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Age determination and growth rate of *Capoeta trutta* in Azad Dam Lake, Kurdistan Province, Iran

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ABSTRACT
A total of 148 specimens of *Capoeta trutta* caught from Azad Dam Lake, Kurdistan Province, northwest of Iran were examined during 2015-2016 for assessing growth parameters. The total length (TL) and weight (W) of *C. trutta* ranged from 4.0 to 29.0 cm and 0.9 to 274.0 g, average (± SD) = 19.3 (± 4.0) cm and 80.3 (± 44.7) g, respectively. The length-weight regression was $W = 0.0121 \times TL^{2.9317}$ indicating isometric growth. The sex ratio (M:F) was 1:0.33, differed significantly from the expected 1:1 ($P < 0.001$). The von Bertalanffy growth parameters were estimated as L_∞ = 29.6 mm, K = 0.33 yr^{-1}, t_0 = -0.57 yr. The instantaneous coefficient of natural mortality was estimated as 0.58 yr^{-1}. The averaged condition factor (KF) was 1.00 ± 0.11, by significantly differences among seasons (P < 0.001). In the present study, the relative condition factor (K_n) of *C. trutta* were close to 1 suggesting the well-being condition of the fish in Azad Dam region.

Key words: Growth parameters, Condition factor, *Capoeta trutta*, Azad Dam, Iran.

INTRODUCTION

The freshwater longspine scraper, *Capoeta trutta* (Heckel 1843), a cyprinid fish species native to the Middle East, has a wide distribution in Tigris-Euphrates basins (Kalkan 2008; Esmaeili *et al*. 2010; Coad 2017). The fish can be found in southwest and northwest of Iran including Dez River, Dezful, Gheshlagh Dam Lakes, Sanandaj, Khuzestan, Ilam, Hamedan, Lorestan and Kermanshah provinces river basins (Abdoli 2000; Coad 2017). *C. trutta* is also an economically important species with a good market value in Iran (Poria *et al*. 2013).
Knowledge of length-weight and length-length relationships, condition factor, growth and recruitment are important tools for adequate management of any fish species (King 2007). The length-weight relationship (LWR) is an important parameter in fish biology and can give information on stock condition, condition indices and several aspects of fish population dynamics (Bagenal & Tesch 1978; Gonçalves *et al*. 1997). It also has been employed in the conversion of fish length and body weight to provide some measures of biomass (Froese 1998) as well as help to estimate the reproduction, life cycle and general health of the fish species (Pauly 1983). The condition factor (KF) is used to compare the condition, fatness or well-being of the fish (Bagenal and Tesch 1978). The relative condition factor (K_n) is

influenced by many environmental and biological factors (Le Cren 1951). KF measures the deviation from a hypothetical ideal fish, while t K_n measures the deviation from the fish average weight or length. A comprehensive review of body condition indices is described by Anderson & Neumann (1996). The determination of fish growth is fundamental for population modeling, stock assessments and managing exploited species (Gulland 1988). Despite the wide distribution of *C. trutta*, knowledge on the life history parameters of the fish is limited. Previous studies on the life history parameters in Iranian inland waters were limited to the length-weight relationship and condition factor of *C. trutta* from Shour River in Khouzestan Province, Kangir and Seimare rivers (Javaheri Baboli *et al.* 2012; Radkhah & Nowfereti 2016), its age determination and growth rate from Gorganrud River (South Caspian basin), Shour and Seimare rivers (Taghaviniya *et al.* 2015; Pazira *et al.* 2015) as well as from the Karayaka Dam Lake in Turkey (Kalkan 2008). To our knowledge no adequate study on *C. trutta* has been published for inland waters and reservoirs in northwest of Iran. Therefore, the aim of the present study was to estimate the population parameters including LWR, condition factor, relation condition factor, age, growth and mortality rate of *C. trutta* in Azad Dam from Kurdistan Province, Iran, which was constructed and established by impounding water in 2011.

MATERIALS AND METHODS

Azad dam is located on the Komasi River, northwest of Iran, at an altitude of about 1400 m above sea level (Fig. 1). It is an earthen dam with a clay core. The crest length and maximum height of the dam are 595 and 117 m, respectively. The total capacity of dam is 300 million m^3. This investigation was carried out seasonally during 2015-2016. Three sampling sites were selected along the dam using multi-mesh gillnet (20 m length and 4 m height, with 14, 18, 22, 26, 30, 33 and 40 mm mesh sizes).

