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Age determination, growth indices and reproduction biology of Prussian carp, *Carassius gibelio* (Bloch, 1782) from four reservoirs in Golestan Province, Southeast Caspian Sea

Eisa Hajiradkouchak[1], Rahman Patimar[1*], Mohammad Harsij[1], Rasoul Ghorbani[2]

1. Department of Fishery, Faculty of Natural Resource, University of Gonbad Kavous, Gonbad Kavous, Iran
2. Department of Fishery, Faculty of Agriculture and Natural Resource of Gorgan, Gorgan, Iran

** Corresponding author's E-mail: rpatimar@yahoo.com*

ABSTRACT

This study aimed to determine age and growth indices of Prussian carp, *Carassius gibelio* collected a total of 942 specimens on a monthly basis from February through September 2015 in three dam lakes including Golestan, Boostan and Voshmgir and one reservoir named Alakoli from the Southeast Caspian Sea. The largest specimen was a female with 220 mm in total length (TL) and 139.787 g in weight from Voshmgir. The maximum condition factor of the fish increased markedly during late April- August in all areas. Growth pattern was positive allometric in females from Alakoli, while negative allometric in females from Golestan, Boostan and Voshmgir and also in males from Voshmgir. The isometric growth observed in males from Golestan and Boostan as well as from Alakoli. The growth parameters of von Bertalanffy fit to the mean observed total lengths-at-age for each sex separately were estimated as L_∞= 378.09 mm, K= 0.12, t_0= -0.35 for females, L_∞= 309.38 mm, K= 0.17, t_0= -0.02 for males, and as L_∞= 355.74 mm, K= 0.13, t_0= -0.35 for total population in Golestan; L_∞= 299.06 mm, K= 0.18, t_0= -0.10 for females, L_∞= 574.17 mm, K= 0.07, t_0= -1.04 for males, and as L_∞= 338.43 mm, K= 0.15, t_0= -0.34 for total population in Boostan; L_∞= 296.37 mm, K= 0.20, t_0= -0.20 for females, L_∞= 186.23 mm, K= 0.51, t_0= -0.42 for males, and as L_∞= 302.94 mm, K= 0.19, t_0= -0.18 for total population in Voshmgir; and L_∞= 347.99 mm, K= 0.04, t_0= -0.12 for females, L_∞= 530.92 mm, K= 0.01, t_0= -0.18 for males, and as L_∞= 477.73 mm, K= 0.01, t_0= -0.40 for total population in Alakoli. A prolonged spawning period was observed from April through August. Maximum egg diameter and absolute fecundity were 1.39 mm and 72865 oocytes in population inhabiting Voshmgir respectively.

Key words: *Carassius gibelio*, Length-weight relationship, VBGF, Reproduction, Southeast Caspian Sea.

INTRODUCTION

The Prussian carp, *Carassius gibelio* inhabits freshwater waterbodies, ponds, streams, lakes and has wide geographic distribution from northern Europe to Asia (Jiang *et al*. 1983; Abramenco *et al*. 1998; Kalous *et al*. 2004). Global awareness about species introductions and invasive species are increasing recently. According to International Union for Conservation of Nature (IUCN) organisms anthropogenically introduced in new areas out of their natural distribution area and with establishment and dispersion causing a negative impact on local ecosystems are considered as invasive species. Spreading of these non-native species and their impact on local ecosystems were reported by many authors (Innal & Erk'akan 2006; Gaygusuz *et al.* 2007; Tarkan *et al.* 2012). Biological invasions have caused considerable distribution to native ecosystems around the world (Rainbow 1998; Williamson 1999; Money & Hobbs 2000). *C. gibelio* is known as one of the most hazardous fish species for native fish communities (Crivelli 1995; Kalous *et al*. 2004).

This species entered into the lakes and ponds in Northern Iran and gained importance because it became one of the most dominant exotic species in the environment in a short time. No comprehensive bio-ecological study exists currently on this species in Northern Iran. So, this study aimed to investigate growth and reproductive characteristics of the species in four waterbodies of Golestan Province, the Southeast Caspian Sea.

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MATERIALS AND METHODS

Gorganroud River Basin is the largest one in the northeastern of Golestan Province which originate at the continental divide of the Golidagh Mountains and flow to the Southeast Caspian Sea. There are four dams on the river. The most important tributaries are dam lakes including Golestan, Boostan and Voshmgir and also a reservoir named Alakoli. We collected specimens from the Golestan (55°16′ E, 37°19′ N), Boostan (55°25′ E, 37°47′ N) and Voshmgir (54°46′ E, 37°13′ N) and also Alakoli (54°55′ E, 37°14′ N).

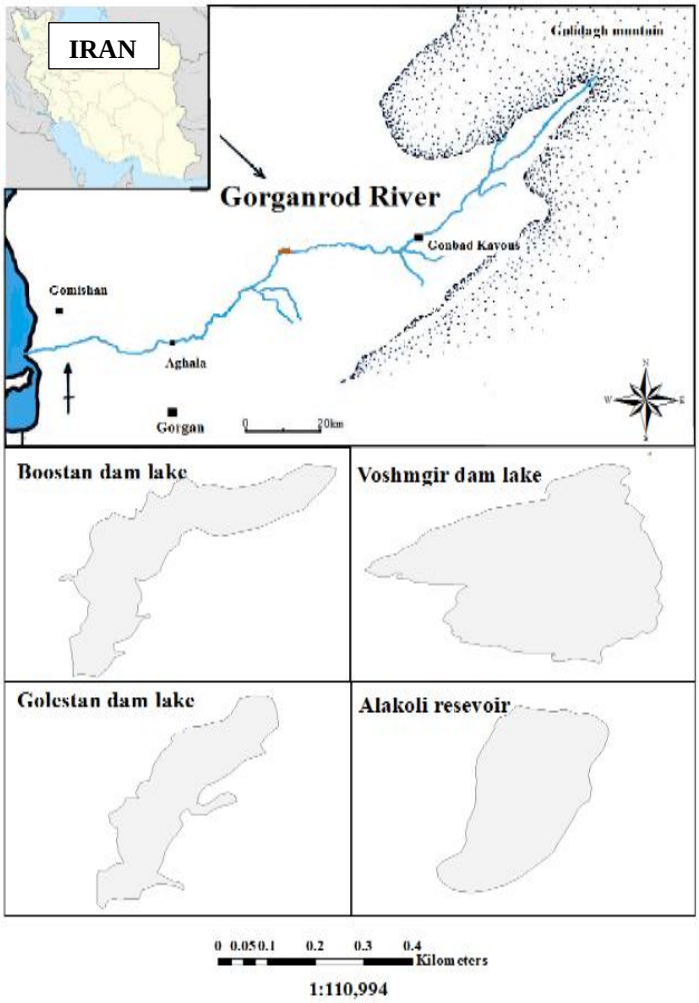

Fig. 1. Study area, the Southeast Caspian Sea.

