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SHORT PAPER

Life-history Aspects of Caspian Shemaya *Alburnus chalcoides* in Two South Caspian Rivers (Siahroud and Gorganroud)

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Abstract

Specimens of *A. chalcoides* caught in Siahroud (central of south Caspian Basin) and Gorganroud (east of south Caspian Basin) during spawning season from February to August 2007 were examined for life history attributes. The fish had a 5-year life cycle in the rivers and grew allometrically, being negative allometric for males of the Siahroud and positive for both males and females of Gorganroud and for females of Siahroud. The von Bertalanffy growth functions were L_t=370.08(1-$e^{-0.15(t+0.70)}$) for males and L_t=432.52(1-$e^{-0.11(t+1.21)}$) for females in the Siahroud and L_t=371.79(1-$e^{-0.14(t+0.96)}$) for males and L_t=436.10(1-$e^{-0.11(t+1.34)}$) for females in the Gorganroud. Overall sex ratio was unbalanced in favor of females in the rivers. The GSI indicated that reproduction of Caspian shemaya occurred between April-July in the Siahroud and March-June in the Gorganroud, peaking in May in both rivers. The absolute fecundity ranged between 1,674–38,340 eggs with a mean of 8,426.25 eggs in the Siahroud and between 623–17,263 eggs with a mean of 4,214.70 eggs in the Gorganroud, while relative fecundity ranged from 23.28 to 598.86 eggs/g with an average of 211.68 eggs/g of body weight in the Siahroud and from 12.11 to 696.38 eggs/g with an average of 111.60 eggs/g of body weight in the Gorganroud. Mean egg diameter in the Siahroud was 1.40±0.14mm and 1.27±0.27mm in the Gorganroud. Comparisons of the results imply that many aspects of life history of Caspian shemaya are different markedly among the rivers. The differences were thought to have emanated from differences in habitat characteristics.

Keywords: *Alburnus chalcoides,* age, growth, reproduction, Caspian Sea.

Güney Hazardaki Siahroud ve Gorganroud Nehilerinde Bulunan Tatlısu Kolyozunun *Alburnus chalcoides* Yaşam Özellikleri

Özet

Siahroud'da (Güney Hazar Havzasının Merkezi) ve Gorganroud'da (Güney Hazar Havzasının Batısı) Şubat 2007'den Ağustos 2007'e kadar olan üreme döneminde yakalanan *Alburnus chalcoides* balıkları yaşam özellikleri bakımından incelenmiştir. Siahroud nehrinin erkek balıklar için negatif allometrik ve Gorganroud nehrinin erkek ve dişileri ile Siahroud nehrinin dişileri için pozitif allometrik olmak üzere balıkların 5 yıllık bir yaşam döngüsü vardı. Von Bertalanfy büyüme fonksiyonları Siahroud'da erkekler için L_t=370,08(1-$e^{-0,15(t+0,70)}$) ve dişiler için L_t=432,52(1-$e^{-0,11(t+1,21)}$), Gorganroud'daki erkekler için L_t=371,79(1-$e^{-0,14(t+0,96)}$) ve dişiler için L_t=436,10(1-$e^{-0,11(t+1,34)}$) bulunmuştur. Genel cinsiyet oranı dişilerin lehinedir. Tatlı su kolyozunun üremesi Siahroud nehrinde Nisan-Temmuz arasında, Gorganroud nehrinde ise Mart-Haziran arasında gerçekleşmekte ve her iki nehirde de Mayıs ayında pik yapmaktadır. Mutlak fekondite, Siahroud nehrinde 1.674–38.340 arasında değişmekle birlikte ortalama 8,426.25 yumurta iken, Gorganroud nehrinde 623–17.263 arasında değişme göstermekte ve ortalama 4.214,70 yumurta olarak bulunmuştur. Relatif fekondite ise Siahroud nehrinde 23,28–598,86 yumurta/g arasında değişerek vücut ağırlığının ortalama 211,68 yumurta/g olurken Gorganroud nehrinde 12,11-696,38 yumurta/g arasında değişerek vücut ağırlığının ortalama 111,60 yumurta/g olarak hesaplanmıştır. Ortalama yumurta çapı Siahroud'da 1,40±0,14mm, Gorganroud'da 1,27±0,27 mm olarak ölçülmüştür. Elde edilen sonuçlara göre, tatlısu kolyozunun yaşam özelliklerine ait durumlar nehirler arasında önemli derece farklı bulunmuştur. Farklılıkların habitat özelliklerinden kaynaklanmış olduğu düşünülmüştür.

Anahtar Kelimeler: *Alburnus chalcoides*, yaş, büyüme, üreme, Hazar Denizi.

