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Age, growth and mortality of the Persian Sturgeon, *Acipenser persicus*, in the Iranian waters of the Caspian Sea

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ABSTRACT

The age and growth of the Persian Sturgeon, *Acipenser persicus*, obtained from the Iranian coastal waters of the Caspian Sea, were studied through analysis of the pectoral fin ray section from 180 specimens, ranging in fork length (FL) from 66 to 203 cm. The specimens were obtained from commercial fisheries between October 2008 and June 2010. Interpretation of growth bands in the pectoral fin ray sections was carried out objectively using the direct reading of thin sections and image analysis. The maximum age recorded in this study for the spacimens of Persian Sturgeon was 39 years. The von Bertalanffy growth parameters estimated for females were greater than for males. The estimates of asymptotic length (L_∞) and growth coefficient (K) of females were 173.07 cm and 0.1 year $^{-1}$, respectively and for males 164.33 cm L_∞ and 0.08 year $^{-1}$ K respectively,. Total mortality coefficient (Z) for females and males was estimated to be 0.45 and 0.76 year $^{-1}$, respectively. This study revealed differences in life history parameters of the Persian Sturgeon compared with those of previous studies, which may be associated with the current increased fishing pressure and degradation of environmental conditions.

Keywords: *Life history, Age, Growth, Longevity, Mortality, Persian Sturgeon, Caspian Sea.*

INTRODUCTION

The Persian Sturgeon, *Acipenser persicus*, is the most common of sturgeon species in the Caspian Sea and the Volga, Kura, and Ural rivers, and to a smaller degree in the Terek, Suli and Tamur Rivers. A small group of individuals live in the Iranian rivers, Sefid-Rud and Gorgan-chaii (Billard & Lecointre 2001). This species is the most common and important sturgeon in landings from the Iranian coastal waters of the Caspian Sea, comprising more than 60% of total catch of sturgeon (Moghim 2003). However, report of sturgeon stocks in trawl surveys show that landings have sharply decreased from 144.4 million individuals in 1976 to fewer than 38.79 million in 2005, as was confirmed by the Russsian Kaspernikh Institute (Pourkazemi 2006). The Persian Sturgeon is a highly valuable species, a long-lived fish that grows and matures slowly with a low rate of natural mortality (Billard & Lecointre 2001). These characteristics coupled with high and unregulated commercial fishing, habitat loss and environmental degradation (such as accumulation of pollutants in sediments, the damming of rivers, and the restriction water flows), have negatively influenced the migration and reproduction of these fish (Birstein *et al*. 1997; Billard & Lecointre 2001). Their stocks have been reduced as have some other marine and freshwater fish species worldwide (Myers & Worm 2003; Pauly *et al* 2003; Safina *et al*. 2005). Quantifying the nature and magnitude of the differences in life history parameters of the Persian Sturgeon, as an example of a species that is under fishing pressure, warrants further investigation into the age structure and mortality rates. The late age at maturity and 3 years spawning interval in the Persian Sturgeon probably inhibits population recovery (Pikitch *et al* 2005). The population of the Persian Sturgeon is expected to be sensitive to biases in estimation of life history traits (Brennan & Cailliet 1989).

Age estimation of the sturgeon is commonly made from cross sections of pectoral fin rays (Koch *et al* 2008). These bony structures provide the greatest precision for the measurer and unlike other structures such as opercles, clavicles, cleithra, and medial nuchals, they can be collected without killing the fish (Brennan & Cailliet 1989). Pectoral fin sections of the Persian Sturgeon fulfill the requirements for the measurement of aging in terms of ease of collection, processing, legibility and precision of interpretation (Brennan & Cailliet 1989; Stevenson & Secor 2000).

The objectives of this study were to explore the somatic growth, age structure and mortality of the Persian Sturgeon in 2008-2010 in order to determine whether changes in their life history parameters have occurred owing to recent fishing mortality.

Materials and methods

Study sites and sampling

A total of 151 of the Persian Sturgeon, *Acipenser persicus*, were obtained from the Iranian coastal waters of the Caspian Sea between October 2008 and June 2010 (Fig. 1). Forty eight samples were obtained from commercial catches (for restocking program) of the Iranian fisheries, using anchored gill nets. Additionally, one hundred specimens were obtained from beach sein fisheries in order to provide a broader range of fish. The gill nets used to collect samples measured 18 m (120 meshes) in length by 2.7 m (18 meshes) in depth, with a mesh size (knot to knot) of 150 mm.