A total of 942 Prussian carp, *C. gibelio* collected from the areas were used for age determination, growth indices and reproduction biology on the monthly basis from February through September 2015. The samples fixed in 10% formaldehyde were studied in the laboratory. Length was measured to the nearest 1 mm and weight to the nearest 0.001 g. Scales taken from the fish body between dorsal and ventral fins, were used for age determination. Fish sex was determined using macroscopic and microscopic examinations. Power regression was used to calculate the relationship between total length and total weight (Ricker, 1975):

$W = aTL^b$

Where a is intercept and b is slope of equation. The growth pattern was determined using least squares method ($SSQ = \sum(Y - (a + bX)^2)$. Parameters *a* and *b* of the weight-length relationship was estimated by linear regression analysis based on logarithms. In this equation, *W* is weight in g, *TL*, total length in mm, *b* regression slope and *a* the regression intercept (Le Cren 1951; Ricker 1975; Froese 2006; Froese & Binohlan 2000). Growth pattern (isometric or allometric) confirmed using Pauly's t-test:

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

Condition factor (CF) and instantaneous growth rate (G) were calculated using the following equations:

$CF = (W / TL^b) \times 100 \quad G = (Lnw_{t+1} - Lnw_t) / \Delta T$

Where *W* and *TL* are total weight and total length respectively; *Wt*: total weight at age *t*; *Wt+1*: total weight at age *t+1*. Von Bertalanffy's growth equation was calculated by the least squares method for length observed at each age (Ricker 1975; Sparre & Venema 1989; Erkoyuncu 1995):

$L_t = L_\infty[(1\text{-}e^{-k(t\text{-}to)}]$

Where L_t is the fish length at age *t*; L_∞ represent the asymptotic length; *k* is a relative growth coefficient and t_0 theoretical age when fish length is zero. Determined equation using Ford- Walford plot: $L_{(t+\Delta T)} = a + bL_t$. In this equation, K and L_∞ are $L_\infty = \frac{a}{1-b}$, $k = \frac{-Lnb}{\Delta t}$. Additionally t_0 and Ø´ were calculated based on $t_0 = t + Log_e \frac{1}{k} \frac{(L\infty - Lt)}{L\infty}$, $Ø' = Ln\ k + 2\ Ln\ L_\infty$ (Pauly & Monroo 1984).

Gonadosomatic index (GSI) was determined on a monthly basis according to the following equation:

$GSI = (w_1 / W) \times 100$

Where *W* is the total weight and w_1 is the gonad weight. The absolute and relative fecundities were determined by weight method using three pieces removed from anterior, posterior and middle parts of the ovaries. Mean GSI values were calculated monthly from February through September.

Analysis of variance (ANOVA) was used to evaluate the monthly differences of growth and reproduction parameters. Inter-sexual differences in growth and reproduction parameters tested by student t-test. All analyses have been done by sexes separately using Excel 2015 and SPSS ver. 22 software.

RESULTS

In the present study, a total of 942 *C. gibelio* specimens were collected from the study areas. The females and males included 225 (91.09%) and 22 (8.91%) in Golestan; 197 (88.74%) and 25 (11.26%) in Boostan; 190 (91.35%) and 18 (8.65%) in Voshmgir as well as 218 (91.60%) and 20 (8.40%) in Alakoli. The overall sex ratio (M: F) was unbalanced in favor of females ($p < 0.05$) as 1: 0.10 in Golestan ($\chi^2 = 166.84$); 1: 0.13 in Boostan ($\chi^2 = 133.26$); 1: 0.09 in Voshmgir ($\chi^2 = 142.23$); and also 1: 0.09 in the Alakoli ($\chi^2 = 164.72$). Descriptive statistics of collected samples are presented in Table 1. As shown in the Table, the largest specimen was caught in Voshmgir, with 280.60 g in weight and 220 mm in total length (TL). Mean of fish size (TL and W) was larger in Voshmgir and Alakoli than in Golestan and Boostan (Table 2).

Table 1. Mean observed length (mm) and weight (g) of Prussian carp (*C. gibelio)* from study areas, the Southeast Caspian Sea.

Location	Genus	Number	TL ± S.D	Max – Min	TW ± S.D	Max – Min
Golestan Dam Lake	Female	225	95.37 ± 48.94	196 – 41	90.23 ± 53.21	141.35 – 1.28
	Male	22	79.32 ± 91.82	156 – 42	31.13 ± 91.12	52.42 – 1.25
	population	247	60.37 ± 45.93	196 – 41	26.23 ± 76.20	141.35 – 1.28
Boostan Dam Lake	Female	197	87.31 ± 58.105	206 – 33	61.20 ± 28.23	141.12 – 0.83
	Male	25	83.14 ± 80.95	126 – 67	59.6 ± 79.14	33.90 – 4.42
	population	222	56.30 ± 48.104	206 – 33	71.19 ± 32.22	141.12 – 0.83
Voshmgir Dam Lake	Female	190	21.40 ± 47.37	220 – 44	85.40 ± 50.51	280.60 – 1.73
	Male	18	51.28 ± 17.131	179 – 85	18.20 ± 65.35	81.75 – 9.03
	population	208	32.39 ± 92.136	220 – 44	71.39 ± 13.50	280.60 – 1.73
Alakoli reservoir	Female	218	20.39 ± 47.36	240 – 44	98.40 ± 49.51	114.65 – 1.67
	Male	20	27.33 ± 60.88	190 – 51	32.23 ± 29.15	98.64 – 2.58
	population	238	01.32 ± 41.104	196 – 43	52.21 ± 30.23	114.65 – 1.67

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Table 2. Age and sex distribution of Prussian carp (*C. gibelio)* from study areas, the Southeast Caspian Sea.

Location	Age	Population		Male		Female	
		N	%	N	%	N	%
	I	51	20.65	8	2.83	43	17.41
Golestan	II	150	60.73	11	4.46	139	56.27
Dam Lake	III	11	4.45	2	0.81	9	3.64
	IV	21	8.50	1	0.40	20	8.10
	V	13	5.26	-	-	13	5.26
	VI	1	0.40	-	-	1	0.40
	I	38	17.11	3	1.34	35	15.77
Boostan	II	136	61.26	20	9.01	116	52.25
Dam Lake	III	24	10.81	2	0.90	22	9.91
	IV	14	6.30	-	-	14	6.30
	V	9	4.05	-	-	9	4.05
	VI	1	0.45	-	-	1	0.45
	I	22	10.58	-	-	22	10.58
Voshmgir	II	44	21.15	8	3.84	36	17.31
Dam Lake	III	31	14.90	1	0.48	30	14.42
	IV	73	35.10	9	4.33	64	30.77
	V	35	16.83	-	-	35	16.83
	VI	3	1.44	-	-	3	1.44
	I	71	31.14	10	5.51	61	25.63
Alakoli	II	83	36.40	8	3.36	75	31.51
Reservoir	III	43	18.86	-	-	43	18.86
	IV	38	16.67	1	1.12	37	15.55
	V	3	1.32	1	0.48	2	0.84
	VI	-	-	-	-	-	-

Table 3. Mean observed total length (cm)-at-age of Prussian carp (*C. gibelio)* from study areas, the Southeast Caspian Sea.