Introduction

The Caspian shemaya *A.chalcoides* is widely distributed in the Black, Caspian and Aral Seas. Many previously described the Caspian shemaya as the species *Chacalburnus chalcoides* (Gueldenstaedti, 1772), but it is now considered as phenotypic variant of *Alburnus chalcoides* (www.fishbase.org). Populations of this species are commonly found in the Black Sea basin and in the Marmara region of Turkey where some studies were conducted to determine on biology of river and lake populations of the fish (Akyurt and Sari, 1991; Balik *et al*., 1996; Tarkan *et al*., 2005). The Caspian shemaya differs from those of the Black and Aral Seas in morphological and life history traits (Berg, 1964; Bogutskaia, 1997). This species occurs mainly in the mostly western to southern coast of the Caspian Sea and supports local subsistence fishery. Recently, because of damming the rivers, over fishing during spawning season and deterioration of its spawning grounds in the rivers and streams, the fish is considered to be vulnerable to endangered species for the south Caspian basin (Kiabi *et al*., 1999; Naderi and Abdoli, 2004). In this basin, its spawning grounds ranges from the Atrak River (southeast) to the Aras River (southwest), being found mainly in the rivers of central parts of the basin. Within such broad spawning grounds, anadromous populations of the shemaya are subject to a variety of environmental conditions, which cause variations in life history traits of the fish.

Even though there have been some studies on different aspects of Caspian shemaya in the south Caspian basin (Karimpour *et al*., 1993; Khaval, 1997; Darabi, 1999; Mohsen-Zadeh and Bahadori, 2001; Azari-Takami and Rajabi-Nezhad, 2002; Rahmani, 2006), there is a lack of knowledge about the life history traits of this species in the many rivers flowing into south Caspian Sea (including Atrak, Gorganroud, Gharasou, Siahroud, Pol-e-roud, Tonekabon, Aras and many small streams) where the fish migration occurs in considerable variation into the rivers every year (Abdoli, 2000; Naderi and Abdoli, 2004).

It is believed that comparative studies on population characteristics are needed to develop life history models for the conservation and management of species. We hypothesized that rivers of the south Caspian basin may contribute to stream-specific variation in life history traits of fish. The aim of the present study is to determine whether population of Caspian shemaya spawning in two rivers of Siahroud (central part of south Caspian Sea) and Gorganroud (eastern part of south Caspian Sea) exhibit variation in their life history parameters.

Material and Methods

Study Area

The present study was carried out in the downstream areas of Siahroud and Gorganroud rivers. These rivers situated in the south Caspian Sea basin in Mazanderan (central south Caspian basin) and Golestan (east of south Caspian basin) provinces respectively, and characterized by their Caspian-Elburz mountains climate (Afshin, 1994). Both rivers are seasonal and their water discharges were cut off in summer. Even because of damming, their discharge was very low in late winter and spring of recent years when anadromous species get into the rivers for spawning. Some environmental properties of the sampling area in the studied rivers are shown in Table 1.

Sampling was carried out on the basis of once per month using small beach seine (30m long and 2m depth) with mesh size of 3mm knot to knot in the mouth of rivers between February and August 2007. Based on Abdoli (2000), spawning migration of Caspian shemaya into the rivers occurs in this period.

In the laboratory, total length was measured to the nearest mm for all fish sampled. Total weight, weight of ovary and its sub-samples were recorded with an electronic analytical balance to the nearest 0.01 g. The age was determined from opercula bones. Growth annuli from each operculum were counted three times, each time by a different person. This age

Table 1. Average of some environmental factors (min. – max.) of the Siahroud and Gorganroud rivers, south Caspian Sea

Characteristics	Siahroud River $\bar{X}$ (min.-max.)	Gorganroud River $\bar{X}$ (min.-max.)
Depth (cm)	85.4 (0-134)	140.5 (0-256)
Width (cm)	625 (222-1400)	951 (525-1909)
Bottom substrate	Clay	Clay
Water velocity (m/s)	0.81 (0.31-0.98)	0.44 (0.22-1.11)
Water t°C	12.08 (8.1-13.2)	13.44 (9.2-14.9)
DO (mg/L)	7.21 (6.8-8.2)	7.01 (6.2-8.3)
PH	7.14 (6.8-8.55)	8.35 (7.2-9.88)
EC	12.6 (1.11-16.05)	14.7 (1.21-21.97)
Salinity (‰)	0.84 (0.22-1.98)	1.03 (0.51-2.70)
Turbidity (NTU)	112.4 (24-124)	125.1 (55-159)
$Po_4^{=}$(mg/L)	1.03 (0.14-2.07)	1.17 (0.53-2.10)
No_3^{-}(mg/L)	2.35 (2.02-2.98)	2.88 (2.01-3.44)