Gutted weight (W) to the nearest kilogram, total length (TL) and fork length (FL) to the nearest centimeter were recorded after sacrificing all samples. Fish were sexed by macroscopic examination of the gonad. The gender of three fish could not be determined and therefore they were classified as immature. The right pectoral fin rays were removed by hack saw for the purpose of age analysis.

Processing of pectoral fin ray

The fin rays were placed in warm water for 10 min (Jearld 1992) to separate soft tissues. They were then defleshed with a stiff brush and placed on filter paper to dry. Transverse sections were obtained using a fret saw and polished with 250 and 400 grit sandpaper successively until a thickness of 0.3-0.6 mm was achieved. Samples were cemented to a glass slide to keep them immobilized. Glycerol was used to enhance the differentiation between the rings and to aid in the examination of growth increment formation under transmitted light using a microscope system and a camera (Motic China Group Company) that displayed the image on a video monitor. The final magnification used varied from 10 - 40 x.

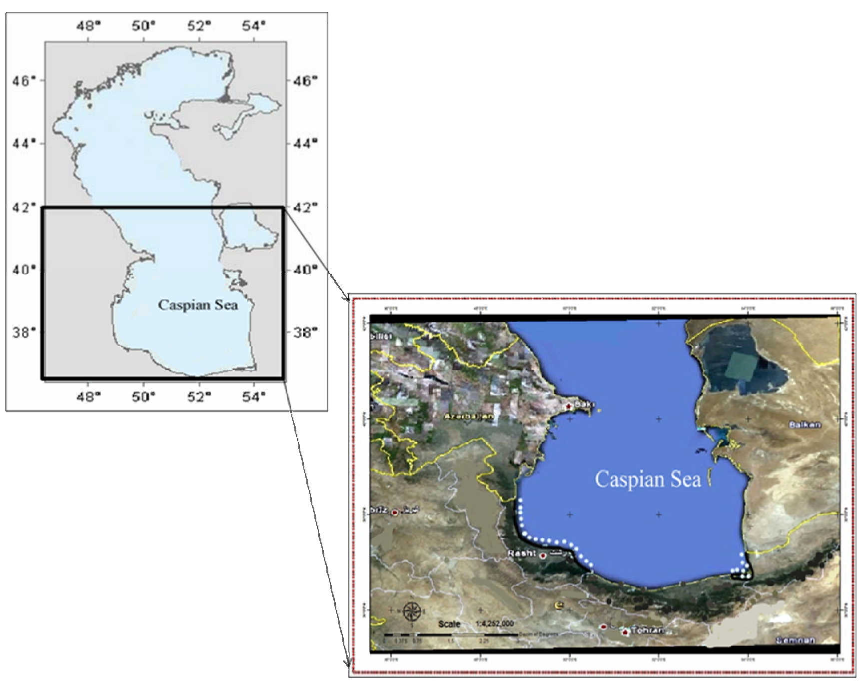

Fig 1. Location of sampling areas (white closed circles) of Persian Sturgeon in the Iranian coastal water of the Caspian Sea

Bias and precision analyses

All sections were read twice by the first reader (the first author) and 11% of the samples were randomly chosen for a second reading (by the fourth author) to determine the percentage agreement (PA). All sections were read blindly without reference to fish size. Age estimates were accepted if counts were identical between readings. If counts differed by 1 year, fish were allocated the higher age on the basis of conservative assumption that a reader was more likely to underestimate age by overlooking a partly obscured section than to overestimate age by counting an anomaly like false bands (Brennan & Cailliet 1989). If counts differed by 2 years or more, sections were read again until agreement was within one year.

To assess the precision of ring counts of the fin ray sections provided using images, the ages of the total 148 samples were estimated by the first reader, from one section provided using both the direct reading and estimates from the images. The average percent error (APE) between the ring counts using the two techniques was calculated using the following formula (Beamish & Fournier 1981):

$$APE = \frac{100}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{|Xij - Xj|}{Xj}\right]$$

where N is the number of fish aged in the sub sample, R is the number of times the age of each fish were estimated, Xij is the ith determination for the jth fish, and Xj is the average estimated age of the jth fish. A paired sample T-test was used to determine if there was a difference between the ages estimated using the two techniques.

