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Original Article

Population Structure and Some Growth Properties of Gibel Carp (*Carassius gibelio*) in a Mesotrophic Lake

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Abstract

The hereby study investigated gibel carp (*Carassius gibelio*) in a mesotrophic lake (Lake Beyşehir, Turkey) from April 2013 to March 2014, in order to outline population structure and some growth properties of the species. Two water quality variables (Chlorophyll-a, Trophic State Index (TSI)) were detected seasonally to define trophic status of the lake. Length and weight distributions, length - weight relationship, sex ratio, gonadosomatic index (GSI), condition factor (CF) and von Bertalanffy equation were calculated for *C. gibelio* sampled monthly. Trophic status of the lake was defined as mesotrophic. Total length and weight of *C. gibelio* samples was determined in the range of 8.5 and 28.4 cm and 15 and 408 g, respectively. Mean total length and weight of individuals were calculated as 17.5 ± 2.37 cm and 88.6 ± 39.02 g, respectively. There was a negative allometry between length and weight for *C. gibelio*. The fish samples were composed of 52% females and 48% males, between II and VII years old. Spawning period of the species occurred between April and June after GSI values reached their maximum in March. The CF values were validated between 1.5-1.7 besides the mean rate of females and males were 1.6 and 1.5, respectively. The parameters of von Bertalanffy equation were calculated as L_∞: 19.8 cm, W_∞: 652.9 gr, k: 0.934. In conclusion, *C. gibelio* has almost lost the economic value since the individuals are smaller than market size (≥ 250 g), probably due to lack of nutrients/mesotrophic situation of Lake Beyşehir.

Keywords: Beyşehir Lake, eutrophication, gonadosomatic index (GSI), length - weight relationship, von Bertalanffy equation

Introduction

The Beyşehir Lake, which is the biggest freshwater lake in Turkey, has some serious problems about sustainability of indigenous fish populations in recent years (Tekinay *et al.*, 2013). Total production in the lake by commercial fishing has been decreasing since 2005 due to several reasons such as changes in bio-ecological conditions of the lake and uncontrolled fishing (Anonymous, 2013).

Eleven species (*Cyprinus carpio*, *Chondrostoma regium*, *Leuciscus lepidus*, *Pseudophoxinus anatolicus anatolicus*, *Knipowitschia caucasica*, *Aphanius anatoliae anatoliae*, *Gambusia affinis*, *Sander lucioperca*, *Tinca tinca*, *Atherina boyeri*, *Carassius gibelio)* belonging to 6 families were reported in the Beyşehir Lake (Çubuk *et al.*, 2006; Yeğen *et al.*, 2006). The last four of these species were introduced to the lake and apparently caused some impacts on the lake ecosystem, although this has not been proven yet. Gibel carp, which was introduced into Lake Beyşehir at the end of 1990s, was adapted to the local conditions (Çınar *et al.*, 2007) and become the dominant species (Tekinay *et al.*, 2013).

C. gibelio displays fast growth until sexual maturation and high survival rates. It is an omnivorous fish (Kottelat and Freyhöf, 2007), reproduces gynogenetically and has extensive tolerance to different environmental conditions (Ekmekçi, 2013). The reason for the intense reproductive success of introduced *C. gibelio* is its capacity for gynogenetic reproduction, whereby females are able to use sperm of other cyprinid fishes and salmonids to fertilize their eggs (Penaz *et al.*, 1979; Tarkan *et al.*, 2012). Consequently, this species easily becomes a dominant species in stagnant and slow running waters (Tsoumani *et al.*, 2006).

Since body weight does not reach to market size (≥ 250 g) in Beyşehir Lake, plenty of uneconomical fish cause labor and time loss. This condition situation of species has been probably affected from the trophic status of lake. Also, biological characteristics of the species need to be determined in the lake to obtain useful information in order to prevent the invasion of *C. gibelio,* as well as for determining population sustainability of natural species and consequently sustainable fisheries in the lake. Therefore, the present study was designed to determine trophic status of lake and investigate population structure and some growth properties of *C. gibelio*.

Materials and Methods

Fish and water sampling

A monthly-sampling-study was carried out in 5 different areas (Tolca, Yeşildağ, Beyşehir Centre, Gölyaka and Çiftlik) in

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Lake Beyşehir (Konya, Turkey) (Fig. 1) between April 2013 and March 2014.