A total of 148 specimens of *C. trutta* were collected. The fork, standard and total lengths (FL, SL and TL) were measured to the nearest 1 mm and total weight to the nearest 1 g (for total individuals). Sex determination was carried out by visual observation. Scales were collected from the middle of the body behind the pectoral fins above the lateral line and preserved in the envelopes for further examinations in the laboratory.

The length-weight relationship was derived by applying an exponential regression as the following equation:

$$W = aTL^b$$

where W is the total weight (g), TL is the total length (mm), and *a* and *b* are parameters to be estimated (Ricker 1975). Parameters estimation was conducted by least squares linear regression on log-log transformed data:
ln (W) = ln (a) + b × ln (TL).
T-test for departure from isometry (b = 3) was carried out according to Pauly 1984):

$$t = \frac{s.d.\ln(TL)}{s.d.\ln(W)} \times \frac{|b-3|}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

where s.d.ln (TL) and s.d.ln (W) are standard deviations of natural logarithm of the total length (cm) and weight respectively, *a* and *b* are parameters and r^2 is regression coefficient between length and weight, while n is sample size.

The condition factor (KF) was calculated by the following equation (Froese 2006):

$$KF = \frac{W}{TL^3} \times 100$$

where W (g) is weight and TL (cm) is total length.

The relative condition factor (K_n) compensates for changes in form or condition by increasing in length and was calculated using following equation (Froese 2006):

$$K_n = \frac{W}{aTL^b}$$

Where W is weight (g), TL is total length (mm), *a* and *b* are the exponential form of the intercept and slope of the logarithmic length–weight equation respectively. The Pearson correlation coefficient was calculated to measure the relationship between K_n and K length. The von Bertalanffy growth curve (von Bertalanffy 1938) was fitted to the observed lengths at age for the resulting age-length key using a non-linear estimation method as the following:

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

Where L_t is the total length at age *t*, L_∞ is the theoretical maximum length, K is a growth coefficient and t_0 is the hypothetical age for L_t = 0. The TropfishR package in R software was used to estimate L_∞, K and t_0 of the von Bertalanffy equation (Mildenberger *et al.* 2017). The parameter (Ø′), the growth performance index, was calculated according to Pauly (1983):

$$\emptyset' = logK + 2logL_\infty$$

where K is the growth coefficient and L_∞ is the theoretical maximum length (cm).

The instantaneous coefficient of natural mortality was estimated using the methods in Pauly model (Pauly 1980) with von Bertalanffy growth parameters.

$$\ln(M) = -0.0152 - 0.279\ln(L_\infty) + 0.6543\ln(K) + 0.463\ln(T)$$

where M is the instantaneous coefficient of natural mortality, K is the growth coefficient and T is the mean annual habitat temperature, *T* = 12.0 °C.

The comparison between the average values for genders was carried out using t-test and for seasons using analysis of variance (ANOVA). Differences in sex ratios from the expected 1:1 were analyzed using Chi-square tests (Zar 2010).

Fig. 1. Map of Azad Dam Lake located at northwest of Iran and defining sampling stations (St.).

RESULTS

A total of 148 specimens were collected in this study. The total length and weight of *C. trutta* ranged from 4.0 to 29.0 cm and 0.9 to 274.0 g, average (± SD) = 19.3 (± 4.0) cm and 80.3 (± 44.7) g respectively (Table 1). The total length group of 20.0-20.9 mm was prevailing and formed 16.8%, followed by the length group of 19-20, comprising 11.5% of the total catch (Fig. 2).

Table 1. Descriptive statistics of weight, total length, condition factor (KF) and relative condition factor (K_n) of *Capoeta trutta* in Azad Dam Lake.