determination was validated by scale reading. The lengths at age were back calculated using the equation $L_i=S_iS_c^{-1}(L_c-c)+c$, where L_i is the total length of the fish at age *i*, L_c the total length of the fish at capture, S_i the largest radius of the operculum at age *i*, S_c the largest radius of the operculum at capture and *c* intercept of the regression of body lengths on opercula radii (Johal *et al*., 2001). The relationship between the total weight and length (WLR) was determined by fitting the data to a potential relationship in the form of: $W=aL^b$ for each river and for males, females and sexes combined, where *W* is the weight in grams, *L* the total length in centimeters, *a* and *b* are the parameters to be estimated, with *b* being the coefficient of allometry (Pauly, 1984). Condition of each fish in the sample was estimated using relative condition index RC=TW/TWe, where TW is observed total weight (g) and TWe is expected total weight derived from the logged length-weight relationships of the sample (Bolger and Connolly, 1989). The adopted growth model was the specialized von Bertalanffy growth function, whose expression is: $L_t = L_\infty(1-e^{-k(t-to)})$ with L_∞ being the predicted asymptotic length, L_t the size at age *t*, *k* the instantaneous growth coefficient, and t_o the point at which the von Bertalanffy curve intersects the age axis. The parameters were estimated using the method of Ford-Walford (Everhart and Youngs, 1975) and phi-prime (ϕ') was used to study overall growth performance (Munro and Pauly, 1983): $\phi'=\ln K+2\ln L_\infty$. Gonadosomatic index (GSI)=(gonad weight/total body weight)×100 was calculated for each fish and all values were averaged for each sampling date. To estimate absolute fecundity (*AF*), ovaries were removed from females, weighed, and then placed in Gilson's fluid for 3-4 days to harden eggs and dissolve ovarian membranes. The number of eggs was estimated by the gravimetric method, using three pieces of approximately 0.01g each removed from the anterior, medial and posterior positions of both ovarian lobes of females caught in April and May. Relative fecundity index (RF) was calculated as *RF=AF/TW*, where *AF* is absolute fecundity and *TW* total weight (Bagenal and Tesch, 1978). Average egg diameter was examined by measuring 3 ova chosen randomly from each gonad pieces which was used for absolute fecundity determination. Measurements were made to the nearest 0.05 mm using an ocular micrometer microscope.

An analysis of co-variance (ANCOVA) was performed to test significance of differences in back-calculated length-at-age, exponents of the length-weight relationship, GSI and fecundity (Zar, 1984). The significance of differences of *b* from 3 was tested using the equation given by Pauly (1984). Comparison of observed mean length of same age groups, relative condition index, relative fecundity and egg size were carried out by analysis of variance (ANOVA). The overall sex ratio was assessed using the Chi square test (Zar, 1984). Statistical analyses were performed by the SPSS 11.5 software package and a significance level of 0.05 was accepted.

Results

Age and Growth

Observations showed that spawning migration of the fish into the Siahroud lasts from April to July and into the Gorganroud from March to June. There are large differences in Caspian shemaya abundance among rivers, relatively few Caspian shemaya were caught in the Gorganroud compared to the relatively high number of Caspian shemaya caught in the Siahroud.

There were large among-population differences in the length distributions (Figure 1). In the Siahroud, Caspian shemaya was the most abundant in 171-180 mm length interval, while in the Gorganroud in 140-145mm length class; mainly corresponding to 3+ and 2+ age groups respectively. The maximum length observed in the Siahroud was 242mm and in the

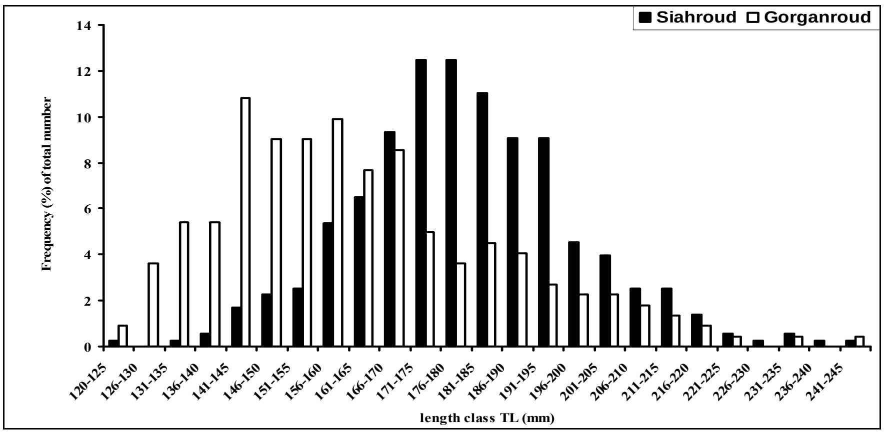

Figure 1. Length distribution of Caspian shemaya *Alburnus chalcoides* in the Gorganroud and Siaroud rivers, south Caspian Sea.

Gorganroud 243mm, both being a five-year-old female.

