Oceanological and Hydrobiological Studies

International Journal of Oceanography and Hydrobiology

Volume 49, No. 4, December 2020
pages (383-390)

ISSN 1730-413X
eISSN 1897-3191

Growth parameters of invasive gibel carp *Carassius gibelio* (Bloch, 1782) in Lake Marmara (Turkey)

by

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DOI: **10.1515/ohs-2020-0033**
Category: **Original research paper**
Received: **February 20, 2020**
Accepted: **May 18, 2020**

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Abstract

The objective of this study was to determine growth parameters, such as age–length and length–weight relationships, as well as condition factors and sex ratio, of the *Carassius gibelio* (Bloch, 1782) population in Lake Marmara (western region of Turkey), which is one of the most important fishing areas. Fish were caught on a monthly basis by gillnets and trammel nets (mesh size 10–50 mm) between March 2012 and February 2013. A total of 1058 specimens (809 females and 249 males) were examined. The female–male ratio was 1:0.31. The maximum age was determined as VI and V for females and males, respectively. The total length of females and males ranged from 10.0 to 27.5 cm and from 10.2 to 24.0 cm, respectively. Their weight varied from 17.1 to 378.4 g and from 17.7 to 244.9 g, respectively. Length–weight relationship parameters were $a = 0.014$ and $b = 3.040$ for females and $a = 0.015$ and $b = 3.039$ for males. Von Bertalanffy growth parameters of the *C. gibelio* population were as follows: $L_\infty = 35.86$ cm, $k = 0.189$ year^{-1}, $t_0 = -1.238$ years. Minimum and maximum condition factors were 1.56 for females in October and 1.82 in May and 1.67 for males in September and 1.94 in January.

Key words: *Carassius gibelio*, invasive species, length–weight relationship, Fulton's condition factor

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Introduction

With its original geomorphological features and three (Caucasus, Irano-Anatolian and Mediterranean) of the 34 hot spots on Earth, Turkey is considered a unique country on the international scene (Şekercioğlu et al. 2011). In addition, this geographical area provides a natural passage for species to spread (Özuluğ et al. 2013), with very rich freshwater fauna in terms of diversity and endemism. There are 368 fish species in freshwaters of the country, 153 (41.8%) of which are known as endemic (Çiçek et al. 2015). A total of 25 invasive and potentially invasive freshwater species have been reported there, including *C. gibelio* (Innal & Erk'akan 2006).

Lake Marmara is one of the very important natural lakes in Turkey with fishing activities and richness of endemic species. A total of 20 fish species occur in Lake Marmara (İlhan & Sarı 2013), most of which are cyprinid species; five of them are known as endemic species in Turkish freshwaters (İzmir minnow *Ladigesocypris mermere*, Marmara goby *Knipowitchia mermere*, Bergama barb *Capoeta bergamae*, İzmir nase *Chondrostoma holmwoodi*, Küçük Menderes spined loach *Cobitis fahirae*). Some translocated species (sand smelt *Atherina boyeri*, common carp *Cyprinus carpio* and pikeperch *Sander lucioperca*) and some exotic species (gibel carp *Carassius gibelio*, topmouth gudgeon *Pseudorasbora parva* and eastern mosquitofish *Gambusia holbrooki*) occur there (*C. carpio* indeed belongs to the native fauna of Lake Marmara, which is continuously stocked to increase inventory).

Lake Marmara is a habitat for approximately 144 different bird species (Gül 2008), which makes it a matchless wetland. The lake has been hypertrophied as a result of eutrophication caused by the accumulation of agricultural fertilizers and pesticides (Gülersoy 2013).

Gibel carp *C. gibelio* as a member of the Cyprinidae family, feeds on zooplankton, zoobenthos, macrophytes and detritus in particular (Specziar et al. 1997). Males can grow to a maximum length of 35 cm and live about 10 years (Kottelat & Freyhof 2007). *Carassius gibelio* has a strong ability to adapt to environmental changes. It inhabits all categories of water bodies, such as lakes, ponds, lagoons and swamps, which are its main habitats (Solarz 2005). The species is native to Asia, was introduced to Europe in the 17th century and was first recorded in North America in 2000 (Froese & Pauly 2010; Docherty et al. 2017).

