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Estimation of growth parameters and mortality rate of common carp (*Cyprinus carpio*, Linnaeus 1758) population in the southern Caspian Sea

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Abstract

Common carp (*Cyprinus carpio*) represents one of the most economically important fish species in the Caspian Sea. In this study, growth and mortality parameters among population of common carp was investigated. Sampling was carried out weekly, using beach seine in the south of the Caspian Sea from October 2006 to September 2007. As a contribution to elaborating management programs for common carp, the age and growth of this species was calculated via scale, growth parameters and mortality rate by length frequency data obtained from commercial fishing and research beach seines. Ten age groups were recorded from 1+ to 10^+ years old, being dominated by 4 and 5 year-old fish. The growth parameters based on scale reading data by length at age analysis were $FL\infty$= 71.52cm and K = 0.16 per year for total population, $FL\infty$= 70.54cm and K = 0.15 per year for males, and $FL\infty$= 72.00 cm and K = 0.16 per year for females, whereas by length frequency analysis, these values were estimated as $FL\infty$ equals 72.0, 69.3 and73.0cm and K equals 0.18, 0.15 and 0.18 per year for total population, males and females, respectively. The total, natural and fishing mortality rates were 0.71, 0.29 and 0.42 per year, respectively.

Keywords: *Cyprinus carpio*, Scale, Age structure, Population dynamics parameters, Caspian Sea

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Introduction

The common carp (*Cyprinus carpio*, Linnaeus 1758) is a semi-anadromous, warm water species, which can be found in fresh and brackish waters such as the Caspian watershed (Ural, Volga, Kura and Atrak rivers). Common carp as an important commercially species is widely distributed in the Caspian Sea (Kazancheev, 1981). In the past ten years, the minimum amount of catch was recorded 222 tons in 2002 and maximum was 3925 tons in 2005.

Growth is an important aspect of the biology and life history of fish, and quantification of growth is frequently a crucial part of fisheries research and management (Summerfelt & Hall, 1987; Weatherley & Gill, 1987).

The structure of a population is determined by the equilibrium between life history characteristics of reproduction, growth and mortality (Sissenwine, 1984). Certain methods of fisheries assessment require the separation of total mortality into its components due to fishing and due to natural causes. Pauly (1980) developed a multiple regression model predecting natural mortality from growth parameters, and mean enviromental temperature, which has been widely used to provide estimates of natural mortality in assessments of fish stocks.

To assess fish populations, many structures have been used to estimate age of fishes. Scales are concluded to be the best mean to age *C. carpio* because they rendered L_∞ values closer to the maximum FL observed, high precision, easiness of collection, low processing time, and the possibility of performing non-destructive monitoring studies.

Modeling fish growth is an important outcome of studies designed to interpret the age profiles of stocks from their calcified structures. Thus, it is often of interest to compare the growth rates of fish stocks from different geographical areas, or of males and females within the same stock, or to describe year-to-year variation in growth as a response to changing abiotic and biotic factors (Weatherley & Gill, 1987).

Previous studies on population characteristics of the *C. carpio* stock in the Iranian waters of the Caspian Sea were limited to the biological characteristics and not to population parameters as growth and mortality rates (Ghaninejad *et al*., 2002). The present study is designed to model growth in a stock of common carp in the south of the Caspian Sea which provides a basis to improve the effective management of *C. carpio*. Therefore, some population characteristics of the carp stock, such as age, length-weight relationship, growth parameters and mortality rates were investigated.

Materials and methods

Sampling units in this study were determined by beach seine fisheries. There are more than 140 fishing cooperatives along the Iranian coastal zones which catch bony fishes by beach seine in the fishing season (*i.e.,* 23rd September to 9th April) in the study area (Fig. 1).

In total 328 fish were collected by beach seines in the southern Caspian Sea, using 3 different nets with stretched mesh sizes of 8, 30 and 33 mm. Beach seines (30 and 33 mm mesh sizes) were investigated weekly by random sampling method from October 2006 to September 2007. Most samples (n=275) were obtained during the fishing seasons between October 2006 and April 2007. Small samples (n=53) were taken by net 8 mm mesh size between May to September 2007.