Parameter	N	Mean	SD	Min-Max
Weight (g)	148	80.3	44.70	0.9-274.0
Total length (mm)	147	19.3	4.02	4.0-29.0
KF	147	1.00	0.11	0.73-1.41
K_n	147	1.01	0.11	0.75-1.30
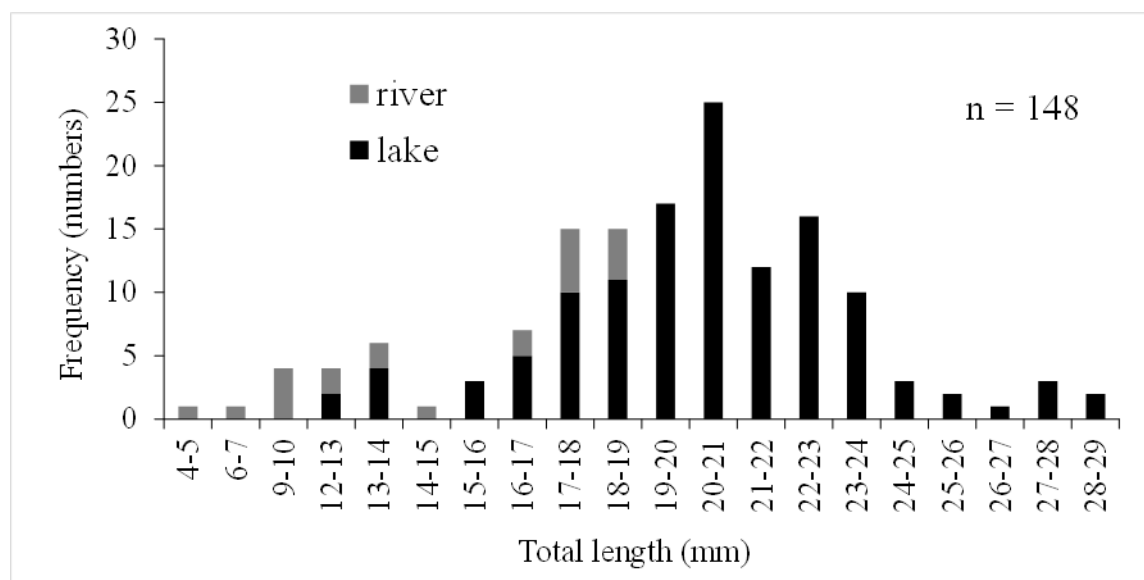
Fig. 2. Size distribution of *Capoeta trutta* in Azad Dam Lake and Komasi River, n = sample size.

The total length and weight regression from all of the whole samples was: $W = 0.0121 \times TL^{2.9317}$ ($r^2 = 0.98$, n = 147). The estimation of "b" = 2.9317, was not significantly different from 3.0 (t-test, p > 0.05), indicating an isometric growth (Fig. 3). The average of KF value was 1.00 ± 0.11 and significant differences were found in the parameters among seasons (ANOVA, p < 0.001, Table 2).

The relative condition factor K_n was calculated using the length-weight relationship. The average K_n values were 1.01 ± 0.11 and there were significantly differences among seasons (ANOVA, p < 0.001). The KF and K_n were the highest in spring (Table 2). The age of *C. trutta* ranged 0–5 years. In the age compositions, age classes of 2 and 3 were the most dominant, representing 74.8% of the samples.

The von Bertalanffy growth equation was estimated and are shown in Table 3 and Fig. 4:

$$L_t = 29.6(1 - e^{-0.33(t-(-0.57))})$$

The growth performance index (Ø') of *C. trutta* was computed as 2.46. Estimates of the instantaneous coefficient of natural mortality for *C. trutta* obtained from the Pauly method was 0.58/yr. The sex ratio (M:F) was 1:0.33, for adult *C. trutta* (n = 118) which differed significantly from the expected 1:1 ($\chi^2 = 30.5$, P<0.001). The gender ratio was not significantly different (P > 0.05) In spring, while males were predominated (P < 0.05, Fig. 5) in other seasons.

Table 2. Seasonal condition factor (KF) and relative condition factor (K_n) of *Capoeta trutta* in Azad Dam Lake.

Seasons		Summer 2015	Autumn 2015	Winter 2016	Spring 2016	ANOVA
Parameters	N	56	54	14	23	
KF	Mean	0.95[a]	1.01[ab]	0.99[a]	1.08[b]	F = 9.8; P<0.001
	S.D.	0.10	0.11	0.07	0.08	
K_n	Mean	0.97[a]	1.02[a]	1.02[a]	1.11[b]	F = 11.1; P<0.001
	S.D.	0.10	0.11	0.07	0.08	

Table 3. The von Bertalanffy growth parameters of *Capoeta trutta* in Azad dam.