Location	Age	N (%)	Max	Min	Mean±SD
	I	20.65	8.9	4.2	5.42 ± 1.16
Golestan	II	60.73	14.9	4.1	8.97 ± 2.59
Dam Lake	III	4.45	13.2	12.0	12.62 ± 3.54
	IV	8.50	16.1	13.4	14.58 ± 4.41
	V	5.26	19.3	15.4	17.01 ± 5.38
	VI	0.40	-	-	19.6 ± 0.00
	I	17.11	8.7	3.3	5.67 ± 1.21
Boostan	II	61.26	12.2	7.9	10.47 ± 2.72
Dam Lake	III	10.81	14.0	12.0	12.77 ± 3.65
	IV	6.31	15.9	14.1	14.77 ± 4.69
	V	4.05	18.5	16.6	17.68 ± 5.54
	VI	0.45	-	-	20.60 ± 0.00
	I	10.58	6.9	4.4	5.73 ± 1.77
Voshmgir	II	21.15	12.3	8.5	10.68 ± 2.72
Dam Lake	III	14.90	14.5	11.9	12.96 ± 3.85
	IV	35.10	17.9	13.9	15.76 ± 4.76
	V	16.83	20.9	16.5	18.02 ± 5.45
	VI	1.44	22.0	19.0	20.83 ± 5.60
	I	29.83	7.9	4.3	6.84 ± 1.18
Alakoli	II	34.87	11.9	7.7	10.02 ± 2.35
Reservoir	III	18.07	13.1	11.0	12.40 ± 3.14
	IV	15.97	17.4	13.2	15.20 ± 3.76
	V	3	19.6	18.1	18.90 ± 4.56
	VI	-	-	-	-

As shown in Table 3, mean observed total-lengths of *C. gibelio* were recorded as 4.2-19.6; 3.3-20.60; 4.4 - 22.00 and 4.3-18.90 cm in the Golestan, Boostan, Voshmgir and Alakoli respectively. The longest individual was a female with 22 cm in TL and 280.60 g in W across all areas. This was obviously observed that dominant length was between 4.1- 5.8 cm (35%) for population from the Golestan; 9.8- 11.4 cm (40%) for Boostan; 14.1- 16.0 cm (40%) for males and 14.1-18.0 (30%) for females from Voshmgir; and 5.5-7.3 (35%) for males

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and also 10.8-12.4 cm (25%) for females from Alakoli (Fig. 2). Females age were recorded between I and VI in the all areas (except for the Alakoli reservoir which females were between I and V); males age between I - IV, I – III, II – IV and I- V in the Golestan, Boostan, Voshmgir and Alakoli, respectively. It was observed that the dominant age was II in all areas, Golestan; 60.73%, Boostan; 61.26%, Voshmgir; 21.15%, Alakoli; 34.87%.

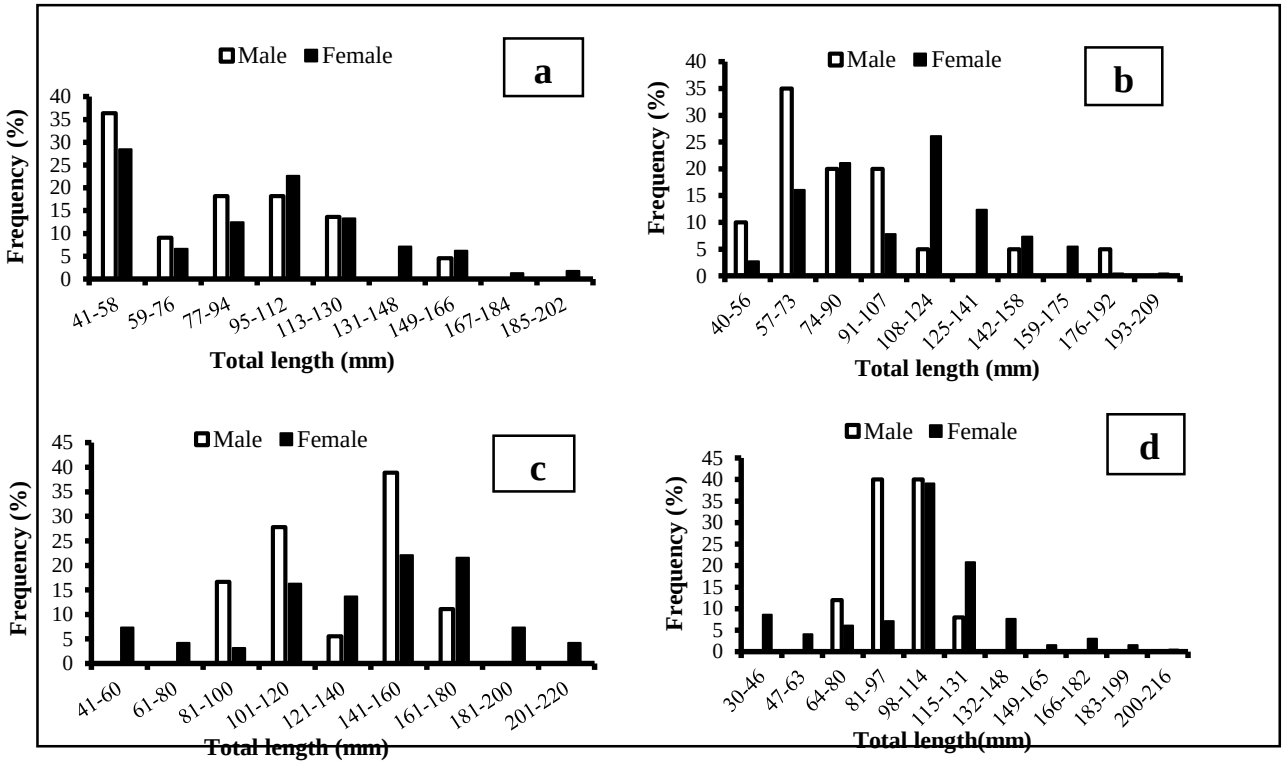

Fig. 2. Length-frequency distribution of Prussian carp *C. gibelio)* from Southeast Caspian Sea. a: Golestan, b: Boostan, c: Voshmgir dam lakes, d: Alakoli reservoir.

Table 4. Mean observed total weight of Prussian carp (*C. gibelio)* from study areas, Southeast Caspian Sea.

Area	Age	N	Max	Min	Mean ± SD
	I	51	12.18	1.25	3.26 ± 0.98
Golestan	II	150	74.71	1.28	15.41 ± 2.65
Dam Lake	III	11	42.14	28.76	33.08 ± 5.54
	IV	21	67.80	39.67	50.42 ± 4.78
	V	13	133.83	55.05	83.46 ± 5.69
	VI	1	-	-	141.35 ± 0.00
	I	38	13.16	0.83	4.17 ± 1.01
Boostan	II	136	31.41	6.60	18.10 ± 2.98
Dam Lake	III	24	47.43	23.55	33.01 ± 3.97
	IV	14	62.25	39.30	47.86 ± 6.69
	V	9	122.58	69.62	93.51 ± 11.54
	VI	1	-	-	97.92 ± 0.00
	I	22	5.80	1.73	3.78 ± 1.03
Voshmgir	II	44	29.58	9.03	20.60 ± 4.75
Dam Lake	III	31	53.89	27.88	34.73 ± 3.85
	IV	73	99.39	34.35	59.73 ± 4.75
	V	35	173.72	56.37	93.82 ± 5.36
	VI	3	280.60	186.79	238.83 ± 6.74
	I	71	8.06	1.67	4.79 ± 1.26
Alakoli	II	83	30.46	6.37	16.46 ± 7.06
Reservoir	III	43	39.75	17.84	30.07 ± 5.56
	IV	38	91.38	34.64	58.70 ± 12.94
	V	3	114.65	98.64	105.26 ± 8.37
	VI	-	-	-	-