Mean length of age groups varied significantly among samples. Caspian shemaya from the Siahroud was significantly smaller in each respective age group (ANOVA, F=98.14, P<0.05) (Table 2). Both in the Siahroud and Gorganroud, the mean total length at age indicated rapid growth in the first year of life and considerable decline in the relative length increments during subsequent years. The back-calculated lengths-at-age of Caspian shemaya in the Gorganroud were higher than those in the Siahroud (ANCOVA, F=74.12, P<0.05).

From WLR, it was evident that growth patterns of Caspian shemaya in the rivers were distinctly different (Fig. 2 and 3), being negative allometric for males of the Siahroud and positive for other considered groups (ANCOVA, F=117.15, P<0.05). With respect to sexes, b-values of males were smaller than those of females in both rivers. To obtain an overall measure of growth parameters, relative condition index (RC) was evaluated for each considered groups (Table 3). Estimations indicated different quantitative values of the index, but comparison pointed out no significant differences between the groups (ANOVA, F_{male}=0.15, F_{female}=0.08, $F_{population}$=0.89, P<0.05).

Simplified von Bertalanffy growth function (in mm) for the fish was estimated as $L_t=370.08(1-e^{-0.15(t+0.70)})$ for males and $L_t=432.52(1-e^{-0.11(t+1.21)})$ for females in the Siahroud, and $L_t=371.79(1-e^{-0.15(t+0.96)})$ for males and $L_t=436.10(1-e^{-0.14(t+1.34)})$ for females in the Gorganroud. Growth performance index was 9.87 and 9.93 for males and 9.93 and 9.94 for females in the Siahroud and Gorganroud respectively.

Sex Ratio

Overall sex ratio for Caspian shemaya was 1 male: 1.54 females in the Siahroud and 1 male: 1.49 females in the Gorganroud, indicating statistically significant deviation from 1:1 in both rivers (Chi-square, $\chi^2_{Gorganroud\chi}$ = 7.471, $\chi^2_{Siahroud}$ = 17.090, P<0.05). Sex ratio changed markedly according to fish size and age. The proportion of males gradually decreased with increasing total length and all specimens exceeding 213mm TL in the Siahroud and 208mm TL in the Gorganroud were female.

Reproductive Effort

During migration into the rivers, GSI varied from 1.30 to 9.38 (with a mean value of 5.31±1.44 S.D.) and from 4.42 to 23.67 (with a mean value of 13.45±3.67 S.D.) for males and females respectively in the Siahroud and from 1.23 to 8.84 (with a mean value of 5.57±1.65 S.D.) for males and from 2.45 to 26.04 (with a mean value of 14.76±5.14 S.D.) for females in the Gorganroud. Based on GSI which differed among the rivers (ANCOVA, F_{female}=84.15, F_{male}=44.28, P<0.05), Caspian shemaya in the Gorganroud invested more into gonads than the fish in the Siahroud. The GSI profile indicated that Caspian shemaya reproduction is extended from April to July in the Siahroud, and from March to June in the Gorganroud peaking in May in both rivers (Figure 4).

Fecundity and Egg Diameter

The populations which differed significantly in mean absolute fecundity (ANCOVA, P<0.05), which were 8426.25±5071.69 (S.D) eggs for the Siahroud population, whereas 4214.70±2630.81 (S.D) eggs for the Gorganroud population. The absolute fecundity (*AF*) ranged from 1674 to 38340 in the Siahroud and from 623 to 17263 in the Gorganroud. Relative fecundity (*RF*) was 211.68±91.81 (S.D) eggs g^{-1} (ranging from 23.28 to 598.86) and 111.60±80.08

Table 2. Mean back-calculated lengths (mm) age (± S.E.) of Caspian shemaya *Alburnus chalcoides* in the Siahroud and Gorganroud rivers, south Caspian Sea

Siahroud population					
Age (year)	1+	2+	3+	4+	5+
Female					
Mean observed TL(mm)	---	141.55±0.24	166.89±0.13	196.77±0.13	225.51±0.11
Mean back-calculated TL(mm)	95.42±0.24	129.71±0.22	162.41±0.13	192.11±0.12	216.01±0.10
Male					
Mean observed TL(mm)	101.02±0.17	131.12±0.12	161.05±0.09	194.55±0.08	213.00±0.00
Mean back-calculated TL(mm)	82.25±0.12	125.07±0.11	155.41±0.09	185.09±0.08	213.00±0.00
Gorganroud population					
Age (year)	1+	2+	3+	4+	5+
Female					
Mean observed TL(mm)	---	149.52±0.21	174.09±0.21	199.87±0.16	226.80±0.08
Mean back-calculated TL(mm)	99.11±0.23	131.52±0.21	167.08±0.18	195.05±0.13	218.75±0.08
Male					
Mean observed TL(mm)	110.20±0.21	134.45±0.21	164.75±0.14	191.55±0.13	221.01±0.13
Mean back-calculated TL(mm)	88.02±0.16	124.52±0.11	154.09±0.13	185.01±0.10	207.50±0.09