The species was first recorded in the Thrace region of Turkey in 1988 (Baran & Ongan 1988) and in Anatolian freshwaters (Lake Marmara) in 1991 by Balık et al. (İlhan et al. 2005). At present, *C. gibelio* can be observed in almost all Turkish freshwater bodies (Ekmekçi et al. 2013).

Known globally as a highly invasive species, *C. gibelio* is one of the most precarious species for native fish communities (Crivelli 1995), which can pose considerable threat to natural fish faunas and related ecosystems. When introduced into a new region, its predation characteristics and impact on other species with which it shares the same habitat are likely to turn *C. gibelio* into the most dominant fish in a given ecosystem (Paulovits et al. 1998). It is believed that *C. gibelio* is responsible for the disappearance of many native populations in Europe (Lusk et al. 2010), which may have had a negative impact on the quality of ecosystems.

The main reason for such an increase in the spread of the carp is that it has been introduced into water resources for various purposes. It is difficult to distinguish fingerlings of the species from those of others, because they are so similar to each other that they can easily be confused with *C. carpio* (Aydın et al. 2011; İlhan et al. 2005). They generally reproduce bisexually, but also occasionally through gynogenesis (Vetemaa et al. 2005), and *C. gibelio* could hybridize with other Cyprinidae members, such as *C. carpio*, *C. auratus*, *C. carassius* (Belgium Forum on Invasive Species 2011). Due to its gynogenetic breeding characteristics and hybridity with other cyprinids, the species can grow very rapidly and put pressure on other species of an ecosystem.

Several aspects of the species *C. gibelio* were studied during various research projects in Turkey. For instance, its growth was determined by Emiroğlu (2008), the ecological impact was established by Gaygusuz et al. (2007), the feeding regime was investigated by Yılmaz et al. (2007), fecundity characteristics were researched by Tarkan et al. (2007), length–weight relationships and reproduction were determined by Şaşı (2008) and distribution by Yerli et al. (2014).

Length–weight relationships are crucial for a wide range of studies, such as presenting growth rates and establishing the age structure and many other population parameters. Moreover, length–weight relationships help compare populations of the same species living in different habitats (Sangun et al. 2007). The results of applying Fulton's condition factor for species would enable the standard of research to be established and would also contribute to the management of invasive fish stocks. Populations of invasive species inhabiting important fishing areas should be regularly monitored based on the above mentioned studies.

Materials and methods

Study Area

Lake Marmara, 12 km long and 6 km wide, is located 75 m above sea level. The area of the lake is 4500 ha and the average depth is approximately 5 m (Ustaoğlu 1993). This alluvial lake is an extension of the Gediz River between the towns of Gölmarmara and Salihli in the Manisa province in West Anatolia (Fig. 1). According to the Köppen–Geiger climate classification system, continental climate prevails in the lake area and the area is rarely affected by the Mediterranean climate (Kottek et al. 2006). As mentioned above, the lake plays an important role in fisheries and irrigation of the region and Turkey as a whole.

Field study and analysis

All samples were collected monthly between March 2012 and February 2013 using 10–50 mm mesh trammel nets, gillnets and seines. A total of 1058 specimens (809 females and 249 males) of *C. gibelio* were examined during the study.

Fish specimens were preserved in 4% formaldehyde solution and transported to the Limnology Laboratory, Faculty of Fisheries, Ege University. The length of all specimens was measured on a fish measuring board to the nearest millimeter and weighed using a digital scale with an accuracy of 0.001 g. The following biological parameters were analyzed: sex, total length (*L*), weight (*W*), age–sex composition, age–length relationships, length–weight relationships (LWR), von Bertalanffy growth parameters and Fulton's condition factor.