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The weights of the individuals varied between 3.3 and 22.0 cm mean total length, 0.83 and 280.60 g total weight (Tables 3 - 4). Based on results (Table 3-4), mean length and weight of age groups were not different significantly in earlier ages. The differences were considerable among older age groups. Results of statistical analyses showed that there were statistically significant differences between mean lengths and mean weight among all areas ($p < 0.05$). Analysis of the average condition factor (CF) showed the highest CF belonged to the age group of VI (CF=2.41) from Golestan; that of V (CF=3.83) from Boostan; that of VI (CF=3.77) from Voshmgir and that of I (CF=2.04) from Alakoli, while the lowest values for that of IV (CF=2.02); that of VI (2.69); that of IV (CF=2.67) and V (CF=1.27) for the Golestan, Boostan, Voshmgir and Alakoli respectively (Table 5). There was a statistically significant difference between average condition factors among different sexes (ANOVA, $p < 0.05$). The length-weight relationship were found at: $W = 0.021\ L^{2.90}$ for females, $W = 0.017\ L^{2.97}$ for males and $W = 0.021\ L^{2.92}$ for total population in Golestan; $W = 0.031\ L^{2.71}$ for females, $W = 0.028\ L^{2.75}$ for males and $W = 0.031\ L^{2.71}$ for total population in Boostan; $W = 0.028\ L^{2.79}$ for females, $W = 0.028\ L^{2.74}$ for males and $W = 0.027\ L^{2.79}$ for total population in Voshmgir; and also $W = 0.013\ L^{3.08}$ for females, $W = 0.016\ L^{2.95}$ for males and $W = 0.013\ L^{3.07}$ for total population in Alakoli (Fig. 3) (Table 6). The results indicated that growth pattern was negative allometric for females in the Golestan, Boostan and Voshmgir ($p < 0.05$), while was positive for the other stations ($p < 0.05$). The isometric pattern was detected for males in the Golestan, Boostan and Alakoli ($p > 0.05$) (t-test). The annual specific growth rate decreased with age (Fig. 4). After the first year of life growth rate in females was higher than that in males from the Golestan and Voshmgir, whereas in females was lower than that in males from the Boostan and Alakoli. The von Bertalanffy length growth for total population of the species inhabiting Golestan, Boostan, Voshmgir and Alakoli were found to be $L_t = 35.57\ [1\text{-}e^{-0.13(t+0.35)}]$, $L_t = 33.84\ [1\text{-}e^{-0.15(t+0.34)}]$, $L_t = 30.29\ [1\text{-}e^{-0.19(t+0.18)}]$ and $L_t = 47.77\ [1\text{-}e^{-0.01(t+0.40)}]$ respectively. The Ø' values were calculated as 5.10, 5.003, 4.78 and 5.69 for Golestan, Boostan, Voshmgir and Alakoli respectively (Table 7).

Table 5. Mean condition factors-at- age groups of Prussian carp (*C. gibelio)* in study areas- Southeast Caspian Sea

Area	Age	CF(population)	N	CF(male)	N	CF(female)	N
	I	2.10	51	1.76	8	2.16	43
	II	2.09	150	1.97	11	2.10	139
Golestan	III	2.03	11	1.93	2	2.06	9
Dam Lake	IV	2.02	21	1.74	1	2.04	20
	V	2.11	13	-	-	2.11	13
	VI	2.41	1	-	-	2.41	1
	Total	2.13	247	1.85	22	2.15	225
	I	3.21	38	3.06	3	3.23	35
	II	3.08	136	3.05	20	3.08	116
Boostan	III	3.21	24	3.28	2	3.20	22
Dam Lake	IV	3.35	14	-	-	3.35	14
	V	3.83	9	-	-	3.83	9
	VI	2.69	1	-	-	2.63	1
	Total	3.22	222	3.13	25	3.22	197
	I	2.85	22	-	-	2.85	22
	II	2.73	44	2.80	8	2.77	36
Voshmgir	III	2.71	31	2.86	1	2.73	30
Dam Lake	IV	2.67	73	2.81	9	2.70	64
	V	2.87	35	-	-	2.86	35
	VI	3.77	3	-	-	3.76	3
	Total	2.93	208	2.82	18	2.95	190
	I	2.04	71	1.59	10	2.11	61
	II	1.30	85	1.27	8	1.30	77
Alakoli	III	1.32	41	-	-	1.32	41
Reservoir	IV	1.36	38	1.36	1	1.36	37
	V	1.27	3	1.17	1	1.32	2
	VI	-	-	-	-	-	-
	Total	1.46	238	1.35	20	1.48	218

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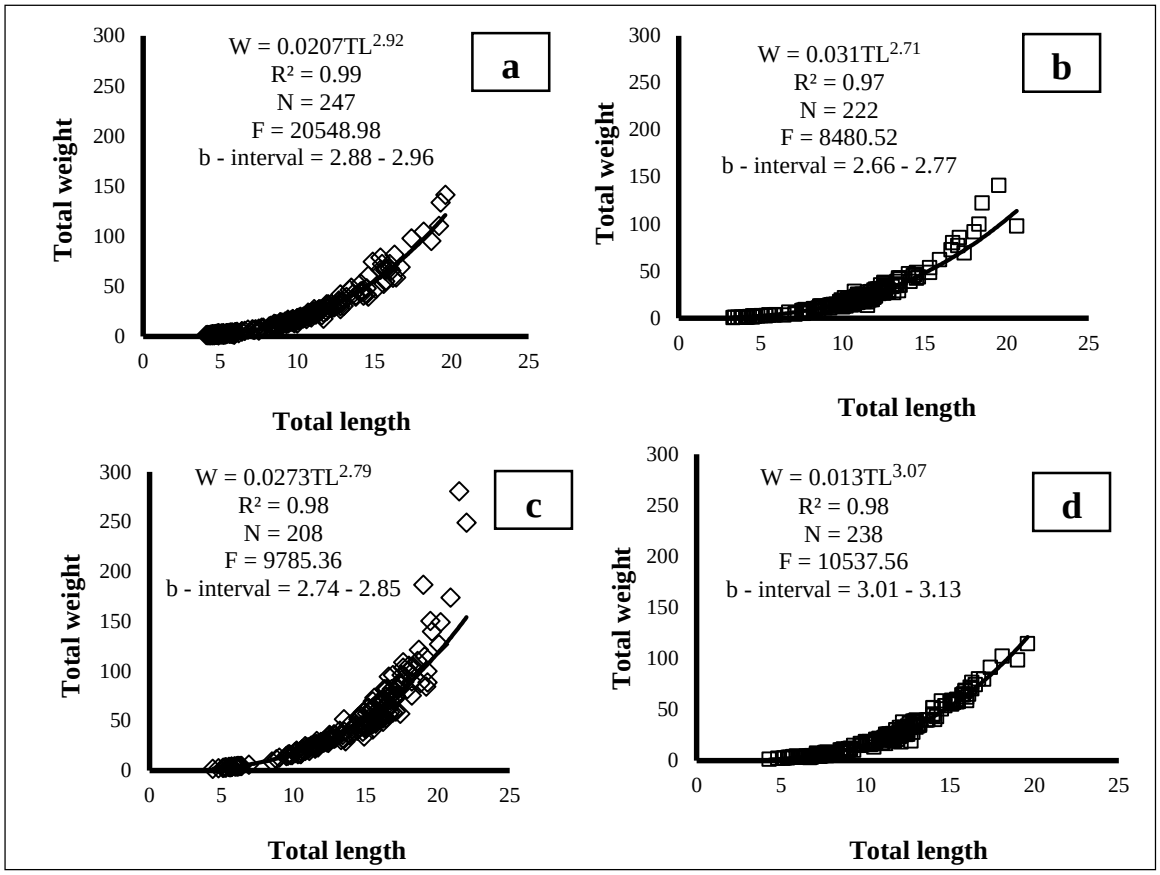

Fig. 3. Length-weight relationship for total population of Prussian carp (*C. gibelio)* from the study area, Southeast Caspian Sea. a: Golestan, b: Boostan, c: Voshmgir and d: Alakoli.