6-10 scales were removed from the antero-medial part of the body above the lateral line (where normal scales usually are found in carp) of each specimen (Bagenal & Tesch, 1978). Mucus was removed from the scales. Then scales were stored in paper envelops. Scales of 328 individuals were collected in the laboratory prior to the reading, they were washed in warm water and age readings were performed according to Chugunova (1959).

All readings for each structure were undertaken twice by independent readers without prior information on length and sex. Scale reading was carried out at the anterior field using binocular lenses (10×).

The obtained length at age was compared with previous studies carried out in different areas with clustering analysis based on Ward's Method (Everitt, 1980). Specimens were measured and weighed. Fork length was determined to the nearest centimeter. total weight was taken by electronic balance to 0.01g accuracy. Data were pooled monthly and subsequently grouped into length classes at 1cm intervals; length-frequency data were analyzed using FISAT software (Gayanilo *et al*., 1996).

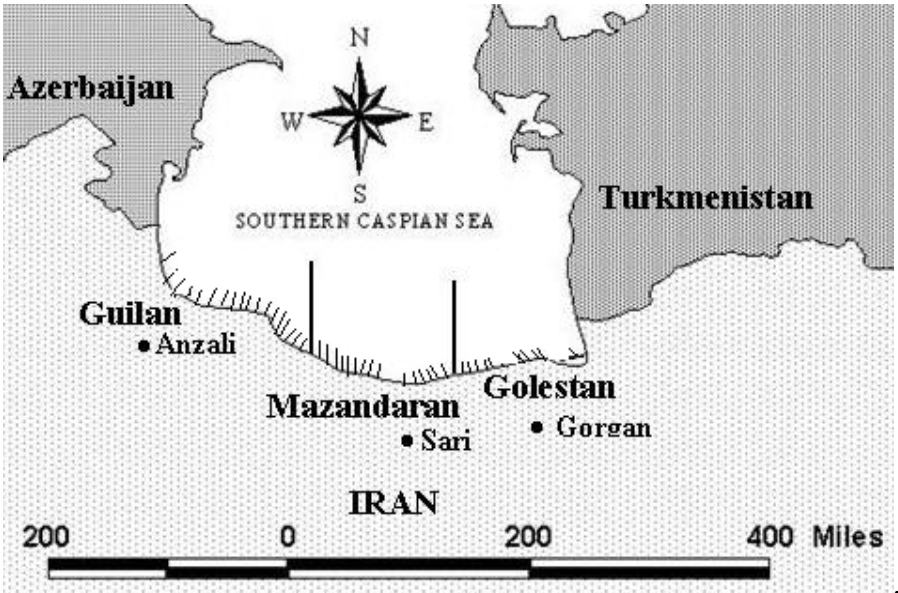

Figure 1. The sampling area (dashed) of common carp in the southern Caspian Sea

Length–Weight relationship was estimated $t_{max} = -LN(1-0.95)/K + t_0 \sim 3/K$

using the potential model ($W=a\times L^b$). To establish the length–weight relationship, the commonly used linear equation Log W= Log a + b Log L was applied (Ricker, 1975), where W is the weight (g), L is the fork length (mm) and Log a and b are constants.

Parameters a and b were calculated by least-squares on log-transformed data. The comparison of the estimated gradients for males and females was carried out via covariance analysis (ANCOVA, $P\leq 0.05$). Deviation of the allometric coefficient b from the theoretical value of isometric growth (b=3) was tested by t-test (Underwood, 1997).

Based on the assumption that fish growth follows the Von Bertalanffy's growth function (1938), which has the basic form $L_t=L\infty[1-\exp^{(-K(t-t_0))}]$, estimates of the growth parameters, the asymptotic length ($L\infty$) and the growth coefficient (K), were derived using FISAT (Gayanilo *et al*., 1996). Pauly's (1979) empirical equation for the theoretical age at length zero (t_0) was used to obtain this parameter as:

$$\log_{10}(-t_0)= -0.392-0.275 \log_{10} L\infty -1.038 \log_{10} K$$

The reliability of these growth parameters was tested applying the growth performance index Φ' (or "Munro's phi prime") which was computed from the equation (Pauly & Munro, 1984):

$$\Phi' = \text{Ln } K+2 \text{ Ln } L\infty$$

The age corresponding to 95% *Linf* is a good predictor of maximum age *tmax* (Taylor, 1958).