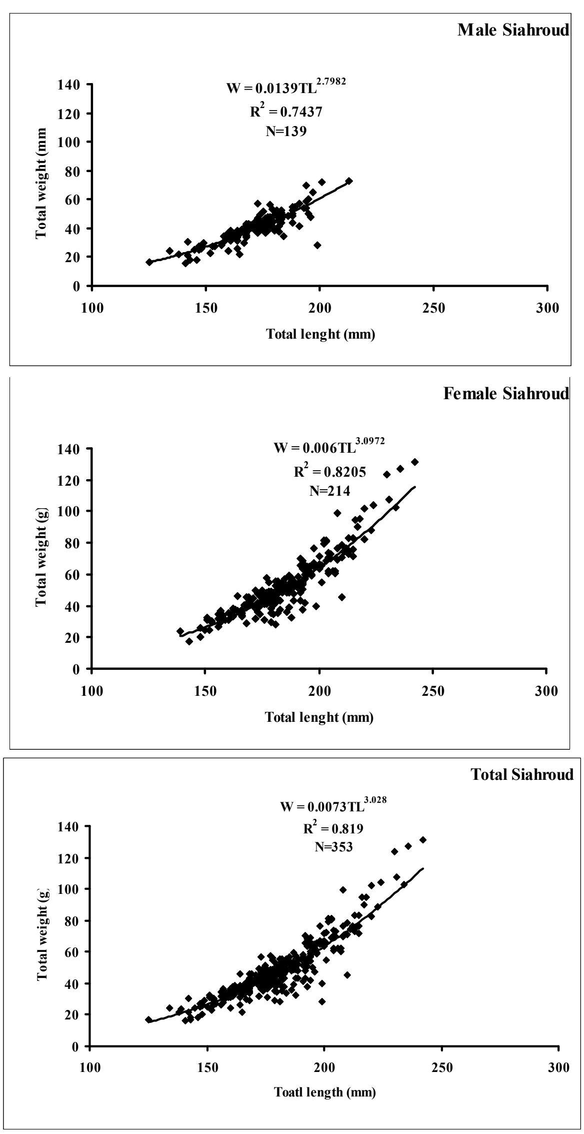

Figure 2. Weight-length relationship of Caspian shemaya *Alburnus chalcoides* in the Siahrud river, south Caspian Sea

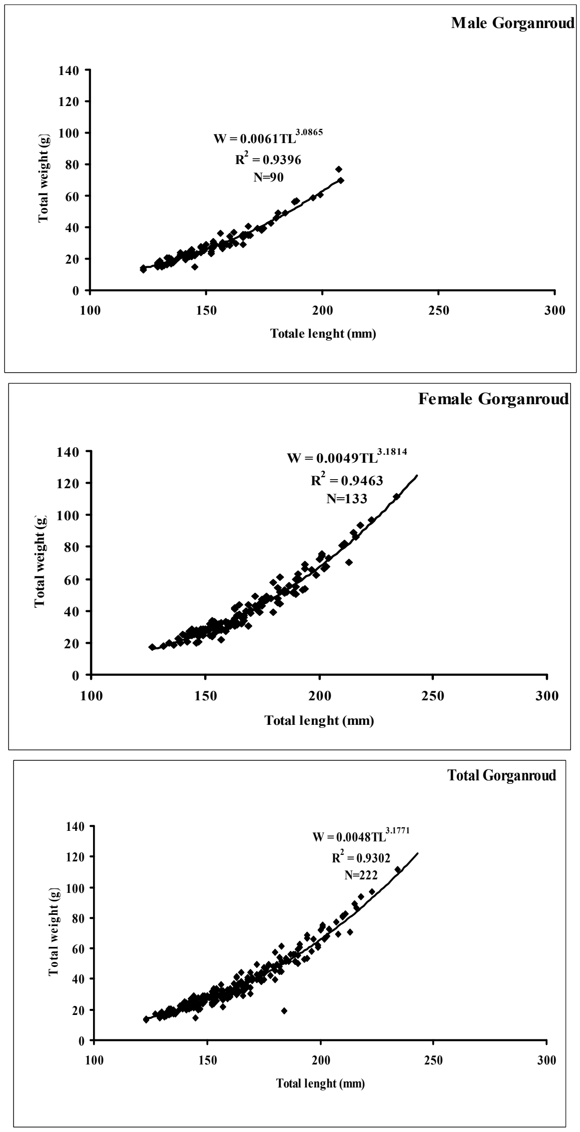

Figure 3. Weight-length relationship of Caspian shemaya *Alburnus chalcoides* in the Gorganroud river, south Caspian Sea.

Table 3. Range and mean Relative condition index (± S.E.) of Caspian shemaya *Alburnus chalcoides* in the Siahroud and Gorganroud rivers, south Caspian Sea.

