Growth and mortality of brown trout, *Salmo trutta fario* in Lar dam, Iran

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Received: February 2011 Accepted: July 2011

Abstract

The length-weight relationship, age, growth parameters, sex ratio, mortality and exploitation rate of *Salmo trutta fario* were determined in Lar dam. The sex ratio (male: female) was 1:1.84 which differed significantly from the expected 1:1. The length-weight regression was $W = 0.028L^{2.706}$ (females) and $W = 0.0341L^{2.624}$ (males) indicating a negative allometric growth for both sexes. Growth parameters were estimated as L_∞ = 45.0 cm, K = 0.27 yr^{-1}, t_0 = -0.23 yr. The instantaneous coefficients of natural, total and fishing mortality were estimated as 0.40 yr^{-1}, 0.75 yr^{-1} and 0.35 yr^{-1}. The results showed that *S. trutta fario* is moderately a rapidly-growing species in Lar dam. The exploitation rate was 0.47. Therefore, the population appeared to be in good condition in 2004.

Keywords: *Salmo trutta fario*, growth parameters, exploitation rate, Lar Dam

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[DOR: 20.1001.1.15622916.2012.11.1.4.0]

Introduction

Salmo trutta caspius Kessler, 1877 has two forms in Iran: the native brown trout (freshwater populations) and Caspian salmon (sea-run populations) in Namak Lake basins and the Caspian Sea, respectively (Saadati, 1977). The sea-run Caspian salmon attains a larger size than the freshwater populations. It attains 51 kg and 1.24 m but most of the ones seen in Iran were 10-15 kg (Walczak, 1972 cited in Coad, 2008). *S. trutta caspius* is distributed in Sardab-roud, Tonekabon Tajan, Babol-roud, Haraz, Tonekabon, Pol-e Rud, and Sefid-roud rivers and Gorgan Bay, the southeast Caspian Sea, southwest Caspian Sea and south-central Caspian Sea (Kiabi et al., 1999). The reproduction takes place in areas with clean gravel and water temperatures of more than 15°C can cause egg mortality. The optimum and preferred ranges of water temperature for adults are 18-24°C and 12.4-17.6°C, respectively (Coad, 2008). In general, freshwater populations can eat mayfly (insects, crustaceans and terrestrial insects), and for larger specimens, fish, crayfish, fogs, salamanders and rodents (Coad, 2008). In Tonekabon River, *Simulium*, Plecoptera and Ephemeroptera were the main food of this population (Afraei et al., 2000). According to IUCN criteria, this is vulnerable species in the south Caspian Sea basin (Kiabi et al., 1999). Coad (2000) reported that *S. trutta fario* is one of the top four threatened species of freshwater fishes and because of overfishing, habitat destruction and spawning ground degradation, this species is endangered in Iran (Nezami et al., 2000). In Lar dam, *S. trutta fario* is very popular sport fish, and the Iranian Department of the Environment has been arranging fishing in the Dam since 1994. Despite its recreational and ecological importance, no studies have been carried out about sex, age, growth, and mortality of *S. trutta fario* in the dam. The objective of the present study was to fill the information gaps on the population biology and provide a basis for improved and effective management of the fishery of *S. trutta fario* in Lar dam.

Materials and methods

The study was performed at Lar dam. The dam is located on Lar River; 84 km northeast of Tehran with 35°53'N, 52°00'E (Fig. 1). It is an earth dam with a clay core. The crest length and maximum height of the dam are 1300 and 105 meters, respectively. The total capacity of the dam is 860 million m^3 (www.scsembenelli.com). Six sampling sites were selected along the dam in June by gill net (20 m length and 4 m height, with 14, 18, 22, 26, 30, 33 and 40 mm mesh sizes), recreational fishing from July to August by hook and four sampling sites in four rivers from September to October in 2004 by electroshock. A total of 2032 *S. trutta fario* specimens were collected. The fork length was measured to the nearest 1 mm and total weight to the nearest 1 g (for overall individuals). Sex of gill net samples (211 specimens) was determined by visual observation. Scales were collected from the middle of the body behind the pectoral fins above the hypothetical lateral line and preserved in

[DOR: 20.1001.1.15622916.2012.11.1.4.0]

the envelopes for future treatment. The scales were washed and placed in small covered Petri dishes with tap water. Following this, the organic layers were removed by rubbing and washing the scales between the fingers in tap water (Taghavi et al., 2010).