Total annual mortality rate, Z, was estimated by constructing linearized length-converted catch curves (Sparre & Venema, 1992). Natural morality rate, M, was computed by the empirical equation of Pauly (1980) using a mean annual surface temperature (T) of 14°C.

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

The fishing mortality rate, F, was calculated as Z−M and exploitation ratio (E) found as E=F/Z (Sparre & Venema, 1992).

Results

Of the 328 specimens measured, 198 were females (60.4%) and 130 males (39.6%) and based on Chi square test analysis, there was significant difference from normal ratio 1:1. Fork length ranged from 6.3 to 65.6 cm in females and 9.9 to 56.3cm in males (Fig. 2). There was a significant difference between maximum length among different sexes. Males reached a maximum size of 56.3cm and 2.9kg, whereas, the maximum size of females was 65.6 cm and 5.6kg. Overall, the mean FL for female was higher than that in males (Kolmogorov–Smirnov test, $P<0.05$).

FL–W relationship was separately evaluated for females and males. While the b-values of males and females implied that the body shape of the males and females displayed allometric form. The results by applying the t-test showed that the body shape of females is allometric ($P>0.01$). Also, length–weight relationships between males and females were significant different ($P<0.01$).

The respective length–weight relationship by sex are presented in Figs. 3 and 4, respectively. The calculated length–weight equations were $W=0.00004\ L^{2.8432}$ ($r^2=0.9794$, n=130); $W=0.00003\ L^{2.9249}$ ($r^2=0.9847$, n=198) and $W=0.00003\ L^{2.8947}$ ($r^2=0.9828$, n=328) in males, females, and males & females, respectively.

The aging of scale reading in males and females were presented in tables 1 & 2 respectively. The mean fork length for each age group in females was higher than that in males.

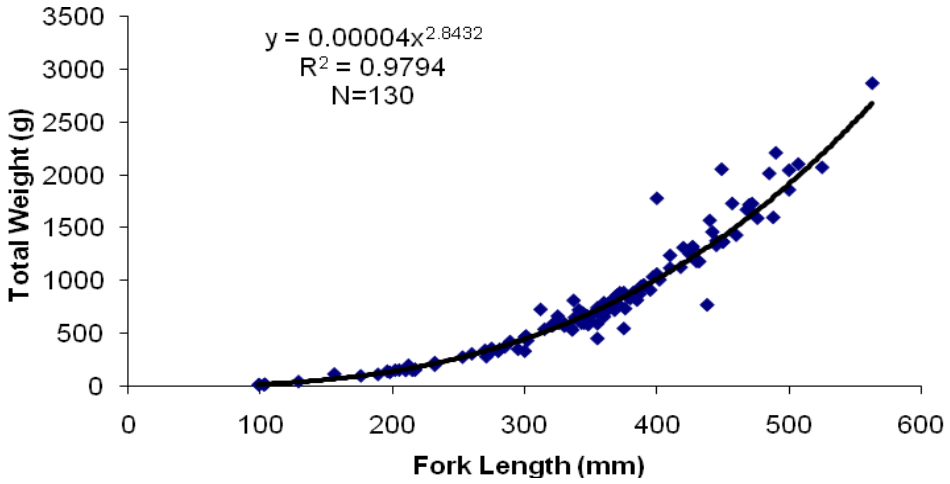

Figure 2: Length–weight relationship for male *C. carpio* in Iranian coastal waters of the Caspian Sea