In addition, the precision of age estimates was also assessed between two readers by the coefficient of variation (CV) as indices of precision (Chang 1982). CV is described as the ratio of the standard deviation of age estimates to the mean:

$$CV_j = 100 \times \frac{\sqrt{\sum_{i=1}^{R}\frac{(x_{ij} - x_j)^2}{R-1}}}{x_j}$$

where Xij is the ith determination for the jth fish, Xj is the mean age of the jth fish, and R is the number of times fish was estimated. CV was averaged across the samples for each reader to make a mean CV.

Growth estimates and curves

The length and weight of the Persian Sturgeon estimated in this study were compared with the mean length and weight obtained from a previous study (Taghavi 1996) in the south Caspian Sea, using the Student's one sample t-test (Zar 1996). Linear, logarithmic, power, Von Bertalanffy, and exponential equations were tested to acquire the best fit of size-at-age data. Finally, growth was characterized using von Bertalanffy growth function, fitting to size-at-age data using standard nonlinear optimization methods. The von Bertalanffy growth function is explained as:

$$L_t = L_\infty (1- e^{-K(t-t_0)})$$

where L_t is length at age t, L_∞ is the asymptotic length, K is the growth coefficient and t_0 is the hypothetical age at which length is equal to 0. The comparison of von Bertalanffy growth curves of the gender was done using an analysis of the residual sum of squares (ARSS) (Chen *et al*. 1992).

Parameters of the length-weight relationship were achieved by fitting the power function to length and weight data (Ricker 1975):

$$W = a\, FL^b$$

where W is the gutted weight, a and b is a regression constant and FL is the fork length. Condition factor (KF) was calculated by $KF=W/a\ FL^b$ and the comparison of KF between the genders was performed by applying the ANOVA test (Saberowski & Buchholz 1990).

Mortality

To estimate annual instantaneous rate of total mortality coefficient (Z) we used the formula (Gulland, 1983):

$$Z = \frac{K(L_\infty - \bar{L})}{(\bar{L} - L')}$$

where Z is the instantaneous total mortality coefficient, K is the shape parameter from the von Bertalanffy growth equation, L_∞ is length at infinity from the von Bertalanffy growth equation, is the mean fork length at capture, and L' is length for which all fish of that length and longer are under full exploitation.

All statistical analyses were performed with SPSS (Version 13) software package. Sigma plot (Version 2000) and Excel (Version 2007) were used for plotting the data.

RESULTS

The Persian Sturgeon females had higher fork length and body weight (Table 1) compared to the males. The relationship between length and weight (Table 2) was best expressed using a geometric mean functional regression (Fig. 2) as described by Ricker (1973).

Table 1. Descriptive length and weight compositions of Persian Sturgeon genders in the Iranian waters of the Caspian Sea in 2008-2010.

Size	Sex	N	Mean	S.D. of mean	Minimum	Maximum
FL (cm)	Female	76	156.39	22.65	66	203
	Male	75	132.37	21.65	62	173
W(kg)	Female	76	21.01	7.06	1	47
	Male	75	12.93	5.11	1	25

Table 2. Weight-length relationship of Persian Sturgeon in 2008-2010, (W = weight (kg), L = fork length (cm)).

Sex	N	Length-weight relationship	Correlation coefficient (r)
Female	76	LogW =3.28 logL -5.91	0.93
Male	75	LogW =3.18 logL -5.68	0.91

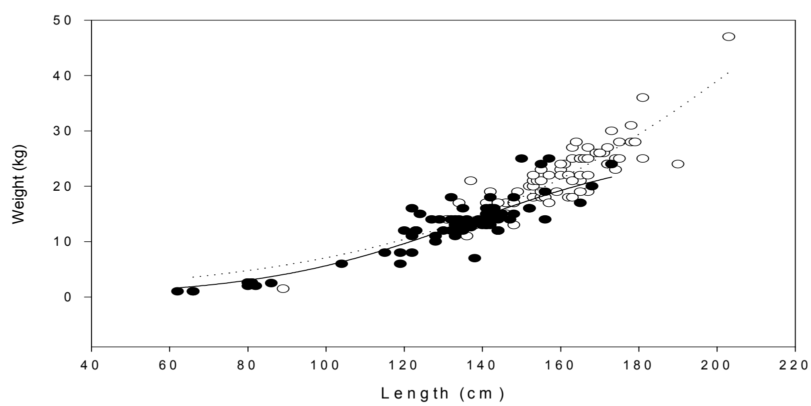

Fig 2. Length-weight relationship for female (open circles and dotted line) and male (closed circles and solid line) Persian Sturgeons in the Iranian coastal waters of the Caspian Sea (n=148).