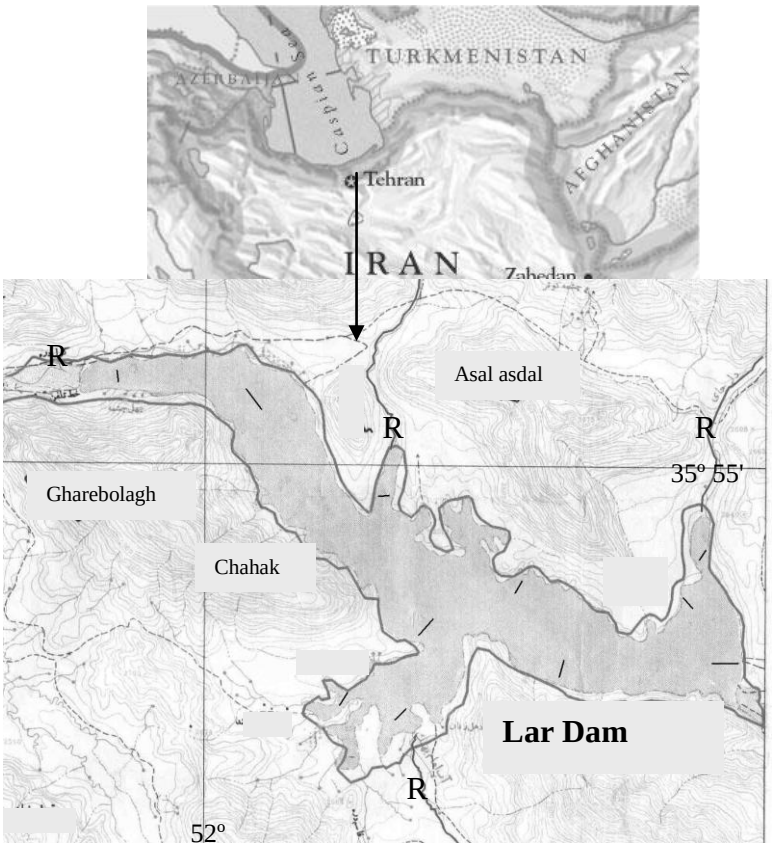

Figure 1: Map of Lar Dam located at northeast of Tehran (R= river)

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

$$W = aL^b$$

where W is the total weight (g). L, the fork length (mm), and a and b are parameters to be estimated (Ricker, 1975).

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 fork 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. Phi prime ($\dot{\Phi}$) was calculated as the following (Pauly and Munro, 1984):

$\dot{\Phi} = logK + 2LogL_\infty$

[DOR: 20.1001.1.15622916.2012.11.1.4.0]

Estimates of instantaneous total mortality (*Z*) were obtained using the age- based catch-curve method (Riker, 1975).

The instantaneous coefficient of natural mortality was estimated using the methods in Pauly mode (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*=8.9 °C.

When the values of *Z* and *M* have been estimated, the value of fishing mortality, *F*, can be derived from the following equation:

$$F = Z - M$$

The exploitation rate (*E*) was estimated as the following equation:

$$E = \frac{F}{Z}$$

where *F* is the instantaneous coefficient of fishing mortality and *Z* is the instantaneous coefficient of total mortality (King, 1996).

Results

A total of 2032 specimens were caught for this study, along with 211 specimens caught by gillnet, 906 specimens caught by the recreational fishing and 915 specimens caught by electroshock equipment in the rivers. The samples caught by gillnet were used for the age and growth study. The fork length and weight of *S. trutta fario* ranged from 4.9 to 44.0 cm and from 1 to 963 g and averaged (±S.D.) 21.5 (±10.6) mm and 169.9 (±168.8) g, respectively. The length-frequency ranged from 11.9 to 41.9; from 13.5 to 44.0 and from 4.9 to 34.1 cm in gillnet, recreational fishing and electroshock, respectively (Fig. 2). Total recreational fishing was 65,000 specimens with the average weight of 299.6 g; the weight of total catch was estimated 19.5 mt in the dam in 2004. Age compositions of recreational fishing catch were derived $L_t = 45(1 - e^{-0.27(t-0.23)})$ from the length composition data and age-length keys ranging from 1 to 6 years. In the age compositions, age 4 was the largest age group and accounted for 33.4% of catches in 2004 (Fig. 3).

The von Bertalanffy growth equation was estimated as shown in Figure 4 and phi prime (Φ) was 2.73.