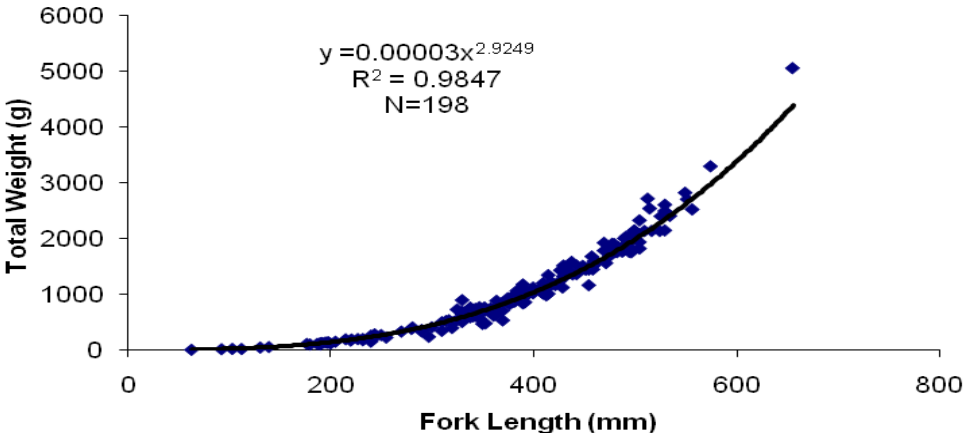

Figure 4: Length–weight relationship for female *C. carpio* in Iranian coastal waters of the Caspian Sea

Table 1: The mean fork length (cm) at each age group of male common carp in Iranian coastal waters of the Caspian Sea

Age (year)	Frequency (N)	Mean FL (cm)	SD
1	8	13.7	4.3
2	12	21.2	2.3
3	16	29.3	2.3
4	23	34.0	2.9
5	34	36.6	2.1
6	23	42.8	2.9
7	7	46.2	2.4
8	6	49.6	1.9
9	-------	-------	-------
10	1	56.3	-------

Table 2: The mean fork length (cm) at each age group of female common carp, in Iranian coastal waters of the Caspian Sea

Age (year)	Frequency (N)	Mean FL (cm)	SD
1	13	15.0	4.6
2	14	22.3	1.7
3	27	30.5	3.2
4	28	35.3	1.6
5	32	38.3	2.2
6	32	43.1	3.1
7	28	47.8	2.6
8	19	50.7	2.5
9	4	56.3	3.2
10	1	65.6	------

For growth parameter estimation, the data set of 328 individuals was used to calculate Von Bertalanffy growth parameters, which was shown by sexes and combined in Table 3. When mean length observed at each age (both in male and female) is compared with that obtained from the theoretical growth curve (Figs. 5 and 6, respectively), a close similarity of both data sets was evident. The agreement of these data sets suggested that the von Bertalanffy theoretical growth curve was consistent with actual growth.

The length frequency distributions output in males and females based on FISAT analysis were shown in Figs 7 and 8, respectively. A summary of the estimated parameters (K, L_∞ and t_0) and derived growth performance index (Φ') were presented in Table 4.

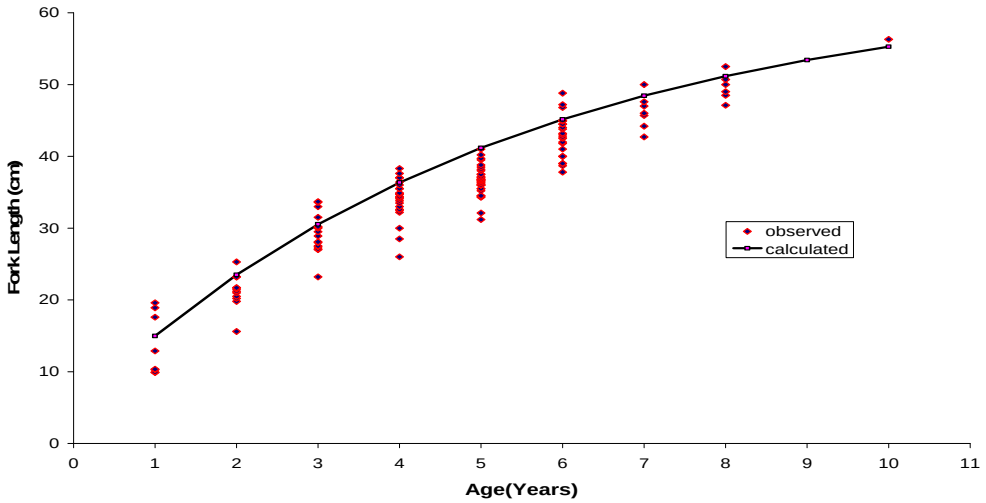

Figure 5: Von Bertalanffy growth curve of common carp (male), in Iranian coastal waters of the Caspian Sea

Table 3: The Von Bertalanffy growth parameters for male, female and combined sexes of common carp in Iranian coastal waters of the Caspian Sea (2006-07)