Table 6. Descriptive statistics and length–weight relationship parameters for males and females of Prussian carp (*C. Gibelio*) from the study areas, Southeast Caspian Sea.

Location	Genus	*n*	*a*	SE *(a)*	*b*	SE *(b)*	R^2	*p*
Golestan Dam Lake	Female	224	-3.85	0.05	2.90	0.05	0.99	<0.05
	Male	22	-4.09	0.02	2.97	0.04	0.99	<0.05
Boostan Dam Lake	Female	197	-3.46	0.07	2.71	0.03	0.98	<0.05
	Male	25	-3.59	0.04	2.75	0.04	0.91	<0.05
Voshmgir Dam Lake	Female	190	-3.59	0.07	2.79	0.04	0.98	<0.05
	Male	18	-3.59	0.03	2.74	0.03	0.97	<0.05
Alakoli Reservoir	Female	218	-4.35	0.07	3.08	0.06	0.98	<0.05
	Male	20	-4.11	0.03	2.95	0.05	0.97	<0.05

n = number of specimens, SE = standard error, *a* = intercept of the regression line, *b* = regression coefficient, R^2 = determination coefficient, *P* = *P*-value.

The gonadosomatic index (GSI) varied throughout in the study area (Table 8). There were significant differences between the males and females ($ANOVA_{Golestan}$: F = 30.61 df = 1, $p < 0.05$), ($ANOVA_{Boostan}$: F = 14.53 df = 1, $p < 0.05$), ($ANOVA_{Voshmgir}$: F = 33.73 df = 1, $p<0.05$), ($ANOVA_{Alakoli}$: F = 22.54 df = 1, $p < 0.05$). The maximum GSI of females observed for Golestan (12.20) and Voshmgir (11.15) in May, for Boostan (10.27) in March and for Alakoli reservoir (11.73) in February (Table 8), indicating the highest reproductive attained in the aforementioned months. While males showed different patterns, this reveals that both sexes do not spawn simultaneously in the stations. Egg diameter ranged from 0.11 to 1.39 mm in Golestan; from 0.11

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to 1.00 mm in Boostan; from 0.13 to 1.11 mm in Voshmgir and from 0.11 to 1.07 mm in the Alakoli, respectively. The highest egg diameter observed ranged from 0.71-0.80 (15.92%), 0.41-0.50 (19.41%), 0.31-0.40 (14.55%) and 0.61-0.70 (17.68%) in Golestan, Boostan, Voshmgir and Alakoli, respectively (Fig. 5).

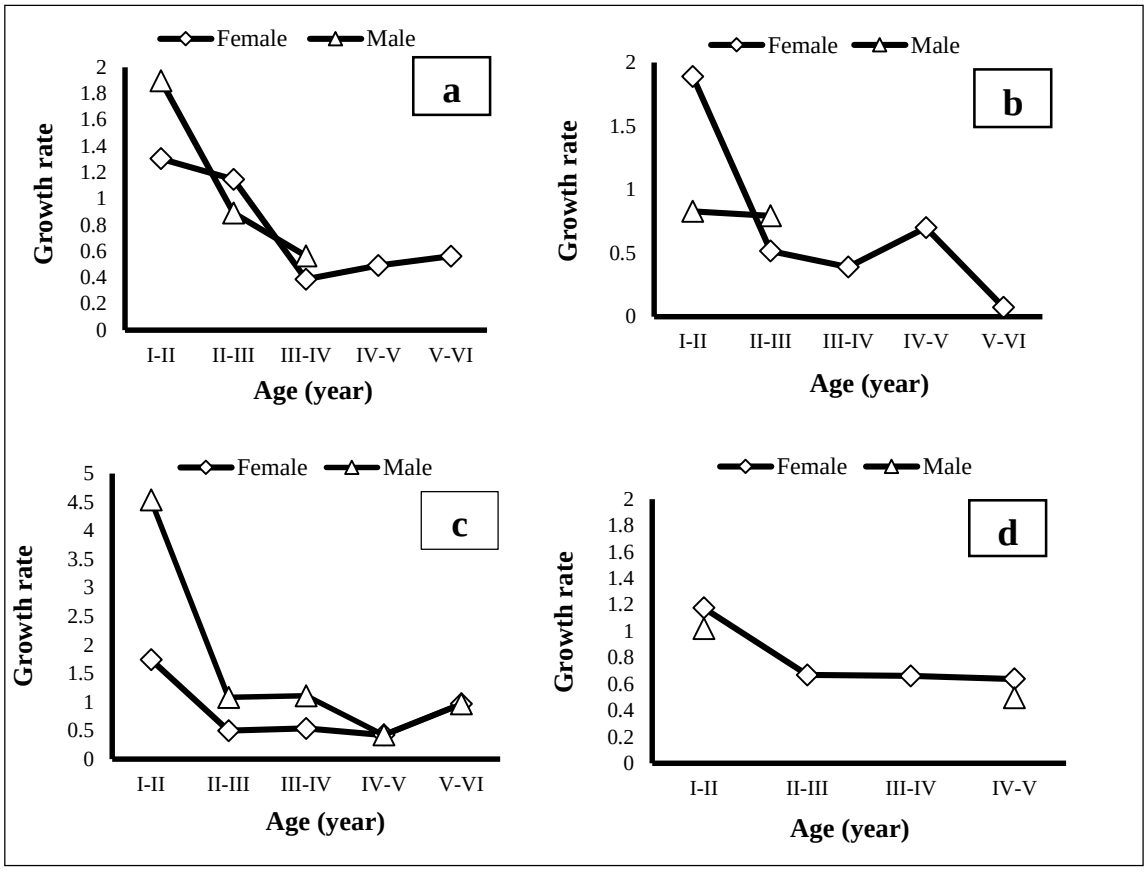

Fig. 4. Growth rates-at-age of Prussian carp (*C. gibelio*) from the study area, Iran. a: Golestan, b: Boostan, c: Voshmgir and d: Alakoli.

Table 7. Estimation of von Bertalanffy parameters for Prussian carp (*C. gibelio*) from the study area, Iran.