Water samples from each location were taken to determine chlorophyll-a and Trophic State Index (TSI) values. Chlorophyll-a measurements were carried out according to Stirling *et al*. (1985). Based on chlorophyll-a variance, TSI was detected. According to this procedure lakes are classified as low productive (TSI < 30), medium productive (TSI: 40-50) and high productive (TSI: 50-70) (Carlson, 1977; Carlson and Simpson, 1996).

Monofilament gill nets with the mesh sizes of 30, 40, 50, 60, 70, 80, 100, 110 and 120 mm and monofilament trammel nets with 130 mm mesh size, which received occupancy permission from the Republic of Turkey, Ministry of Food, Agriculture and Livestock, were layed within Lake Beysehir Ecosystem Rehabilitation Project. Also, multi-filament gill nets with the mesh sizes of 30, 40 and 50 mm and multi-filament trammel nets with 70 and 110 mm mesh sizes were used for *C. gibelio* sampling. Monthly sampled were taken, thus 59 to 346 (mean 156) individuals of species from five stations were investigated.

Fish samples were immediately transferred to Izmir Katip Çelebi University, Faculty of Fisheries Laboratories in cooler boxes.

Qualitative analysis and statistical procedures

For each sample, the total length (TL) was measured to the nearest 0.1 cm and the total weight (W) to the nearest 0.1 g. 20 scales were collected from each sample for age determination according to Lagler (1966) and Nikolsky (1963). After dissection, sex was determined by macroscopic observation, and gonad weights were weighed. Sex ratios, length and weight distribution and length - weight relationship were determined. Condition factor (as formulated $CF = (W / L^3) \times 100$ by Ricker (1975)) and gonadosomatic index (GSI) (as formulated $GSI = (W_G / W_T) \times 100$ by Wootton (1990)) were calculated. Water temperatures were also determined on monthly basis with Hach HQ40d Water Quality Multiparameter, in order to associate with GSI values. Also von Bertalanffy equation data were estimated according to $L_{(t)} = L_\infty * (1 - e^{-K}(t - t_0)$ in length and $W_\infty = a * L_\infty$ in weight.

Statistical analyses were used to assess if the parameters (total length, weight, condition factor, gonadosomatic index) differed between seasons and sexes. The homogeneity of variances was tested (the Kolmogorov-Smirnov and Levene's test) and, whenever necessary, the log-transformation log (x + 1) was used.

One way analysis of variance (ANOVA) was used at the 5% significance level to determine differences among the mean results ($p \leq 0.05$). The Tukey-HSD test was applied when it was significant. A regression analysis was used to examine morphometric relations (length and weight) (Zar, 1999). All statistical analyses were carried out using Microsoft Excel and the IBM SPSS 21 Software package.

Results

The results of chlorophyll-a and TSI parameters were shown in Table 1. In autumn, both of these parameters have the highest values than during other seasons. The chlorophyll-a and TSI were determined as 26.19 ± 3.59 and 62.26 ± 1.28, respectively. The mean values were calculated as 9.26 ± 2.19 (chlorophyll-*a*) and 47.20 ± 2.25 (TSI) (Table 1).

Total length of 1,868 *C. gibelio* samples caught from Lake Beyşehir was determined in the range of 8.5 and 28.4 cm. Minimum and maximum total lengths for female, male and unidentified individuals were detected as 11.0, 8.5 and 10.2 cm and 28.4, 25.9 and 27.1, respectively. The weight parameters varied between 15.0 and 408.0 g; which minimum and maximum values for females as 21.0 and 408.0 g, whereas for males these were 15.0 and 278.0 g and for unidentified individuals, they were 14.0 and 238.0 g, respectively. Mean total length and weight of individuals were measured as 17.5 ± 2.37 cm and 88.6 ± 39.02 g, respectively. Mean total length and weight of females were calculated as 18.4 ± 2.46 cm and 105.8 ± 44.29 g, respectively. Also mean total length and weight of male individuals were determined as 17.1 ± 2.04 cm and 79.0 ± 29.51 g, respectively (Table 2). In addition, a, b and R^2 rates were estimated as length-weight relationship values 0.017, 2.959 and 0.924, respectively. A negative allometry (b: 2.959) was obtained length - weight relation (Fig. 2).