	Parameters	Estimates	s.e. of estimates	C.v. of Estimates
Male	FL_∞ (cm)	70.54	6.77	0.09
	K (per year)	0.15	0.03	0.20
	t_0 (year)	0.40	0.27	-0.68
Female	FL_∞ (cm)	72	13.5	0.18
	K (per year)	0.15	0.08	0.56
	t_0 (year)	-0.40	0.27	-1.90
Male & Female	FL_∞ (cm)	71.52	10.2	0.14
	K (per year)	0.16	0.05	0.32
	t_0 (year)	-0.30	0.43	-1.44

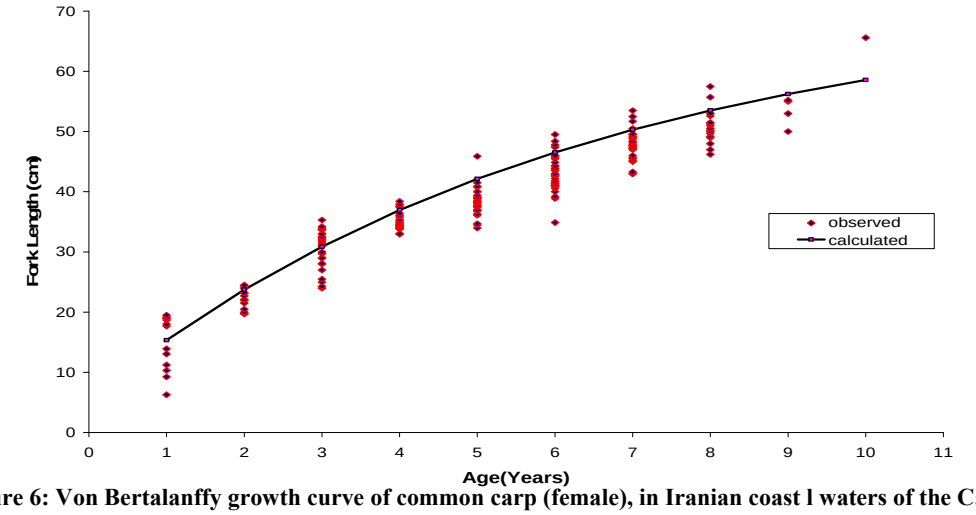

Figure 6: Von Bertalanffy growth curve of common carp (female), in Iranian coast l waters of the Caspian Sea

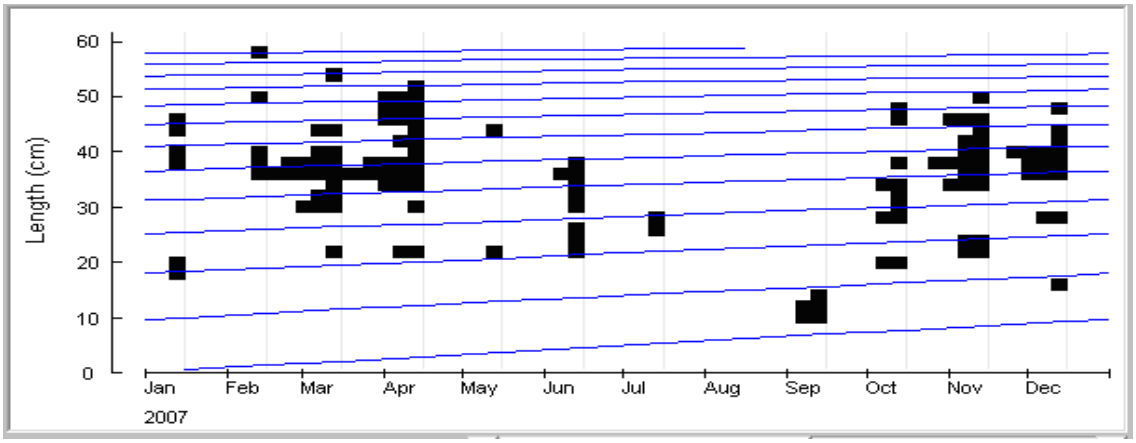

Figure 7: Length frequency distribution output from FISAT with superimposed growth curves in male *C. carpio* in Iranian coastal waters of the Caspian Sea. L∞=69.3cm; K=0.15yr−1