Group	$\bar{X}$ ± S.E.	Min.-Max.
Female- Siahroud River	1.008±0.009	0.704 -1.266
Male- Siahroud River	1.008±0.011	0.571-1.208
Female- Gorganroud River	1.001±0.008	0.806-1.211
Male-Gorganroud River	1.014±0.010	0.738-1.148

(S.D) eggs g^{-1} (ranging from 12.11 to 696.38) for the Siahroud and Gorganroud respectively. Thus, the population of the Gorganroud significantly had lower absolute and relative fecundities than that of the Siahroud (ANOVA, F_{AF}=135.14, F_{RF}=88.07, P<0.05). *AF* increased significantly with female size (Figure 5), while the relationship of *RF* with fish size (total length and weight) was not found to be statistically significant for both populations (R^2<0.10, P>0.05).

Observations showed that egg size was relatively heterogeneous within each female. There were significant differences in the mean egg diameter among the rivers (ANOVA, P<0.05). The egg size ranged from 0.97 mm to 1.80 mm with mean value of

1.40±0.14 (S.D) mm in the Siahroud and from 0.30mm to 1.85mm with mean value of 1.27±0.27 (S.D) mm in the Gorganorud. Relationships between egg diameter and females size (length and weight) in the Gorganroud were significant (ANOVA, F_{TL}=20.06, R_{TL}=0.22, F_{TW}=8.19, R_{TW}=0.19, P<0.05), while in the Siahroud, the relationship was considerably not significant (ANOVA, F_{TL}=0.01, R_{TL}=0.07, F_{TW}=1.36, R_{TW}=0.09, P>0.05).

Discussion

Comparison of Caspian shemaya from the rivers under consideration with each other and with those from the Anzali lagoon (southwest Caspian Sea) (Karimpour *et al*., 1993), Haraz and Shiroud rivers (central parts of south Caspian Sea) (Rahmani, 2006), Omerli Reservoir (Turkey) (Tarkan *et al*., 2005) shows that the maximum size (length as well as weight) varies considerably quite a lot among the regions. Variation in maximum size (in lengths and weights) of population of a species could be explained on the basis of the different exploitation patterns and/or ecological condition. In this sense, while the Caspian shemaya is not subject to commercial exploitation, most direct hypothesis is that in the basin, habitat quality (lagoon, river and stream environment) is the main factor determining maximum size of Caspian shemaya.

In this study, the most abundant age group in the

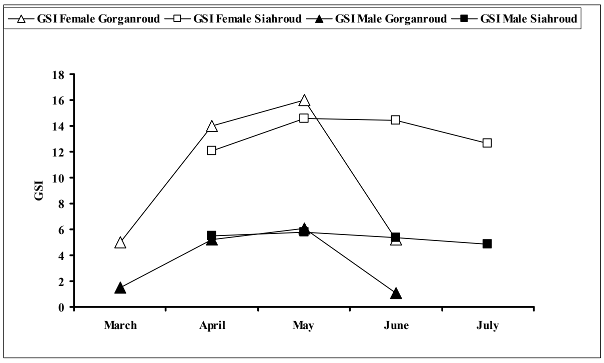

Figure 4. GSI of Caspian shemaya *Alburnus chalcoides* in the Siahroud and Gorganroud rivers, south Caspian Sea.

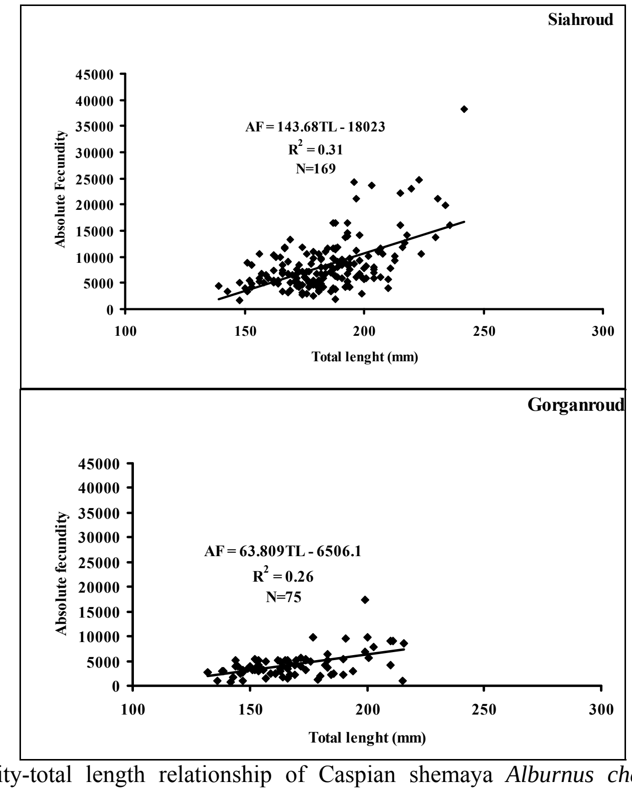

Figure 5. Absolute fecundity-total length relationship of Caspian shemaya *Alburnus chalcoides* in the Siahroud and Gorganroud rivers, south Caspian Sea.