The fork length and weight regression of all samples was: $W = 0.029L^{2.710}$ (R^2= 0.98, n=951); for female $W = 0.028L^{2.706}$ (R^2= 0.98, n=116) and for male $W = 0.0341L^{2.624}$ (R^2= 0.98, n=65) (Fig. 5). The slopes (*b* values) of the length-weight regressions were significantly different between sexes (*t*-test, t=19.26, *P*<0.001). The estimation of "*b*" for females and males were 2.706 and 2.624, significantly different from 3.0 (*t*-test, t=121.7, *P*<0.001; t=126.0, *P*<0.001, respectively), indicating an allometric growth.

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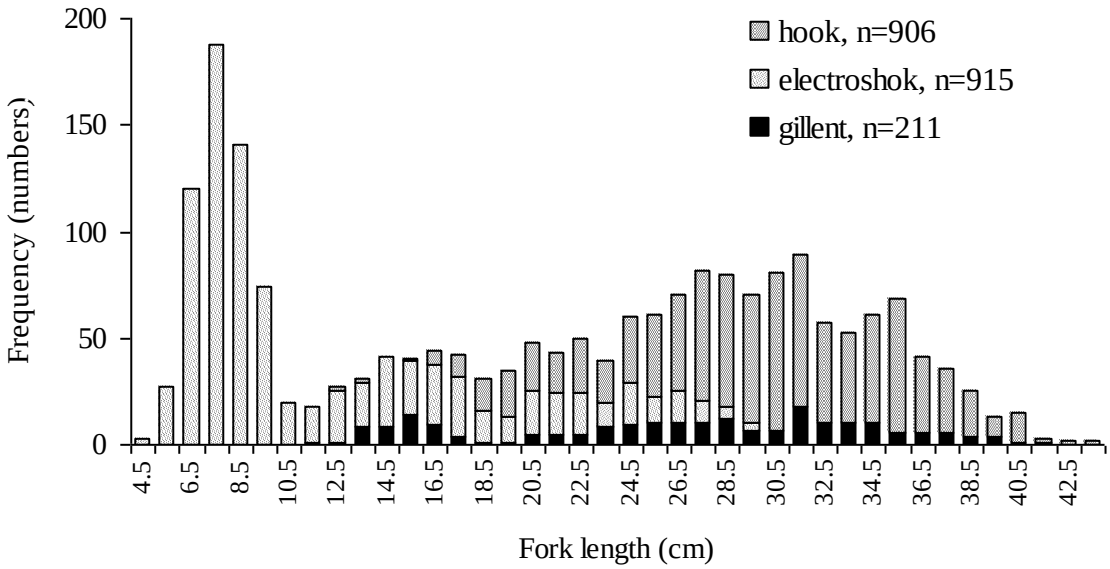

Figure 2: Size distribution of the samples of *Salmo trutta fario* collected by hook, electroshock and gillnet, n=sample size

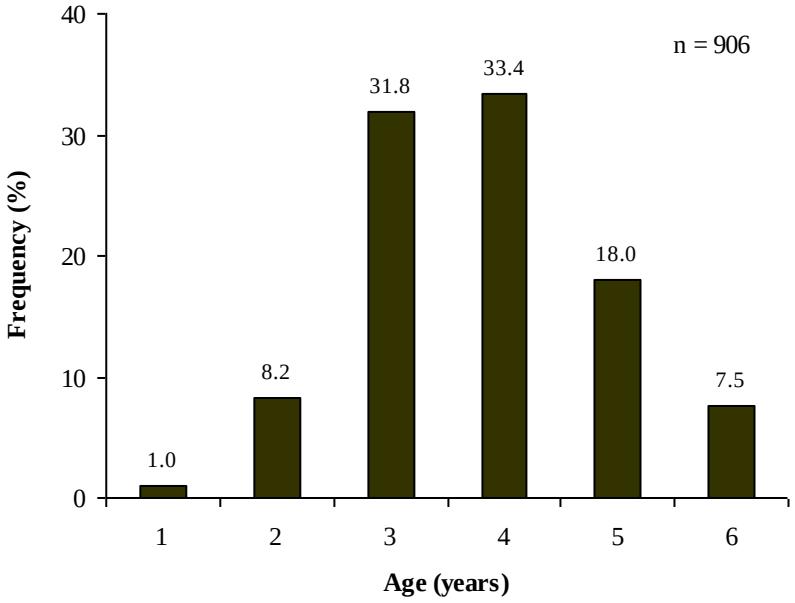

Figure 3: Age distribution of *Salmo trutta fario* as determined in samples taken from the recreational fishing in Lar dam throughout the study period in 2004

n= catch sample size. Numbers of the bars represent percentages of the year class in relation to total sample.