Bands were present in all fin sections examined. Growth bands were more widely spaced near the origin and in older fish were usually more tightly grouped toward the outer edge. Tight groupings of growth rings were a common problem in age determination, and they occurred even in the youngest sample. Moreover, presence of numerous vascular channels and incorporation of secondary fin rays into the posterior lobe of the first ray could potentially lead to errors in age determination. Two independent readers agreed on the same age 43% of the time, and 36% differed within ± 1 band counts (Fig. 3). Because of high agreement and precision between the two readers on the subsample (PA = 79%; CV= 4.77), only one reader continued with the age estimates for all the samples. There was no significant difference between counts taken by two techniques (the direct reading and reading from the images) (t=0.38, df 147, P=0.70). The average percent error (APE) was very low (0.95%), suggesting no difference between the profiles of pectoral fin rays and their images. An APE of less than 5% is indicative of consistent interpretation of age (Morison *et al.* 1998).

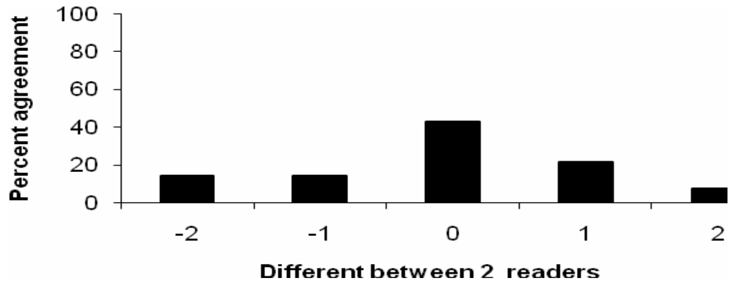

Fig 3. Percent agreement of band pair counts between two readers for the Persian Sturgeon (n=14).

The estimated ages for females caught in 2008-2010 ranged from 4 to 39 years with a median age of 23 and that for males the ages ranged from 4 to 32 years with a median age of 20 (Fig. 4). Approximately, 70% of females and 86% of males were between 15-27 years old. The frequency of the Persian Sturgeon younger than 20 years is low (Fig. 4), suggesting that these age classes were under sampled. The maximum age recorded for the Persian Sturgeon was 39 years, almost the same as for the previous record presented by Taghavi (1996). Growth trajectories were significantly different between the sexes for the Persian Sturgeon ($F=19.40$, df 142, $P < 0.05$). The growth curves for both sexes therefore were plotted separately (Fig. 5). The predicted length at age for females was greater than for males (Table 3).

Total annual mortality coefficient (Z) for females and males were calculated as 0.45 and 0.76 year $^{-1}$, respectively.

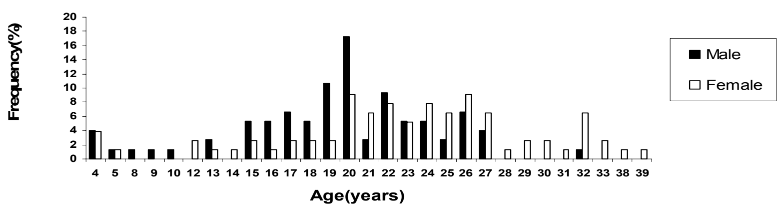

Fig 4. Age composition for female and male Persian Sturgeon between 2008 and 2010 in the Iranian coastal waters of the Caspian Sea (n=148).