samples was as same as observations of Rahmani (2001), who found that most individuals were 2+ in males and 3+ in females in Shiroud and Haraz rivers. Darabi (1999) reported that 2-years-old specimens are dominant in both sexes of a population in the Shiroud. The age groups found for the study areas are consistent with those in other populations of this species in the southern Caspian basin (Rahmani, 2006) and in Turkey (Akyurt and Sari, 1991; Balik *et al*., 1996; Tarkan *et al*., 2005). It seems that the fish commonly live for five years.

The growth of Caspian shemaya seems to be variable between years and among the geographical areas in the south Caspian basin (Figure 6). In terms of growth type, growth model of the fish differed among the rivers, suggesting allometry coefficient of WLR may vary between habitats. Comparing the data previously reported for Caspian shemaya from Shiroud and Haraz rivers (Rahmani, 2006) with the results obtained in this study reveals that those data involve different coefficient of allometery (b_{male}=3.118 and b_{female}=3.186 for samples in the Shiroud and b_{male}=3.126 and b_{female}=2.911 for samples in the Haraz), indicating a presence of inter-population instability of the coefficient for this species. The variation in the *b* exponent which was interpreted as variation in fish condition or fitness could be attributed to the different environmental conditions that vary between rivers and influence as local selective pressure on the fish. Therefore, variation in the *b* exponent can be attributable to species response to different habitat conditions.

The different relative condition index we found was no significant, suggesting that different growth patterns estimated for each considered groups didn't support the differences in relative condition index. Therefore, the index is not relatively sensitive to population condition-based comparisons and to quantification of habitat conditions resulting in stream-specific variation in population parameters.

In the present study, fitting the von Bertalanffy growth function to the observed lengths resulted in the estimation of higher values of maximum theoretical length than the maximum observed total lengths. The L_∞ value of female was calculated to be higher than that of males in the rivers. The reason for this may be that females grow faster than males and live longer (Weatherly, 1972). The higher coefficient (k) for males emphasizes that they grow rapidly initially and approach their asymptotic length (L_∞) earlier in life. According to Rahmani (2006), the function (in mm) was estimated as L_t=405.9 $(1-e^{-0.1(t+1.542)})$ and L_t=359.5$(1-e^{-0.146(t+1.002)})$ for males and L_t=442.5 $(1-e^{-0.10(t+1.432)})$ and L_t=446.7$(1-e^{-0.1(t+1.599)})$ for females of Haraz and Shiroud respectively, while Darabi (1999) earlier reported the function (in mm) as L_t=386.3$(1-e^{-0.208(t+0.969)})$ for males in the Shiroud and Tarkan *et al*. (2005) as L_t=315.6 $(1-e^{-0.325(t+0.254)})$ and L_t=397.4$(1-e^{-0.227(t+0.294)})$ for males and females in Omerly reservoir (Turkey) respectively. Intra- and inter-population differences in the parameters of von Bertalanffy growth equation can be attributed to differences in the mean size of the age groups of Caspian shemaya from different areas. Calculated from the data of K and L_∞ (Balik *et al*., 1996; Rahmani, 2006; Tarkan *et al*., 2005), the growth performance index values are almost close to those of the Siahroud and Gorganroud populations. This evidence confirms the reliability of the Caspian shemaya growth curves, as the overall growth performance has minimum variance within the species because it is independent from growth rates.

In both rivers, in the present study, the overall sex ratio was unbalanced in favor of females, probably either the consequence of higher survival rate and greater longevity of females or the greater endurance of females to environmental variability. The observed sex ratio was contrary to the one found by Rahmani (2006) and Balik and Sari (1994) who reported predominance of males in the Haraz and Shiroud (Southern Caspian basin) and in one dam lake of Turkey respectively, while Karimpour et al.

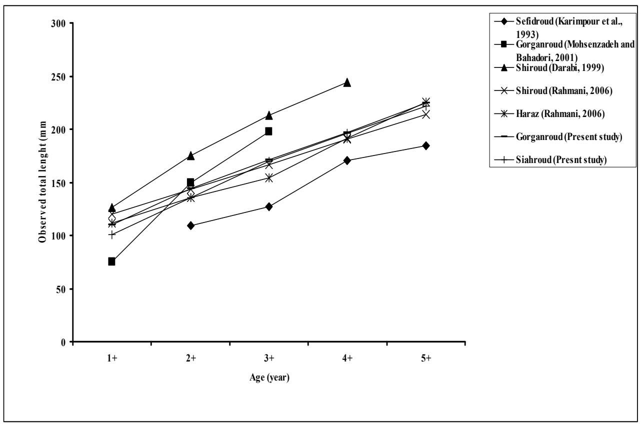

Figure 6. Observed total length (in mm) at age (in years) of Caspian shemaya *Alburnus chalcoides* in the various areas from published sources.