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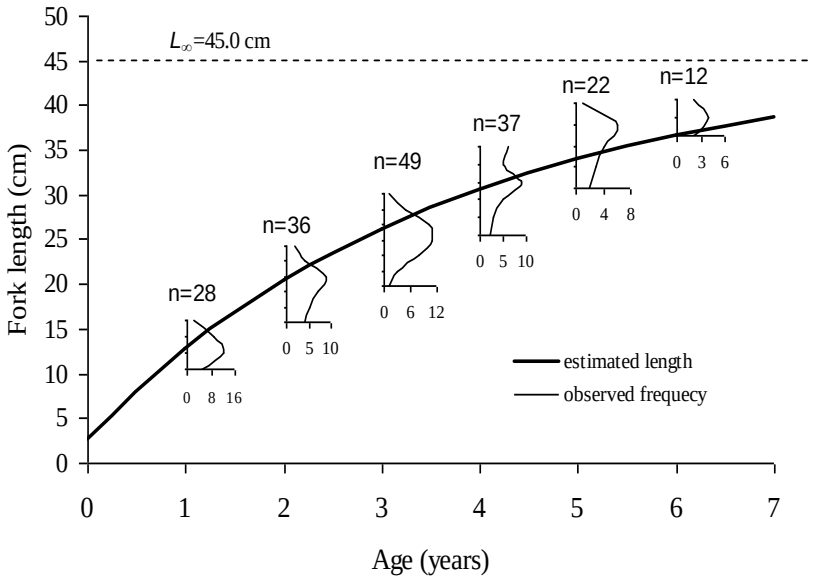

Figure 4: Theoretical growth curve calculated for fork length of *Salmo trutta fario* from Lar dam; n= sample size

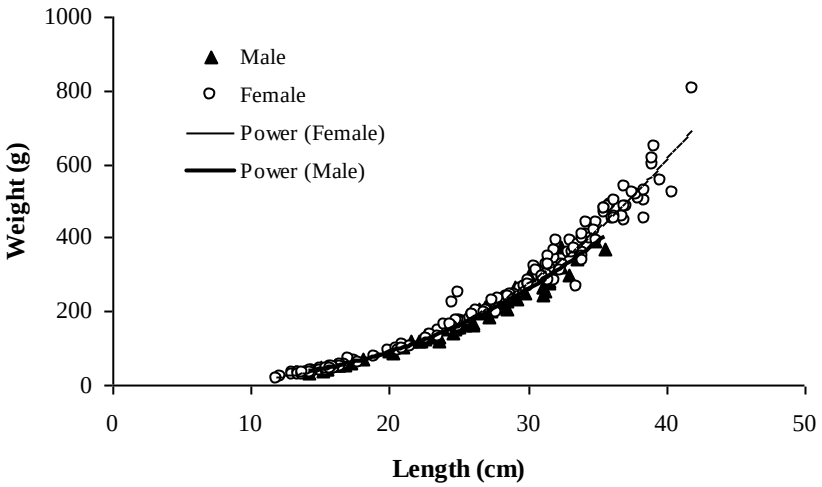

Figure 5: Length-weight relationship for male and female of *Salmo trutta fario* from Lar dam

The sex ratio (male:female) was 1:1.84, for adult *S. trutta fario* (n=179) which differed significantly from the expected 1:1 (χ^2=14.4, P<0.001; Table 1). In the size classes less than 20 cm, 20-25 cm and 25-30 cm the sex ratios were not significantly different (χ^2=0.18, P>0.670; χ^2=0.03, P>0.862; χ^2=1.72 and P>0.189, respectively, Table 1). In the size classes 30-35 and >35 females were most abundant (χ^2=7.69, P>0.006 and χ^2=23.1, P>0.001).

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Table 1: Chi-square test for *Salmo trutta fario* sex ratio comparisons by size classes

Size group	Sex		χ^2	P
	Male	Female		
<20	12	10	0.18	0.670
20-25	17	16	0.03	0.862
25-30	19	28	1.72	0.189
30-35	16	36	7.69	0.006
>35	1	26	23.1	0.001
Total	65	116	14.4	0.001

Based on the catch curve method, the annual survival rate (*S*) of *S. trutta fario* was estimated as 0.47. Given these survival rates the instantaneous coefficient of total mortality (*Z*) was calculated to be 0.75 yr^{-1}. The estimation of instantaneous coefficient of natural mortality (*M*) for *S. trutta fario* obtained from the Pauly method was 0.40 yr^{-1}. With the estimation of instantaneous coefficients of total and natural mortality, the fishing mortality and the exploitation rate were 0.35 yr^{-1} and 0.47, respectively.