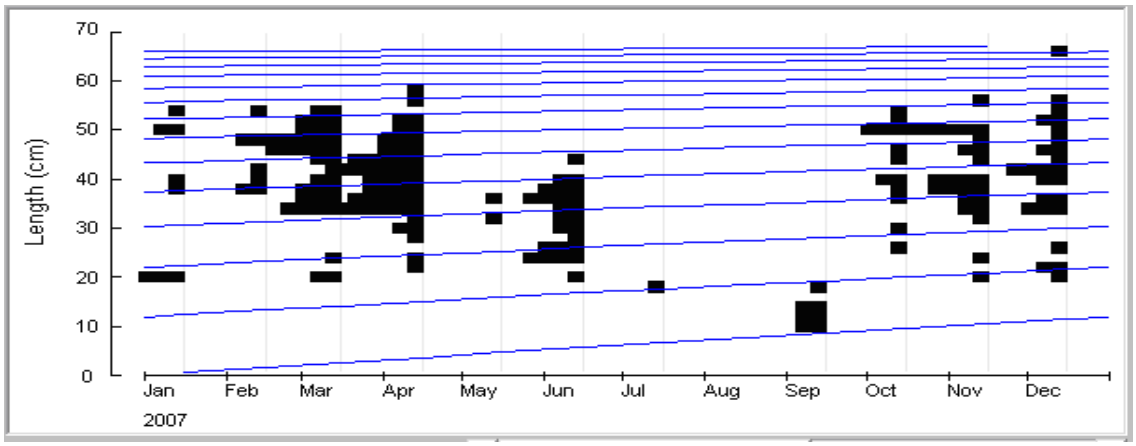

Figure 8: Length frequency distribution output from FISAT with superimposed growth curves in female *C. carpio* in Iranian coastal waters of the Caspian Sea. L_{∞}=73.0cm; K=0.18 yr−1.

Table 4: Estimated population dynamics parameters of *C.carpio*, in Iranian coastal waters of the Caspian Sea in 2006- 07(by LFA)

Parameters	male & female	male	Female
$L\infty$ (FL,cm)	72.0	69.3	73.0
K(yr-1)	0.18	0.15	0.18
*t*0 (yr)	-0.65	-0.25	-0.25
Φ'	2.97	2.86	2.98

Using the estimated value of the average growth coefficient, K, the longevity (t_{max}=3/K) was found to be about 16 years (Table 4) and the von Bertalanffy growth model for the species, irrespective of their sex, was described as

L_t=72 [1−exp(−0.18(t+0.25))]

The inverse Von Bertalanffy growth equation was used to find the lengths of the fish at various ages presented in Table 5. The species attained at least 50% of the asymptotic length at the 5th age class indicating growth in length at the early age class (Table 5).

Total mortality coefficient (Z) was estimated for male, female and combined as 0.75, 0.81 and 0.71 year^{-1}, respectively, using the length converted catch curve (Figs. 9 & 10). Natural mortality (M) was calculated in males, females and combined as 0.30, 0.33 and 0.29 year^{-1}, respectively and fishing mortality (F) was calculated as 0.45, 0.48 and 0.42 year-1, in males, females and combined, respectively (Table 6). From these figures, an exploitation rate (E) was obtained for male, female and combined as 0.61, 0.59 and 0.59 year$^{-1,}$ respectively, which seemed to be higher than the expected optimum level of exploitation (E=0.50).

Table 5: Calculated age-length data for *C. carpio* based on its respective Von Bertalanffy growth equation

Age Class(yr)	Mean FL (cm)	% of L_∞
1	14.5	20
2	21.8	30
3	30.1	42
4	34.7	48
5	37.4	52
6	43.0	60
7	47.5	66
8	50.5	70
9	56.3	78