Research on the range of the age indicated that the fish in the Lake Beyşehir showed an alteration between II and VII years of age (Table 3). The age distribution of

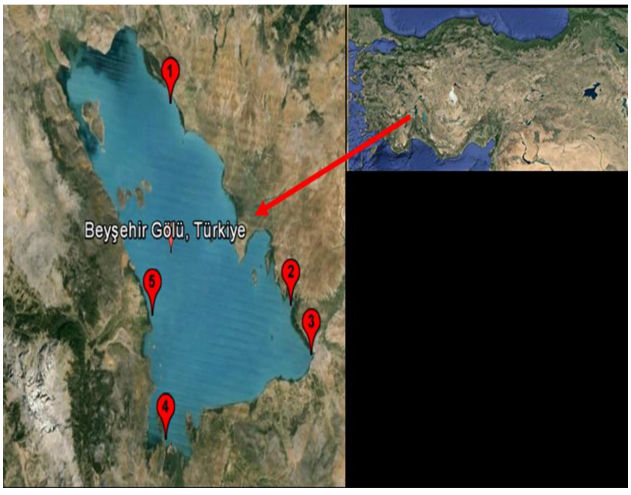

Fig. 1. Study area (Lake Beysehir) and sampling stations: 1. Tolca, 2. Ciftlik, 3. Beysehir Centre, 4. Yesildag, 5.Golyaka

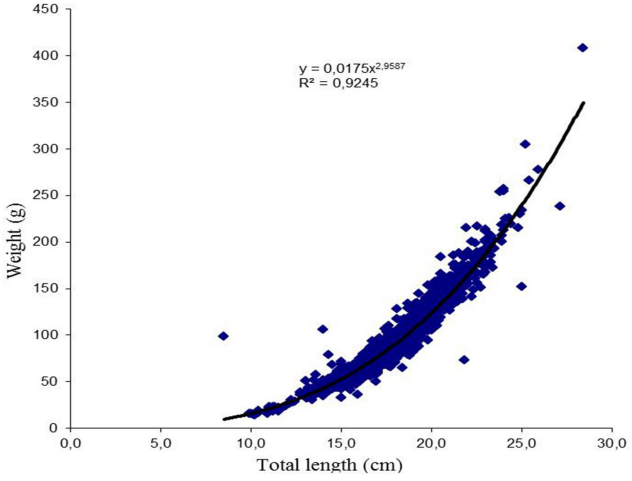

Fig. 2. Length-weight relationship of *C. gibelio*

Table 1. Seasonal and mean chlorophyll-*a* (Chl-*a*) and Trophic State Index (TSI) values of Beyşehir Lake

	Winter	Spring	Summer	Autumn	Mean
Chl-a (µg/lt)	6.01 ± 0.61	3.36± 0.88	5.30± 1.06	26.19± 3.59	9.26 ± 2.19
TSI	48.07± 1.05	3.36± 0.88	46.33± 1.95	62.26± 1.28	47.20 ± 2.25

Table 2. Total length and weight parameters of *C. gibelio* by sexes

	Total length (cm)				Weight (g)			
	Female	Male	Unidentified	Total	Female	Male	Unidentified	Total
n	708	780	380	1868	708	780	380	1868
Min - Max	11.0 - 28.4	8.5 - 25.9	10.2 - 27.1	28.4 - 8.5	21.0 - 408.0	15.0 - 278.0	14.0 - 238.0	408.0 - 14.0
Mean ± SD	18.4 ± 2.5	17.1 ± 2.0	16.7 ± 2.3	17.5 ± 2.4	105.7 ± 44.3	79.0 ± 29.5	76.6 ± 34.3	88.6 ± 39.2

Min: Minimum; Max: Maximum; SD: Standard deviation

captured fishes between II and VII years were determined as 13.3, 32.4, 24.8, 18.1, 8.6 and 2.9%, respectively. Von Bertalanffy growth equation, which is based on the length and age parameters, is shown in Table 4. L_∞, W_∞ and k were calculated as 19.8 cm, 652.9 g and 0.934, respectively (Table 4).