Discussion

The fork length of *S. trutta fario* ranged from 4.9 to 44.0 cm in Lar dam (Fig. 2). In contrast, RaLonde and Walczak (1970); Afraei et al. (2000) reported a lower maximum length in Lar and Tonekabon rivers with 27 and 17.5 cm length, respectively.

There was great variation in the literature on the maximum recorded age for *S. trutta fario*. It ranged from 0-4 (McFadden and Cooper, 1962; Afraei et al., 2000), 0-5 (Lobon-Cervia et al., 1986), 0-6 (Hesthagen et al., 2004), 0-10 (Alp et al., 2003) and 0-12 (Hauugen and Rygg, 1996). In this study the life span was up to 6 years. Maximum longevity and age in fish are affected by their genetics, food intake, water temperature, floodplain and fishing activities (Elliott, 1994; Crisp, 2000).

There were no previous estimates on growth rate of *S. trutta fario* in Iranian habitats. The results showed that the growth rate of *S. trutta fario* was high for the first three years of their life and then gradually decreased. Comparison of the literature (Table 2) showed that in Lar Dam the trout had a partially high L_∞, *K* and growth rate. Considering both L_∞ and *K*, growth can also be judged by Φ, which in the present study is partially higher than the other data reported in other habitats (Table 2). This could be due to available food resources and sufficient temperature for *S. trutta fario* in Lar dam.

The *b* values of length-weight relationships were calculated as 2.624 and

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2.706 for males and females, respectively. These values, significantly lower than 3 (P<0.001) indicated negative allometric growth. In comparison to literature, *S. trutta fario* from Tonekabon River had higher *b* values (2.994 and 2.935 for males and females, respectively; Afraei et al., 2000). Geographic 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 and Tesh, 1978).

Table 2: von Bertalanffy growth parameters and phi prime for *Salmo trutta fario* from different habitats

Author	Study area	L_∞ (cm)	K (yr^{-1})	$\grave{\Phi}$
Crisp and Beaumont, 1995	Afon Dyfi, UK	21.6	0.34	2.20
Crisp *et al.*, 1974	Cow Green Stream, England	39.0	0.15	2.36
Crisp and Beaumont, 1996	Wye and Severn Rivers, UK	21.5	0.34	2.20
Hesthagen *et al.*, 1999	Sub-Alpine Reservoir, Norway	39.1	0.21	2.51
Haugen and Rygg, 1996	Norwegian Reservoir, Norway	42.8	0.29	2.73
Lobon-Cevira *et al.*, 1986	River Ucervo	65.9	0.18	2.89
	River Avion-Milanos, Spain	64.0	0.18	2.87
Arslan *et al*., 2007	Aksu Stream	32.1	0.12	2.09
Present study	Lar Dam	45.0	0.27	2.73

The male:female ratio of *S. trutta fario* was 1:1.84, significantly different from 1:1, and different from Tonekabon River, 1.41:1 (Afraei et al., 2000) .

RaLonde and Walczak (1970) found that 22 fishermen had caught 222 trout with an average of 2.56 fish per fisherman per hour, and Surber (1969) sport fishermen took 50,000 trout from Lar River in 1967. This production of trout in Lar River was expected to decline drastically with the construction of a dam on it, Coad (2008) and Malek-Eizadi (1993) confirmed its decline. In the present study, the exploitation ratio was 0.47 in 2004. This is lower than the rate of 0.5, where $F_{opt} = M$ ($F < F_{opt} = M$), suggested by Gulland (1983), as the theoretical exploitation rate that could maximize harvest. More recently, Pauly (1987) proposed a lower optimum fishing mortality, $F_{opt} = 0.4 \times M$ ($F > F_{opt} = M$). Lar Dam located in the Lar Protected Area (formerly a National Park) and the Iran Department of the Environment (IDE) has arranged fishing in the Dam since 1994. Although the population appeared to be in good condition in 2004, but in a

[DOR: 20.1001.1.15622916.2012.11.1.4.0]

precautionary approach lower fishing mortality should be selected.

In conclusion, *S. trutta fario* moderately had a fast growth rate in Lar dam. This could be due to available food resources and sufficient temperature for *S. trutta fario* in Lar dam. The findings on age, growth and mortality of *S. trutta fario* from this study will help to elucidate the age distribution and sustainable management of fish in Lar dam. Moreover, for better management of *S. trutta fario* we recommend that the IDE plan to conduct this study annually.

Acknowledgements

This research was supported by Prof. Azari-Takami. The authors thank Mr. Elmi and the staff of the Lar Protected Area and the Iran Department of the Environment.

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