Parameter	Estimated	SE	t value	P
L_∞ (cm)	29.6	3.32	8.9	0.001
K (yr^{-1})	0.33	0.09	3.7	0.001
t_0 (year)	-0.57	0.24	2.4	0.020

$$W = 0.012TL^{2.932}$$
$$R^2 = 0.9804$$
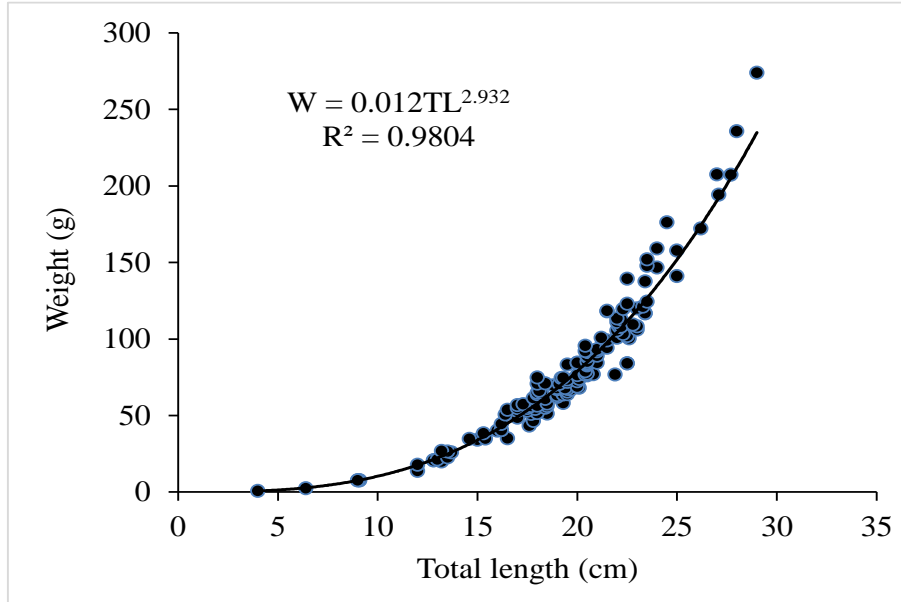
Fig. 3. Length-weight relationship of *Capoeta trutta* in Azad Dam Lake.
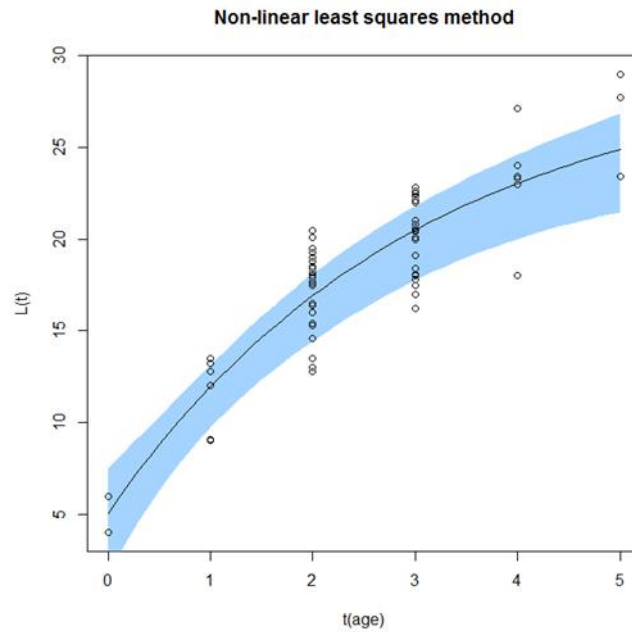