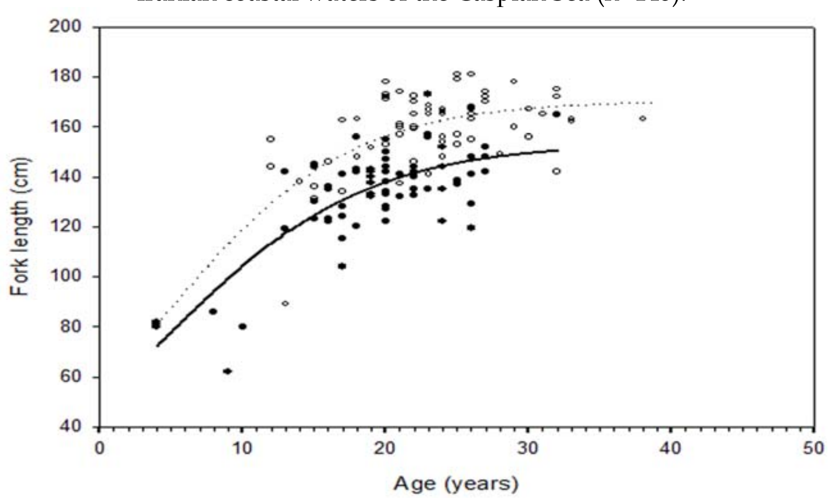

Fig 5. The von Bertalanffy growth function fit to size at age relationships for female (open circles and dotted line) and males (closed circles and solid line) Persian Sturgeon in the Iranian coastal water of the Caspian Sea. (n=148).

Table 3. The von Bertalanffy growth function fit to size at age relationships for the Persian Sturgeon between 2008 and 2010.

Sex	growth parameters			n	Correlation coefficient (r)
	L_∞ (cm)	K (y^{-1})	t_o (y)		
Female	173.07	0.11	-0.94	76	0.68
Male	164.33	0.08	-3.26	75	0. 65

DISCUSSION

Life history characteristics can be used to classify the vulnerability of a species to fishing pressure and to judge the level of productivity within a population (Musick 1999; Roberts & Hawkins 1999). The slow growth and high longevity of the Persian Sturgeon in combination with their big size and late achievement of sexual maturity cause variation in their life-history characteristics. The age estimate precision from pectoral fin ray sections for Persian Sturgeon is acceptable compared to the relatively imprecise estimate reported for other long-lived species such as the Atlantic sturgeon (*Acipenser oxyrinchus*) (Stevenson & Secor 2000) and white sturgeon (*Acipenser transmontanus*) (Rien & Beamesderfer 1994). Nevertheless, difficulties in reading the fin ray sections were caused by damaged sections, abnormal and compressed bands on the anterior fin ray margin of older fish.

It is assumed that the size and associated age structures were representative of the study populations because samples were obtained throughout the year. Part of the estimating Persian Sturgeon population in the south Caspian Sea originated from the hatchery, but due to their long living time in the Sea they now represent a wild population. The maximum recorded age for the Persian Sturgeon in the Kura (Babushkin & Borzenko 1951) and Volga (Putilina 1981) were 48 and 38, respectively. The results of this study indicate that the south Caspian Sea population is comprised of younger individuals. Markarova and Alekperov (1988) found 8 to 33 years old sturgeons, while some of the older age groups (18-23) are located along the western shore of the south Caspian from 1982-1985. Age of the Persian Sturgeon captured in the main southern Caspian fishing sites was between 7 and 48 years in which males and females were 13 to 24 (70%) and 19 to 30 (66%) years old, respectively (Babushkin & Borzenko 1951).

The mean fork length of females was the same as that of the females in 1990-1994. However, males showed decreased size in 2008-2010 and also the mean fork length of both females and males was lower than that reported by Markarova and Alekperov (1988) which were 170.8 cm for females and 153.6 cm for males. Moreover, the average weight of Persian Sturgeon of both sexes showed a decrease compared to the fish studied in 1990-1994 (Taghavi 1996). The weight-length relationship of the Persian Sturgeon appears to be dependent on age, sex, and feeding conditions in the habitat (Babushkin & Borzenko 1951; Putilina 1981). Although the type of sampling gear may introduce a bias in the size structure of the fish, in this current study the use of both gill nets and beach seine nets allows for representation of all exiting sizes of the Persian Sturgeon.

The length and weight-at-age relationships were asymptotic in form, with the majority of growth being achieved early in life, beyond which there was a comparatively small increase in size with age, similar to the growth scenario for white sturgeon, *Acipenser transmontanus* (Brennan & Cailliet 1989). The reduction in growth rate coincided with the age at sexual maturity, suggesting a physiological shift from somatic growth to reproductive development. The von Bertalanffy growth parameters estimated in this study (2008-2010) were different from those in the study done in 1990-1994 (Taghavi 1996). Bias in individuals L_∞ and K estimates can be overcome by considering parameter estimates jointly (Sainsbury 1980). In both time periods, the predicted length at age in different size classes and asymptotic length (Fig. 6) for females was greater than for males. Estimates of asymptotic length for females in 2008-2010 was much lower than for females in 1990-1994, together with a moderate growth coefficient that shows their size decreased at similar ages and they grow to a smaller size than before. This may be a result of increased fishing pressure on the large (female) component of population as males in 2008-2010 approached a smaller asymptotic size at a same rate of males of 1990-1994.