Location	Genus	L_∞ (cm)	K	T_0	Ø'
	Female	37.81	0.12	-0.43	5.22
Golestan	Male	30.94	0.17	-0.02	4.82
Dam Lake	Population	35.57	0.13	-0.35	5.10
	Female	29.91	0.18	-0.10	4.76
Boostan	Male	57.42	0.07	-1.04	3.81
Dam Lake	Population	33.84	0.15	-0.34	5.003
	Female	29.64	0.20	-0.20	4.74
Voshmgir	Male	18.62	0.51	-0.42	3.81
Dam Lake	Population	30.29	0.19	-0.18	4.78
	Female	34.80	0.04	-0.18	5.06
Alakoli	Male	53.09	0.01	-0.12	4.95
Reservoir	Population	47.77	0.01	-0.40	5.69

Majority of the population consisted of females and it is possible that it is a monosexual, triploid and gynogenetic form in all areas. Ovaries contained oocytes at different stages of development, indicating that the females could spawn several times during the reproductive period. Such asynchronous oocyte development classifies this fish as a multi-spawner.

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Table 8. Monthly variation in gonadosomatic index and mean fecundity of Prussian carp (*C. gibelio*), Southeast Caspian Sea.

Location	Month	GSI (%)		Mean AF
		Female	Male	
Golestan Dam Lake	Feb			
	Mar	5.20(3.97)	1.03(0.55)	5599.01
	Apr	8.02(4.44)	1.97(0.73)	12154.07
	May	12.01(3.83)	3.28(0.45)	20383.59
	Jun	12.20(2.96)	2.81(0.35)	19673.00
	Jul	9.66(3.51)	2.20(0.37)	8119.20
	Aug	6.68(5.20	2.96(0.08)	16526.60
	Sep	5.50(2.23)	1.33(0.26)	16345.15
		2.74(1.58)	1.15(0.19)	12528.77
Boostan Dam Lake	Feb			
	Mar	7.82(3.04)	3.56(1.21)	16600.51
	Apr	10.27(4.40)	3.87(1.73)	23857.24
	May	3.11(3.47)	1.50(0.56)	10873.62
	Jun	6.38(5.52)	1.62(0.34)	12240.93
	Jul	7.99(5.69)	2.03(1.12)	10444.68
	Aug	8.13(6.23)	2.82(0.27)	17579.63
	Sep	7.47(2.38)	1.81(0.42)	16142.07
		3.45(1.95)	1.46(0.21)	9535.02
Voshmgir Dam Lake	Feb			
	Mar	6.44(1.46))	1.50(0.35)	6884.93
	Apr	6.62(1.13)	1.55(0.80)	72865.59
	May	8.13(1.94)	1.90(0.74)	16052.07
	Jun	11.15(2.93)	1.87(0.12)	36864.50
	Jul	7.11(2.92)	2.10(0.02)	19162.27
	Aug	4.74(1.86)	2.85(0.08)	11394.64
	Sep	2.88(2.22)	2.33(0.64)	13904.64
		2.07(0.58)	1.18(0.14)	17270.57
Alakoli Reservoir	Feb			
	Mar	11.73(2.99)	1.95(0.36)	52602.86
	Apr	8.30(3.88)	2.07(0.45)	29419.08
	May	8.92(3.59)	3.22(0.85)	10943.23
	Jun	8.44(1.62)	2.11(0.80)	13604.64
	Jul	1.68(0.30)	1.95(0.45)	25420.84
	Aug	3.60(1.39)	1.75(0.08)	12077.78
	Sep	3.03(1.23)	1.30(0.08)	10852.70
		4.76(1.58)	1.68(0.19)	13411.06

Values in parentheses are standard deviations; GSI = gonadosomatic index, AF = total fecundity.

DISCUSSION

The introduction of invasive non-indigenous species is considered to be a leading cause of species endangerment and extinction in freshwater systems. The understanding of population biology of invaders and the effect of introduced species is necessary for constructing a robust theory of invasion biology that would provide a basis for rational decisions about species introduction and eradication efforts (Simberloff 2003). The Gibel carp is an invasive species for fresh-water in Iran and Middle East as well. In many European countries it was detected following carp introduction practices (Copp *et al*. 2005), as supposed in many reservoirs in Iran. There was no comprehensive published study about this species in northern Iran until our discovery in 2015.

The oldest age groups observed in this study were different from 8^+ in the Alma-gol and Ala-gol wetlands, northern Iran (patimar 2009), 6^+ in Anzali Lagoon- northern Iran (Seyyad-Bourani *et al*. 2001), 5^+ in Gelingullu Reservoir –Turkey (Kirankaya & Ekmekci 2013), 4^+ in Eğirdir Lake- Turkey (Balık *et al.* 2004), 7^+ in Bafra Fish Lake- Turkey (Bostancı *et al.* 2007), Beyşehir Lake (Çınar *et al.* 2007), 6^+ in Buldan Reservoir (Sarı *et*

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al. 2008), 6^+ in İznik Lake (Tarkan *et al.* 2006), 7^+ in shore and inner side waters of Estonia (Vetemaa *et al.* 2005), 7^+ in Seitler Reservoir (Bulut *et al*. 2013). Additionally there are some reports about longer life span of 11^+ in European freshwaters (Szczerbowski 2001) and of 9^+ in Turkish inland waters (Özkök *et al*. 2007). It seems that the maximum age vary among population of the species considerably. Differences obtained in age composition and longevity could be explained on the basis of the different exploitation patterns and/or ecological conditions. In this sense, while the *C. gibelio* is not subject to commercial exploitation in the study areas, environmental conditions seem to affect significantly the longevity of this species.