Non-linear least squares method

Fig.4. Theoretical growth curve calculated for total length of *Capoeta trutta* in Azad Dam Lake.
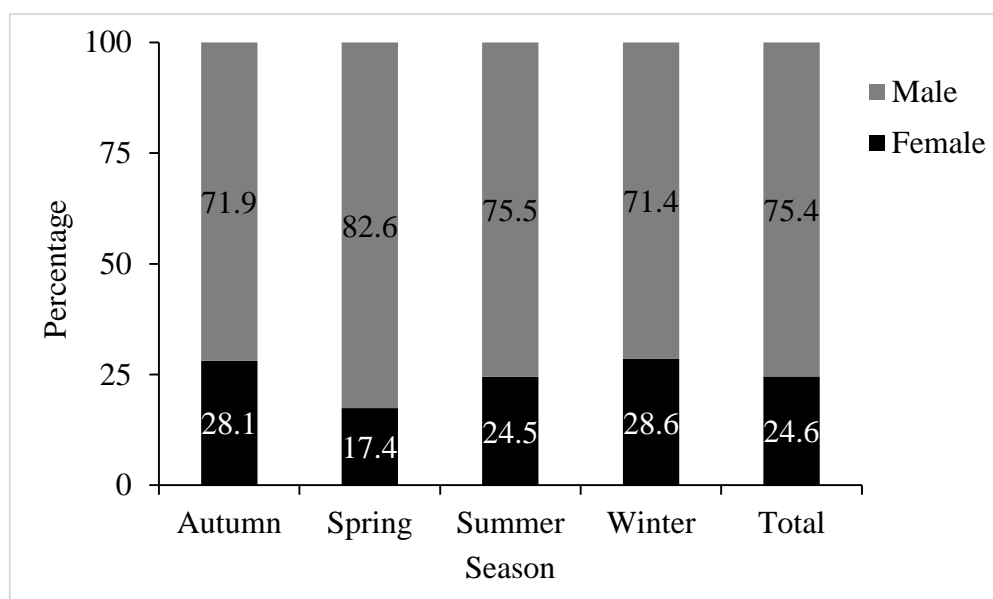
Fig. 5. Seasonal sex composition of *Capoeta trutta* in Azad Dam Lake.

DISCUSSION

The study on life history of *C. trutta* in Iranian inland waters were limited to southwest and northwest of Iran (Javaheri Baboli *et al*. 2012; Pazira *et al*. 2015; Taghaviniya *et al*. 2015; Radkhah & Nowfereti 2016, Table 4). The *b* value usually varies between 2 and 4 (Tesch 1971) or ranges from 2.50 to 3.50 (Froese 2006). In the present study, the exponent *b* of length–weight relationship was 2.932, remained within the expected range, indicating an isometric growth (Fig. 3). Similar results were reported from Iran by Javaheri Baboli *et al*. (2012), Pazira *et al*. (2015) and Taghaviniya *et al*. (2015), whereas Radkhah & Niwferesti (2016) reported a lower *b* value (2.69 and 2.85, in those caught from Kangir and Seimare rivers, respectively). The sampling gear might influence the size range covered and cause deviations from existing values LWR parameters. In addition, geographical location and associated environmental conditions such as water temperature, which is the determining factor of feeding capacity, seasonality, stomach fullness, disease and parasite loads can affect the value of *b* (Bagenal & Tesh 1978; Froese 2006). According to Kumolu & Ndimele (2010) the condition factor reflects information on physiological states of fish relating to welfare. Also, high condition factor values indicate favorable environmental conditions (Blackwell

et al. 2000). In the present study, *C. trutta* was found to be in suitable condition, as the value of "KF" was close to 1, in all seasons except spring. K_n has been used as it indicates suitability of the environment for fish growth. According to George *et al*. (1985) K_n indicates the general well-being of the fish. If the values of $K_n > 1$, it indicates that the well-being of the fish is good whereas, its value <1 reflects that the well-being of the fish is not in a good condition and feeding activity. In the present study, the K_n of *C. trutta* were close to 1 (in summer, autumn and winter) or higher than 1 (in spring). These results suggested that the well-being of the fish was good in Azad Dam Lake. Similar results were reported for *Alburnus mossulensis* in Azad Dam Lake (Fazli *et al*. 2018). According to Le Cren (1951), Bagenal & Tesch (1978) and Simon *et al*. (2012) seasonal variation of K_n can be influenced by the maturity, gonad development, feeding activity and several other factors. Knowledge of fish age and growth is necessary for stock assessment, develop management or conservation plans (Helfman *et al*. 1997).

There are no previous estimates on growth rates of *C. trutta* in the Iranian inland waters, except for those reported by Taghaviniya *et al*. (2015). The results of the present study showed that the rapid growth of *C. trutta* was found during the two first years of life, followed by a

period of slow rate during the rest (Fig. 4). The age of *C. trutta* varied from 0 to 5 years, while Taghaviniya *et al*. (2015) and Kalkan (2008) reported a higher age ranges (between 0-6 and 0-7 respectively, Table 5). According to Holmgren & Appelberg (2001) and Bautista *et al*. (2012) the range of age distribution in a population is closely related to the nutritional status of the environment. The asymptotic length (L_∞) of *C. trutta*, 29.6 cm, was similar to that reported by Taghaviniya *et al*. (2015). In contrast, Kalkan (2008) reported a very higher, different L_∞ (76.4 and 89.5 cm for male and female respectively). The growth performance index ($\varnothing'$) in *C. trutta* (2.46) was higher than fish species caught from other Iranian inland waters. Kalkan (2008) also reported higher $\varnothing'$ values (Table 5). Holmgren & Appelberg (2001)

and Bautista *et al*. (2012) reported that the growth characteristics of the local populations in the same species change due to habitat variations, water quality and nutrients.

