ۴/۴۷ سال و برای جنس نر ۳/۶۱ سال بدست آمد. میزان مرگ‌ومیر طبیعی این ماهی براساس فرمول تجربی پائولی برای جنس ماده به میزان ۱/۲۵ و برای جنس نر به میزان ۱/۱۴۱ در سال به‌دست آمد. نسبت جنسی نر به ماده در این مطالعه ۱:۱/۱۴ بود که تفاوت معنی‌داری مشاهده نشد. نتایج مطالعه حاضر می‌تواند به عنوان مبنا برای مطالعات آتی درباره این گاوماهی مورد توجه قرار گیرد.

کلمات‌کلیدی: وزن-طول، سن-طول، طول بی‌نهایت، پارامتر رشد، سن-وزن.