(1993) proposed female dominance in overall sex ratio in the Anzali lagoon and Azari-Takami and Rajabi-Nezhad (2002) in Sefidroud river (southwest of Caspian Sea). Predominance of females also has been reported in Turkey (Balik *et al*., 1996; Tarkan *et al*., 2005). It seems that sex ratio of Caspian shemaya is highly significant throughout its range of distribution in the south Caspian basin. It seems that different sex ratio is a characteristic feature of this species in different rivers.

Based on the GSI, reproductive season of Caspian shemaya in both studied rivers is about 4 months although it starts earlier in Gorganroud. Rahmani (2006) reported that reproduction occurs between April-May in Haraz and April-June in Shiroud. Tarkan *et al.* (2005) reported different situation for the fish in Omerli reservoir (Turkey) where spawning period is in May-June. It is evident that time and duration of reproductive season is different among the rivers. Nikolsky (1963) pointed out that the spawning characteristics of a fish vary in respect to their species and ecological characteristics of water system in which they live, and duration of spawning is an important parameter in the reproductive strategy for fishes. The extended reproductive season in the studied rivers may be interpreted as an increase of reproductive effort of Caspian shemaya to promote increase in the number and distribution of the population.

Fecundity-body weight relationship can probably be used to discriminate between the different stocks of the same species of fishes due to variable growth rates in different localities. In this study, fecundity of Caspian shemaya was positively correlated to fish size (length or weight). Range and mean absolute fecundity estimated in the Siahroud and Gorganroud rivers were different than the values obtained previously by Karimpour *et. al.* (1993) in Anzali lagoon, Azeri-Takami and Rajabi-Nezhad (2003) in the Sefidroud river and Rahmani (2006) in the Haraz and Shiroud rivers (Table 4). Geographical variation in the fecundity is affected by many factors such as the size and age of females (Thorpe *et al*., 1984), life history strategy (Morita and Takashima, 1998), and food supply and temperature (Fleming and Gross, 1990). Differences in absolute fecundity can be attributable to the combination of one or more above factors.

In this study, the estimated mean relative fecundity was also different than that of 100.1±27.5 in the Haraz and that of 93.7±23.2 in the Shiroud (Rahmani, 2006). Here, no effect of female size on RF was observed, which is in agreement with findings of Rahmani (2006) for Caspian shemaya from the Shiroud and Haraz. It can be hypothesized, however, that the largest spawners were not able to increase the quantity of eggs per unit somatic weight proportionally to the absolute number of eggs and thus, the egg quantity relative to fish size is not significant. This means that total energetic investment in reproduction tends to be higher in the larger member of the fish, but proportional energetic investment in reproduction (as energy allocation per unit of fish size) tends to be changed with increasing in fish size.

In this work, there was a considerable variation in egg size within females in both rivers. The same heterogeneity in egg size was observed in the Shiroud and Haraz (Rahmani, 2006). Intra-female variation in offspring size may be optimal for the mothers' fitness in this species by decreasing competitive intensity between juveniles. Average egg size of the population in this study was higher than that reported by Rahmani (2006) in the Haraz (ranged from 0.695mm to 1.282mm with a mean value of 1.001mm±0.135 (S.D.) mm and the Shiroud (ranged from 0.032mm to 1.052 mm with a mean value of 1.111±0.032 (S.D.) mm. Azari-Takami and Rajabi-Nezhad (2002) also reported higher value of 1.59mm in the Sefidroud population. Inter-female variation in egg size agrees with the hypothesis that there should be an optimal egg size for a given environment (Smith and Fetwell, 1974; Streans, 1992)

In conclusion, the characteristics of Caspian shemaya are markedly different among the rivers of south Caspian basin. These patterns are important with respect to conservation management of the species. The inter-population variations relating to growth and reproduction may be interpreted as species response to different habitat conditions and species adaptation to local selective pressure.

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Table 4. Absolute fecundity as mean (min.-max) of Caspian shemaya *Alburnus chalcoides* by different authors in the south Caspian Sea- Iran

Author	Area	mean (min.-max.)
Karimpour *et al.* (1993)	Anzali lagoon	6630 (2951-11855)
Azari-Takami and Rajabi-Nezhad (2003)	Sefidroud river	9960 (2929-18860)
Rahmani (2006)	Shiroud river	3906 (1370-10387)
Rahmani (2006)	Haraz river	3568 (1647-6932)
Present study	Siahroud river	8426 (1674-38340)
Present study	Gorganroud river	4215 (623-17263)

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