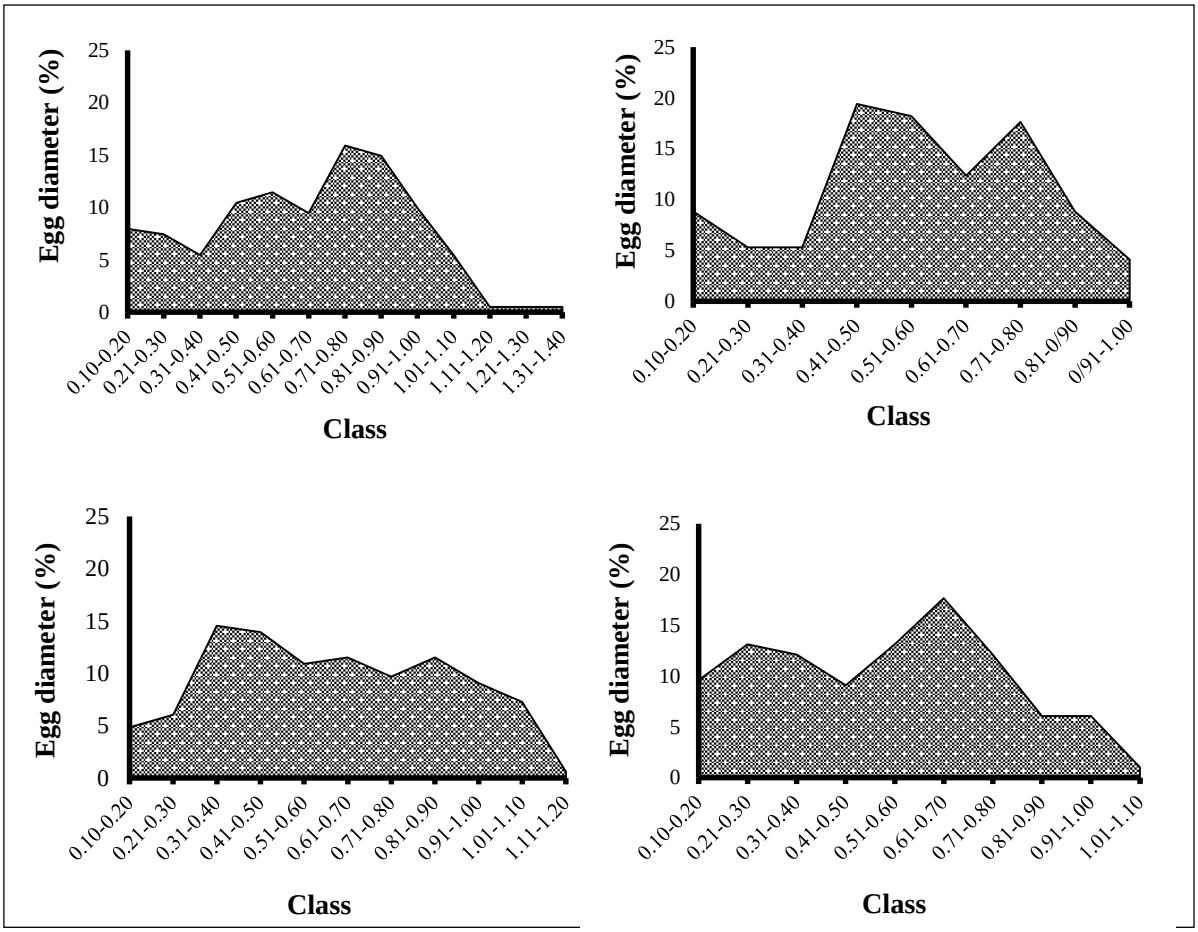

Fig. 5. Frequency (%) of egg diameter (mm) in Prussian carp (*C. gibelio*), the Southeast Caspian Sea. a: Golestan, b: Boostan, c: Voshmgir and d: Alakoli.

The age range of studied populations is similar to those reported from Lake Eğirdir (Balık *et al*. 2004), Buldan Reservoir (Sarı *et al*. 2008), Ömerli Reservoir (Tarkan *et al*. 2006), but different from those reported from Lake Eğirdir (Özkök *et al*. 2007), Buldan Reservoir (Sarı *et al.* 2008) and Lake Uluabat (Emiroğlu 2008). All of these authors reported that male individuals have shorter life spans that females. The most numerous age groups observed in the present study were 2^+ and 3^+ (approximately 80% of the total), as same as observed in many European (Szczerbowski 2001) and Turkish populations (Balık *et al.* 2004; Sarı *et al.* 2008, Emiroğlu unpublished*; Kirnkaya & Ekmekci 2013). The rang of total length (TL) and total weight (TW) in the previous studies were observed, 2.5-31.5 cm and 0.4-593.5 g from Anzali Lagoon (Seyyad Bourani *et al*. 2001); 20.57-48.88 cm and 1.57-124.43 g from the Alma-gol and Ala-gol international wetlands in Iran (Patimar 2009); 11.70- 29.60 cm and 42- 857.50 g from lake Egirdir in Turkey (Balık *et al*. 2004); 9.70- 25.50 cm and 23.60-269.10 g from Buldan Reservoir in Turkey (Sarı *et al*. 2008); 14.50- 37.70 cm and 26-450 g from Seyhan River in Turkey (Erguden 2015); 10.30- 30.50 cm and 25- 607 g from Aksu River in Turkey (Innal 2012); 14.80-32.50 cm and 43.10- 807.30 g from seitler Reservoir in Turkey (Bulut *et al*. 2013); and 14.5- 37.7 cm from 12

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different lakes in Greece (Tsoumani *et al*. 2006).The ecological differences, for example, food and temperature are important for changing the length and weight in different ecosystems (Tsoumani *et al*. 2006). Additionally the decreased length and weight could be due to higher coefficient mortality and a kind of selectively in the population, that be causing the elimination of big individuals.

Table 9. Length (cm) at age (year) data for various Prussian carp (*C. gibelio*) in different Regions.

Location	Length	Mean observed length at ages										Source
		0^+	1^+	2^+	3^+	4^+	5^+	6^+	7^+	8^+	9^+	
Lake Eğirdir	FL		11.9	18.1	22.9	25.5	27.4	29.6				Balık *et al*. 2004
Buldan Reservoir	FL		11.66	14.13	16.98	18.89	20.26	22.03				Sarı *et al*. 2008
Lake İznik	TL		13.75	19.67	25.33	30.05						Tarkan *et al*. 2006
Ömerli Reservoir	TL		12.61	20.41	26.74	30.88	33.12	35.7				Tarkan *et al*. 2006
Topçam Reservoir	FL				23.8	25.4	27.01	28.38				Şaşı 2008
Lake Beyşehir	FL	9.2	12.0	19.6	22.1	24.3	26.7					Çınar *et al*. 2007
Lake Eğirdir	FL	9.4	11.96	18.62	21.82	24.41	26.8	28.6	30.57	31.02	32.6	Özkök *et al*. 2007
Lake Uluabat	TL		17.6	23.07	25.87	28.87	31.25	31.93	33.20			Emiroğlu unp.*
Gelingüllü Res.	FL	6.37	12.6	15.8	18.4	22.3	26.6					Kirankaya & Ekmekci 2013
Golestan Dam lake	TL			5.50	9.29	12.67	15.60	17.02	19.60			This study
Boostan Dam lake	TL		6.67	10.64	12.62	14.33	17.68	20.60				This study
Voshmgir Dam lake	TL		5.73	10.78	13.60	15.78	18.02	20.83				This study
Alakoli Reservoir	TL		6.31	10.09	12.40	14.11	19.00					This study

As expected, the male/female ratio in the present samples of Gibel carp differed significantly from parity. In previous reports, the male/female ratios were calculated 1:0.73 from Gelingüllü Reservoir in Turkey (Kirankaya & Ekmekci 2013), 1:1.14 in Eğirdir Lake (Balık *et al.* 2004); 1:0.03 Bafra Fish Lake (Bostancı *et al.* 2007b); 1:1.46 in Eğirdir Lake (Bostancı *et al.* 2007a); 1:0.92 in Beyşehir Lake (Çınar *et al.* 2007); 1:1.08 in Eğirdir Lake (Özkök *et al.* 2007) 1:0.52 in Ulubat Lake (Emiroğlu 2008); 1:0.005 in Buldan Reservoir (Sarı *et al.* 2008); 1:0.07 in Ömerli Reservoir, 1:0.63 in İznik Lake (Tarkan *et al.* 2008); 1:0.026 in Pomvotis Lake (Tsoumani *et al.* 2006). Obviously, females were dominant in all populations. The fact that female individuals dominate the population can be explained by gynogenesis (Buth *et al.* 1991).