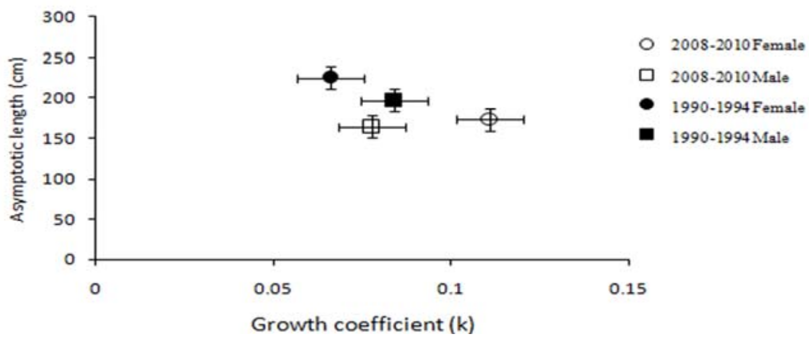

Fig 6. Confidence regions (95%) of mean for growth parameter estimates (K and L_∞) for males and females of Persian Sturgeon in1990-1994 and 2008-2010 in the Iranian coastal waters of the Caspian Sea.

However the effect of fishing on the Persian Sturgeon population can be determined where estimates of the age at first sexual maturity exist, and there may be a minimum threshold age below which sexual maturation does not occur. Therefore, overfishing which specially increased after breakdown of the ex-Soviet Union (Pourkazemi 2006) could be one factor influencing severe depletion of Persian Sturgeon stocks. In addition, several environmental conditions such as pollution (from factories and oil rigs) can be influential on demographic variables since pollutants affect both the gills and liver of the Persian Sturgeon is revealed (Halajian *et al*. 2006).

The mortality coefficient of Persian Sturgeon female (Z= 0.24 y^{-1}) and male (Z= 0.56 y^{-1}) in 1990-1994 (Taghavi 1996) was considerably lower than for the period 2008 - 2010 for both females and males, which indicates that intensive commercial fishing may be a causative factor in the sharp decline of the Persian Sturgeon stock. The current fishing pressure on the Persian Sturgeon, as one of the most precious species in the Caspian Sea, is high and makes this species vulnerable. To improve the status of Persian Sturgeon stocks, it is essential to introduce new fishing regulation for reducing fishing mortality.

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بررسی پارامترهای سن، رشد و مرگ و میر قره برون (*Acipenser persicus*) درسواحل ایرانی دریای خزر

ش. بخشعلی زاده، ع. بانی، ش. عبدالملکی، رض. نهرور، ر. راستین

چکیده

پارامترهای سن و رشد قره برون با بررسی مقاطع شعاع سخت باله سینه ای ۱۸۰ نمونه با رنج طولی (طول چنگالی) ۶۶-۲۰۳ cm درسواحل ایرانی دریای خزر مورد ارزیابی قرار گرفت. نمونه برداری از ابتدای مهر ۱۳۸۷ آغاز گردید و درانتهای خرداد ۱۳۸۹ پایان پذیرفت. تعیین سن مقاطع با دوروش مشاهده مستقیم زیر لوپ و مشاهده غیر مستقیم از روی تصاویر دیجیتالی انجام و مقایسه شد. حد اکثر سن خوانده شده در این بررسی ۳۹ سال بود. پارامترهای رشد von Bertalanffy بر آورد شده در جنس ماده مقادیر بالاتری را نسبت به جنس نر به خود تخصیص دادند و طول مماس ازلی برای ماده ها ۱۷۳/۰۷ cm با نرخ رشد ۰/۱ y^{-1} و برای نرها ۱۶۴/۳۳ cm و ۰/۰۸ y^{-1} برآورد شدند. ضریب مرگ ومیر کل برآورد شده برای دو جنس ماده و نر نیز به ترتیب ۰/۴۵ و ۰/۷۶ محاسبه گردید. این بررسی نشان داد که مقادیر متفاوت برآورد شده این تحقیق در جنبه های مختلف تاریخچه زندگی تاس ماهی ایرانی نسبت به مطالعات پیشین ناشی از فشار بالای صید و شرایط نامطلوب محیطی می باشد.