The condition factor (CF) values were validated between 1.5 - 1.7 besides the mean rate of females and males were 1.6 and 1.5, respectively (Fig. 3). Between the II and VII ages, condition factor values were determined 1.5, 1.6, 1.5, 1.6, 1.7 and 1.6, respectively. Gonado-somatic index (GSI) values of female individuals were showed in Fig. 3. Between April and June period it was prominent on account of spawning period. The water temperatures of Lake Beysehir were detected as 13.9 °C for April, 19.5 °C for May and 22.0 °C for June, when the spawning period occurred. In this study, the male and female rate of the *C. gibelio* was determined as 1:1.1.

Statistical analyses of total length, weight, condition factor and gonadosomatic index values by sexes and seasons are shown in Table 5 and 6. It was determined that the values of mean total length and weight for female individuals were higher in all seasons than for the male individuals. Said length and weight difference between female and male individuals was found statistically significant (except for winter season, for total length) (Table 5 and 6). There were significant differences detected in GSI and CF values between sexes (Table 5). Not only between sexes, but also the values between seasons were determined as different in GSI and CF parameters statistically ($p \leq 0.05$) (Table 6).

Discussion

Total length of 1,868 *C. gibelio* samples caught from Lake Beyşehir was in a range of 9.9-28.4 cm and it was detected that the individuals in Lake Beyşehir were smaller than the ones reported in other studies. For example, it was reported a total length distribution of 12.5-35.7 cm in Ömerli Dam Lake (Turkey) (Tarkan *et al*., 2006); 5.2-30.2 cm in Lake İznik (Turkey) (Tarkan *et al*., 2006); 8.5-33.3 cm in Lake Uluabat (Turkey) (Emiroğlu, 2008); 10.3-30.5 cm in Aksu River (Turkey) (İnnal, 2012); 21.9-37.0 cm in Chimaditis Lake (Greece) (Leonardos *et al*., 2008).

The same finding also applies to the value of maximum theoretical length (L_∞) (19.8 cm) calculated for the species. For example, the value of L_∞ was reported as 36.2 cm for the same lake (Çınar *et al*., 2007); 31.7 cm for Buldan Lake (Sarı *et al*., 2008); 33.3 cm for Lake Eğirdir (Balık *et al*., 2004); 48.1 cm for Seyitler Dam Lake (Bulut *et al*., 2013) and 36.0 cm (female) and 32.2 (male) for Gelingüllü Dam Lake (Kırankaya and Ekmekçi, 2013). Differences in total lengths could be attributed to sampling time, sampling method and ecological properties of the working areas.

Mean total length for female and male individuals was detected as 18.4 ± 2.46 and 17.1 ± 2.04 cm respectively, whereas mean weight was detected as 105.8 ± 44.29 and 79.0 ± 29.51 g. It was determined that the values of mean total length and weight for female individuals were higher in all seasons than those of male individuals. Said length and weight difference between female and male individuals was found statistically significant (except for winter season for total length). Different researchers (Balık *et al*., 2004; Kırankaya

Table 3. Sex ratio, total length (cm) and weight (g) for different ages of *C. gibelio*

	II	III	IV	V	VI	VII
N	14	34	26	19	9	3
%	13.3	32.4	24.8	18.1	8.6	2.9
Mean TL ± SD	14.0 ± 2.3	16.8 ±2.2	19.2 ± 2.7	19.0 ± 2.6	21.3 ± 2.3	21.9 ± 2.2
Mean W ± SD	45.3 ± 26+.2	80.7 ±34.5	113.9 ± 49.8	118.1 ± 58.8	167.7 ± 60.5	151.5 ± 55.4
Female n	1	9	14	7	7	2
Female %	2.5	22.5	35.0	17.5	17.5	5.0
Male n	8	14	4	9	1	1
Male %	21.6	37.8	10.8	24.3	2.7	2.7

TL: Total length; W: Weight; SD: Standard deviation

Table 4. *C. gibelio* length and age parameters

n	Minimum age	Maximum age	a	b	R^2	L_∞	W_∞	k
146	2	7	11.991	0.393	0.815	19.755	652.907	0.934