In the present study, the overall sex ratio is unbalanced in favor of males. Similar results were reported by Poria *et al*. (2012) in northwest of Iran and Kalkan (2008) in Turkey (1:0.54, 1:79 and 1:0.98, respectively), while the overall sex ratios were reported to be 1:1.96 by Taghaviniya (2015). Nikolsky (1963) reported that the sex ratio of fish population changes based on spawning season, life stage of the fish, spawning ground and migration. Moreover, sex ratio depends on the fishing area, since it is possible to determine females and males as being more abundant in heterogenic habitats (Mouine *et al*. 2011).

Table 4. The length-weight relationships in *Capoeta trutta* from different locations.

Study area	Sex	N	TL (cm) Min-Max	b	r^2	Author (s)
Shour River, Iran	F+M	268	-	3.01	-	Javaheri Baboli *et al*. 2012
Seymareh River, Iran	F+M	-	8.3-28.0	3.09	0.98	Pazira *et al*. 2015
Kangir River, Iran	F+M	42	6.0-21.0	2.69	0.96	Radkhah & Niwferesti 2016
Seimare River, Iran	F+M	20	9.1-20.5	2.85	0.94	Radkhah & Niwferesti 2016
Karayaka dam lake, Turkey	F+M	210	-	3.016	-	Kalkan 2008
Azad Dam, Iran	F+M	148	4.0-29.0	2.932	0.98	Present study

Table 5. The von Bertalanffy growth Parameters in *Capoeta trutta* from different locations.

Study area	Sex	Age	L_∞	K	t_0	$\varnothing'$	Author (s)
Shour River, Iran	M	0-6	24.5	0.33	-2.54	2.30	Taghaviniya *et al*. (2015)
	F	0-6	36.5	0.129	-4.02	2.23	
Karayaka Dam Lake, Turkey	M	0-7	76.4	0.064	-2.65	2.57	Kalkan (2008)
	F	0-7	89.5	0.057	-2.41	2.66	
Azad Dam Lake, Iran	M+F	0-5	29.6	0.33	-0.57	2.46	In the present study

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سن و رشد ماهی *Capoeta trutta* در دریاچه سد آزاد در استان کردستان، ایران

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چکیده

برای برآورد پارامترهای رشد سیاه ماهی *Capoeta trutta* در دریاچه سد آزاد استان کردستان (واقع در شمال غرب ایران) تعداد ۱۴۸ نمونه طی سال‌های ۱۳۹۴ الی ۱۳۹۵ بررسی شد. دامنه طول کل و وزن کل به ترتیب ۴/۰ الی ۲۹/۰ سانتی متر و ۰/۹ الی ۲۷۴/۰ گرم و به طور متوسط (±انحراف معیار) ۱۹/۳ (۴/۰±) سانتی متر و ۸۰/۳ (۴۴/۷±) گرم بود. رابطه بین طول و وزن $W=0.0121 \times TL^{2.9317}$ بود که بیانگر رشد ایزومتریک است. نسبت جنسی (ماده : نر) ۱: ۰/۳۳ بود که با نسبت ۱:۱ دارای اختلاف معنی داری است ($P < 0.001$). پارامترهای معادله رشد برتالان فی شامل $L\infty = ۲۹/۶ \ cm$، K ۰/۳۳ $yr-1$ و $t0 = -۰/۵۷ \ yr$ برآورد شد. ضریب مرگ و میر لحظه‌ای ۰/۵۸ yr^{-1} محاسبه شد. میانگین ضریب چاقی ۰/۱۱ ± ۱/۰۰ بود که در فصول مختلف بین آنها اختلاف معنی‌داری وجود داشت ($P < 0.001$). در این مطالعه ضریب چاقی نسبی سیاه ماهی نزدیک ۱ بود که نشان می‌دهد این ماهی در وضعیت زیستی خوبی در دریاچه سد آزاد برخوردار است.

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