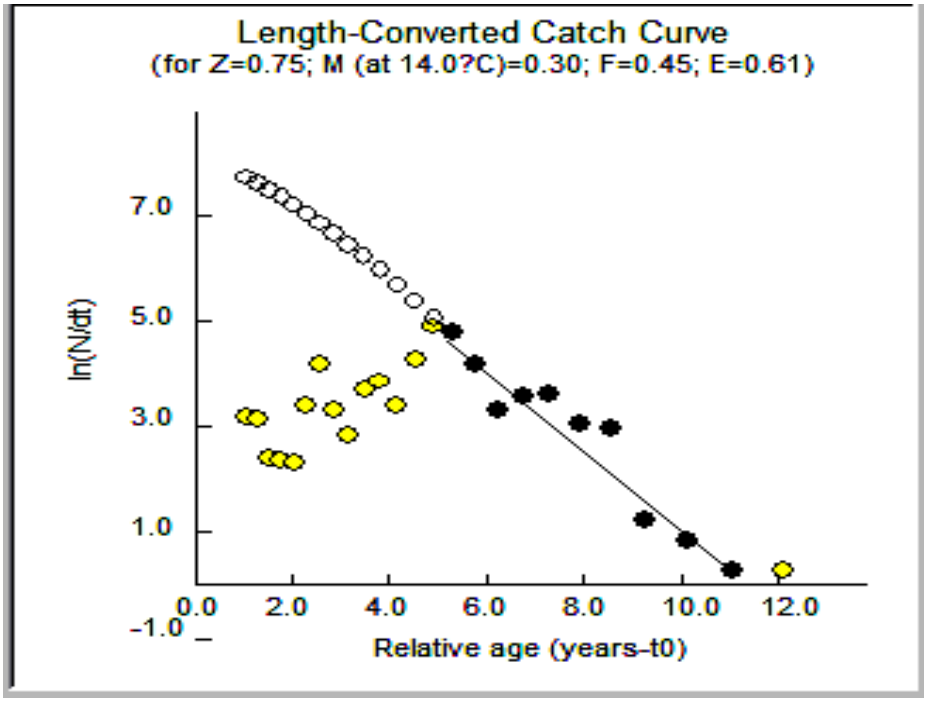

Figure 9: Length converted catch curve of *Cyprinus carpio* (male) in Iranian coastal waters of the Caspian Sea. (Solid dots used in calculating through least square linear regression. open dots either not fully recruited or nearing L_∞)

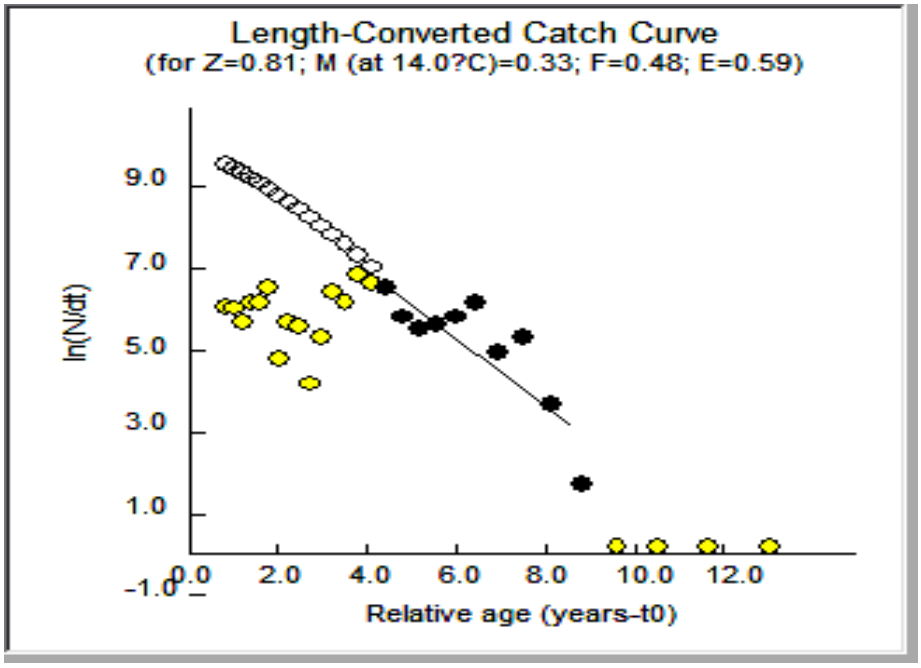

Figure 10: Length converted catch curve of *Cyprinus carpio* (female) in Iranian coastal waters of the Caspian Sea. Solid dots used in calculating through least square linear regression. Open dots either not fully recruited or nearing L_∞.