Table 5. Statistical analyses of *C. gibelio* individuals between sexes

	Total length (cm)				Weight (g)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Female	20.3±0.22[a]	17.6±0.21[a]	19.1±0.18[a]	18.9±0.12	140.7±4.41[a]	92.1±3.68[a]	116.8±3.85[a]	108.5±2.11[a]
Male	19.1±0.35[b]	16.5±0.19[b]	17.3±0.16[b]	18.5±0.09	117.5±5.69[b]	69.6±2.43[b]	80.5±3.55[b]	96.8±1.52[b]
	CF				GSI			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Female	1.63±0.02[a]	1.61±0.01[a]	1.60±0.01[a]	1.60±0.01[a]	8.73±0.60[a]	1.48±0.12	5.88±0.28	6.14±0.23[a]
Male	1.79±0.22[b]	1.53±0.02[b]	1.53±3.65[b]	1.51±0.01[b]	2.26±0.19[b]	2.47±1.37	5.39±0.34	3.14±0.13[b]

[a, b]There are statistically significant differences between the sexes ($p \leq 0.05$)

Table 6. Statistical analyses of *C. gibelio* individuals between seasons

	Total length (cm)		Weight (g)	
	Female	Male	Female	Male
Spring	20.3±0.22[a]	19.1±0.35[a]	140.7±4.41[a]	117.5±5.69[a]
Summer	17.6±0.21[b]	16.5±0.19[b]	92.1±3.68[b]	69.6±2.43[b]
Autumn	19.1±0.18[c]	17.3±0.16[c]	116.8±3.85[c]	80.5±3.55[a]
Winter	18.9±0.12[c]	18.5±0.09[d]	108.5±2.11[c]	96.8±1.52[c]
	CF		GSI	
	Female	Male	Female	Male
Spring	1.63±0.02[ab]	1.79±0.22[a]	8.73±0.60[a]	2.26±0.19[a]
Summer	1.61±0.01[a]	1.53±0.02[ab]	1.48±0.12[b]	2.47±1.37[b]
Autumn	1.60±0.01[a]	1.53±3.65[b]	5.88±0.28[c]	5.39±0.34[c]
Winter	1.60±0.01[b]	1.51±0.01[b]	6.14±0.23[c]	3.14±0.13[d]

CF: Condition factor; GSI: Gonadosomatic index; [a, b, c, d] There were statistically significant differences between the seasons ($p \leq 0.05$)

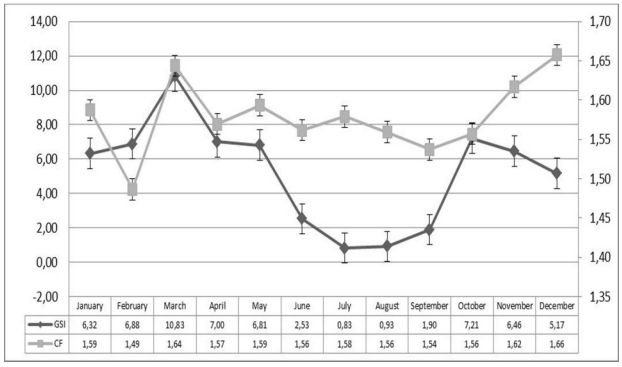

Fig. 3. Monthly changes in gonadosomatic index and condition factors of for female *C. gibelio* in the Beyşehir Lake

and Ekmekçi, 2013) reported that female individuals were longer and heavier compared to male individuals, and b values in the length-weight relationship were calculated higher for females than males.

It was determined that the species showed a negative allometric growth in Lake Beyşehir. In other studies, similar to the hereby investigation, a negative allometry (Bulut *et al*., 2013; Kızına, 1986; Leonardos *et al*., 2008; Sarı *et al*., 2008) as well as a positive allometry (Balık *et al*., 2004; Bostancı *et al*., 2007; Çınar *et al*., 2007; İnnal, 2012; Özkök *et al*., 2007; Tarkan *et al*., 2006) were detected. Differences in b value can be caused by age and maturity (Bulut *et al*., 2013); geographical location and environmental conditions (Bagenal and Tesch, 1978), season and nutrition (Tesch, 1968) and trophic state of the lake (Tsoumani *et al*., 2006). It was reported the relationship that as b value was reduced when the concentration of phosphate phosphorus (PO_4 – P), which trophic level indicator increased, the species exhibited better growth in mesotrophic and oligotrophic lakes, whereas the growth was affected negatively in eutrophic and hypertrophic lakes. On the other hand, Tarkan *et al*. (2012) reported that total phosphorus was not correlated with growth features of *C. gibelio* in a mesotrophic reservoir.