The *WLR*s observed in this study suggest that there was a difference in growth pattern between sexes: negative allometric growth almost in all females, whereas males grew either isometrically or allometrically. Negative allometry seems to be most common pattern in Gibel carp, as also reported by Tsoumani *et al*. (2006) and Kirankaya & Ekmekci (2013). In the present study, condition factor of the studied populations were almost similar to those of some population inhabiting Seitler Reservoir, Lake Eğirdir, Lake Beyşehir- Turkey (Özkök *et al*. 2007; Çınar *et al*. 2007; Bulut *et al*. 2013) and much lower from those of some others such as Lake Bafra Fish, Lake Eğirdir, Gelingüllü Reservoir- Turkey (Balık *et al*. 2004; Bostancı *et al*. 2007b; Kırankaya & Ekmekçi 2013). Differences in condition coefficients may change within the same species depending on age, season, sexual maturity, spawning period, feeding condition and environmental conditions (Bulut *et al*., 2013; Çetinkaya *et al*., 2005). Additionally differences in condition factor values may be attributed to variation in salinity, temperature and possible differences in feeding habits. In this species a high growth rate during earlier ages of life may be an adaptation for increasing fitness rapidly. The growth rate values decreased sharply after sexual maturity was attained. It is known that such an accelerated growth rate allows the fish to attain early maturity (Nikolskii 1963; Tarkan 2006). The von Bertalanffy model showed that females grew to a greater theoretical maximum length ($L\infty$) than males. The k value in males was higher than in females but differences of k value in males and females were found to be very small. The asymptotic length of the species were reported as follows: 36.2 cm in Beyşehir Lake, 48.09 cm in Lake Beyşehir, 31.66 cm in Buldan Reservoir, 33.3 cm in Eğirdir Lake- turkey (Balık *et al.* 2004; Bulut *et al*. 2013). The results showed that our fish have values similar to others. The largest $L\infty$ reported was 48.09 in Seitler Reservoir- Turkey (Bulut *et al.* 2013). This could be considered as an exception.

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The phi-prime test (Ø´) which reflects the overall growth performance, is used to evaluate the reliability of the growth parameter (Pauly & Munro 1984). The variations in phi-prime estimations could be caused by different results obtained in age readings by the different researchers, sampling differences and fish condition. The growth performance values of the studied populations ranged from 4.78 to 5.69. The growth performance values of the species was 5.37 in the Seyitler Reservoir (Bulut *et al*. 2013); 5.59 in Beyşehir Lake (Çınar *et al.* 2007); 5.91 in Eğirdir Lake (Balık *et al.* 2004) in Turkey. The growth performance of species in our studied stations was similar to those reports (Çınar *et al.* 2007; Sarı *et al.* 2008; Bulut *et al*. 2013). The low variations in Ø´ values also indicate that the VBGF was calculated correctly.

In the present study, spawning occurred between April and May. The GSI values revealed that the fish in the present study had a short gonadal quiescent period. Based on egg diameter results, the species could be considered as multiple spawner. Successful invaders have asynchronous gonad (oocyte) development and multiple spawning properties (Bogutskaya *et al*. 2005). The multiple spawning strategy has advantages in fluctuating environments, as all progeny are not at risk during one reproductive event, when a climatic change could destroy all offspring in a given year (Oliva-Paterna *et al*. 2002). So, multiple spawning and invasion are believed to be the most important characteristics of this species.

Reported values for absolute fecundity showed that the AF range is very large, from 5599.01 to 72865.59. The maximum AF reported for different populations are as follows: 130 000 from Gelingüllü Reservoir, Kızılırmak River Basin in Turkey (Kırankaya & Ekmekçi 2013), 141000 from Lake Egirdir in Turkey (Balık *et al*. 2004), 205000 from Wiebelsheim in Germany (Szczerbowski 2001) and 72865 found in the studied stations in the present study, exhibiting that the species is very fecund.

CONCLUSION

Based on the results and extrapolations, it is obvious that *C. gibelio* has typical characteristics of an invasive species, especially high growth rate, multiple spawning in short period, higher fecundity, earlier mortality and shorter life span.

Authors' contribution

Eisa Hajiradkouchak performed experimental part and wrote the manuscript draft and prepared the final version of the paper. Rahman Patimar purposed the research idea, guided research team scientifically, altered the various parts of the draft and designed the study protocol and supervised the whole project. Mohammad Harsij and Rasoul Ghorbani was the advisors and helped the writing up.

Declarations

It is confirmed that work has not been published, not under consideration for publication elsewhere, approved by all authors and, if accepted, it will not be published elsewhere in the same form, in English or in any other language.

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سن، طول و تولیدمثل ماهی کاراس نقره‌ای (Prussian carp *Carassius gibelio* Bloch, 1782) در ۴ آبگیر استان گلستان- جنوب شرقی دریای خزر

عیسی حاجی‌رادکوچک[۱]، رحمان پاتیمار[۱*]، محمد هرسیج[۱]، رسول قربانی[۲]

۱- گروه شیلات، دانشکده منابع طبیعی، دانشگاه گنبدکاووس، گنبدکاووس، ایران

۲- گروه شیلات، دانشگاه کشاورزی و منابع طبیعی گرگان، گرگان، ایران

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چکیده

در این مطالعه با هدف تعیین و بررسی پارامترهای سن و رشد ماهی کارس نقره‌ای (*Carassius gibelio*)، تعداد ۹۴۲ نمونه به صورت ماهانه از اسفند ۹۳ تا مهرماه ۹۴ در ۴ آبگیر در جنوب شرقی دریای خزر انجام شد. بزرگترین نمونه ماده با طول ۲۲۰ میلی‌متر و وزن ۱۳۹/۷۸۷ گرم در سد وشمگیر بود. بالاترین فاکتور وضعیت در ماه‌های اردیبهشت تا شهریورماه افزایش قابل توجهی داشت. الگوی رشد برای جنس ماده در آببندان آلاکولی آلومتریک مثبت و در سدهای گلستان، بوستان و وشمگیر و جنس نر در سد وشمگیر آلومتریک منفی بود. الگوی رشد ایزومتریک برای جنس نر در سدهای بوستان و گلستان و آببندان آلاکولی به‌دست آمد. پارامترهای رشد فان برتلانفی متناسب با میانگین طول کل در سن مشاهده و در هر جنس به طور جداگانه، در منطقه سد گلستان ($L\infty$= 309.38 mm, K= 0.17, t_0= -0.02) در جنس ماده و ($L\infty$= 378.09 mm, K= 0.12, t_0= -0.43) در جنس نر و ($L\infty$= 299.06 mm, K= 0.18, t_0= -0.10) در جمعیت، در منطقه سد بوستان ($L\infty$= 355.74 mm, K= 0.13, t_0= -0.35) در جنس ماده و ($L\infty$= 338.43 mm, K= 0.15, t_0= -0.34) در جنس نر و ($L\infty$= 574.17 mm, K= 0.07, t_0= -1.04) در جمعیت، در منطقه سد وشمگیر ($L\infty$= 186.23 mm, K= 0.51, t_0= -0.42) در جنس ماده و ($L\infty$= 296.37 mm, K= 0.20, t_0= -0.20) در جنس نر و ($L\infty$= 347.99 mm, K= 0.12, t_0= -0.40) در جمعیت و در منطقه آببندان آلاکولی ($L\infty$= 477.73 mm, K= 0.04, t_0= -0.01) در جنس ماده و ($L\infty$= 530.92 mm, K= 0.01, t_0= -0.18) در جنس نر و در جمعیت محاسبه شد. دوره تخم‌ریزی طولانی از اردیبهشت تا شهریورماه مشاهده شد. بزرگترین قطر تخمک ۱/۳۹ میلی‌متر و بالاترین هم‌آوری مطلق ۷۲۸۶۵ عدد تخم در ماهیان سد وشمگیر بود.

*مؤلف مسئول

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