Table 6: Estimates of instantaneous rates of total mortality (Z), natural mortality (M) and fishing mortality (F) for each of the sex

Sex	*Z* (year^{-1})	*M*(year^{-1})	*F* (year^{-1})	*E*
Female	0.81	0.33	0.48	0.59
Male	0.75	0.30	0.45	0.61
Combined	0.71	0.29	0.42	0.59

Discussion

In a Length–weight relationship (of the form of W=a×Lb), it is the value of b which is interesting. The L-W relationship equations for males, females and combined sexes given by Alp & Balik, 2000, are as below:

Females: $W=0.00258\ L^{2.8676}$

Males: $W=0.0243\ L^{2.8874}$

Females & Males: $W=0.0252\ L^{2.8739}$

The length-weight relationship of the carp population in lake Karamik was $W=0.0245\ L^{2.952}$ ($r^2=0.996$) (Balik *et a*l., 2006), Whereas in the present study b=2.8947 in combined sexes. In all studies, the calculated b values were lower than 3 and Estimated asymptotic fork length (FL_∞) is 69.3 to 73.0 cm and growth co-efficient (k) is 0.15 to 0.18 year^{-1}. Comparisons with growth parameters from other studies (Table 9) show that there are considerable differences among *C. carpio* populations. The highest value of FL_∞ (73.0 cm) was observed in the present study; the lowest value (33.77) was in the Gulf of Lyon (Girardin and Quignard, 1986). The highest value of K (0.19 year^{-1}) was obtained in the Gulf of Lyon; the lowest value (0.08 year^{-1}) in the Gulf of Lyon (Girardin, 1981). These different growth coefficients among common carp populations are due to dissimilar ecological characteristics in the Caspian Sea and the Gulf of Lyon.

LFA, length frequency analysis; L_∞, asymptotic mean fork length; K, growth rate; t_0, hypothetic age at zero length.

Z rate among higher that 25cm long carp stock was estimated as 0.40±0.003 year^{-1} (±95% CI) based on the length-based linearized catch curve method in Lake Karamik (Afyonkarahisar/Turkey) (Balik *et al*., 2006), whereas in the present study it was estimated 0.71-0.81 for higher than 20 cm long fish.

Using L∞=130cm, k=0.0754 year^{-1} and T=14 c values, the natural mortality (M) rate of the carp stock was calculated to be 0.16 year^{-1}, the F and E rates were also calculated as 0.24 year^{-1} and 0.60 year^{-1}, respectively (Balik *et al*., 2006).

Total mortality (Z) in this study for combined sexes was 0.71, but Karatas *et al*., (2007) estimated Z as 0.64 year^{-1}. In this study, natural and fishing mortalities were estimated 0.33 and 0.42, respectively but Karatas *et al*., 2007 estimated both rates as 0.32. Estimated E equals to 0.50 indicated that there is not any fishing pressure on carp population in Almus Dam Lake, whereas in the present study E equals to 0.59 and it

shows a relatively more exploitation compare to normal value of 0.5. Therefore, no increasing of fishing effort is proposed.

Table 9: Von Bertalanffy growth parameters and growth performance indices (ϕ') obtained in studies of *C. carpio*

Author	Location	Method	FL∞(cm)	*K* (per year)	t_0 (year)	ϕ'
Girardin (1978)	Gulf of Lyon	Scale	46.06	0.15	−0.87	2.50
Girardin (1981)	Gulf of Lyon	Otolith	46.50	0.08	−3.54	2.24
Anato and Ktari (1986)	Tunisia	Otolith	39.60	0.11	−1.69	2.24
Girardin and Quignard (1986)	Gulf of Lyon	Scale	33.77	0.19	−0.75	2.34
Alp and Balik (2000)	Turkey (Golhisar Lake)	LFA	72.76	0.17	−0.44	6.82
Gordo (1992)	S Portugal	Otolith	43.53	0.14	−2.40	2.43
	W Portugal	Otolith	42.39	0.15	−2.29	2.43
Present study	Caspian Sea	LFA (male)	69.3	0.15	−0.25	2.86
Present study	Caspian Sea	LFA (female)	73	0.18	−0.25	2.98
Present study	Caspian Sea	LFA (combined)	72	0.18	−0.25	2.97
Present study	Caspian Sea	Scale (male)	70.54	0.15	−0.40	2.87
Present study	Caspian Sea	Scale (female)	72	0.15	−0.40	2.89
Present study	Caspian Sea	Scale (combined)	71.52	0.16	0.30	2.91

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