In the present study, Beyşehir Lake was classified as medium productive (mesotrophic lake) (TSI: 40-50) according to TSI values, since it has 47.20 ± 2.25 mean TSI value as stated in previous studies (Nas *et al*., 2008; Kazancı *et al*., 2009; Fakıoğlu and Demir, 2011). It is thought that negative allometric growth of the species is correlated with the trophic state of Lake Beyşehir.

In Lake Beyşehir, the condition factor values for males and females of the species ranged between 1.5 to 1.7 and it was found to be lower than the values recorded within other studies (Balık *et al*., 2004; Bostancı *et al*., 2007; Çınar *et al*., 2007; Özkök *et al*., 2007; İnnal, 2012; Bulut *et al*., 2013; Kırankaya and Ekmekçi, 2013). The condition factor varies by the age of species, season, maturity, spawning period, nutritional status and environmental conditions (Çetinkaya *et al*., 2005). Balık *et al*. described that the condition factor values increased based on age. On the contrary, condition factor values did not increase based on age in Lake Beyşehir. This situation showed that the species does not exhibit the expected growth.

In the current study, the age range of the caught fish was determined as II-VII. In a previous study upon Lake Beyşehir, the age range was determined as 0-V (Çınar *et al*., 2007). In the study, the age group, III and IV constituted approximately half of the population (57.2%). The same

situation was reported for many populations in Europe (Szczerbowski, 2001) and Turkey (Balık *et al*., 2004; Sarı *et al*., 2008; Kırankaya and Ekmekçi, 2013). It is believed that in Lake Beyşehir the age group III (mean total length: 16.8 cm) and IV (mean total length: 19.2 cm), in population of the species is dominant, since the outsized individuals are caught because of their commercial value and the small individuals are not targeted. The small individuals which are incidentally caught on the gill net are returned to the lake and this causes labour and time loss.

In Lake Beyşehir, the male and female rate of the species was determined as 1:1.1 and when considered the values in previous studies (1:0.92) (Çınar *et al*., 2007), it is believed that the population prefers bisexual reproduction. Conversely, it is reported that the reproduction strategy is gynogenesis in many population in which the female individuals are dominant (Vetemaa *et al*., 2005; Tarkan *et al*., 2006; Tsoumani *et al*., 2006; Bostancı *et al*., 2007; Leonardos *et al*., 2008; Sarı *et al*., 2008; Şaşı, 2008; Liasko *et al*., 2010; Bulut *et al*., 2013). In gynogenesis reproduction, gynogenetic females use the sperms of a male of their kind or the males of another carp species to fertilize the eggs and to induce reproduction, but sperms does not have any genetic effect on reproduction (Penaz *et al*., 1979). By means of this reproduction type, the species become dominant in habitat in a short time. Thus, the reproduction type of the species should be determined exactly through the genetic studies in Lake Beyşehir.

In Lake Beyşehir, the spawning period was determined between April and June, following March, in which GSI reached the peak value. In a similar manner with the hereby results, the beginning of the spawning period in different fish populations in Turkey was between March-April (Balık *et al*., 2004; Şaşı, 2008; Tarkan *et al*., 2006; Kırankaya and Ekmekçi, 2013). The spawning period of the species depends on environmental factors such as photoperiod and water temperature (Wootton, 1990). Thus, some alteration may appear in population in different geographical regions. It was determined that the spawning period of the species in populations in Europe begins in May-June, when the temperature is higher (18-19 °C) (Szczerbowski, 2001), while the spawning period begins in April at a temperature of 13.9 °C in Lake Beyşehir.

Conclusions

In conclusion, *Carassius gibelio* has almost lost the economic value since the individuals are smaller than market size, probably due to lack of nutrients/mesotrophic situation of Lake Beyşehir. In addition, this species is able to reproduce gynogenetically, which involves the use of sperm from males of other species to activate egg development, so reproductive competition is a likely, but virtually unstudied, impact of gibel carp on native populations. It has been reported that a dramatic decrease in the relative stocks of native fish species was significantly correlated with an increase in *C. gibelio* population. Thus, further studies are required in order to reveal the impacts of *C. gibelio* on native fish stocks and sustainable fisheries in mesotrophic lake.

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