LWR was determined using the formula $W = aL^b$, where W = weight, L = length, a = intercept and b = regression coefficient (Ricker 1975). The correlation coefficient significance test was used (Sümbüloğlu & Sümbüloğlu 2005).

The von Bertalanffy growth model (Sparre et al. 1989) was calculated using the following formulas: $L_t = L_\infty [1 - e^{-k(t-t_0)}]$ and $W_t = W_\infty [1 - e^{-k(t-t_0)}]^b$, where L_t = length (cm) at age t, L_∞ = asymptotic length, k = Brody growth coefficient, t = age (years), t_0 = age at zero length, e is the base of natural logarithm, W_t is weight (g) at age t, W_∞ is asymptotic weight.

The age was estimated for each sample from fish scales. Scales for the analysis were removed from the lateral side, above the lateral line, near the dorsal fin of each specimen (Baglinière & Le Louarn 1987). Scales were preserved in 3% sodium hydroxide (Agger et al. 1974; Bagenal 1978) and alcohol (70–90%) to clean them before the reading process. Scales were examined under a binocular microscope for age determination using a 10× stereomicroscope. Age readings were performed according to Chugunova (1959) and Lagler (1966). Scale readings were taken twice by two independent readers (Avşar 2005). The data were tested by Student's t-test and the growth types were determined. Fulton's condition factor (*K*) was estimated using the formula: $K = W * 100/L^3$ (Cone 1989).

Figure 1

Map of Lake Marmara

Results and discussion

In this study, n = 809 females and n = 249 males were examined. The maximum age was estimated as VI and V for females and males, respectively. In the case of females, the maximum number of specimens was found in age II (28.92%) and in the case of males – in age I (18.43%). The samples did not include juveniles or small individuals. The total male rate was 0.30 (Table 1).

Table 1

Age and sex ratio of *C. gibelio*

	Females		Males		Combined Sex		F:M
Age	n	%	n	%	n	%	
I	216	20.42	195	18.43	411	38.85	1:0.90
II	306	28.92	36	3.40	342	32.33	1:0.11
III	235	22.21	14	1.32	249	23.53	1:0.05
IV	32	3.02	3	0.28	35	3.31	1:0.09
V	7	0.66	1	0.09	8	0.76	1:0.14
VI	13	1.23	---	---	13	1.23	---
Total	809	76.47	249	23.53	1058	100.00	1:0.30

Previous research on other lakes and reservoirs showed that the maximum age of *C. gibelio* was VI for Lake Marmara (Balık et al. 1991), Lake Eğirdir (Balık et al. 2004), the Buldan Reservoir in Denizli (Sarı et al. 2008), the Topcam Reservoir in Aydın (Şaşı 2015), Lake İznik in Bursa (Uysal et al. 2015) and Lake Marmara (the present study). The maximum age for *C. gibelio* was VII in Lake Bafra in Samsun, Lake Uluabat in Bursa and the Seyitler Reservoir in Afyonkarahisar (Table 5). In all studies, the age for the majority of specimens was determined as II and III.

The total length of females and males ranged from 10.0 to 27.5 cm and from 10.2 to 24.0 cm; their weight varied from 17.1 to 378.4 g and from 17.7 to 2449.1 g, respectively. Table 2 presents the age–length relationship in the *C. gibelio* population.

Table 2

Age–length relationship of *C. gibelio* (CI: Confidence Interval; SD: Standard Deviation)

	Age	n	Length (cm)			
			Min.	Max	Mean ± CI	SD
Female	I	216	10.0	14.8	12.62 ± 0.117	0.979
	II	306	14.2	18.5	16.79 ± 0.108	0.958
	III	235	16.8	23.5	19.43 ± 0.197	1.531
	IV	32	18.2	24.8	22.23 ± 0.716	1.986
	V	7	24.0	25.8	25.11 ± 0.529	0.572
	VI	13	26.0	27.5	26.77 ± 0.245	0.405
Male	I	195	10.2	14.0	12.04 ± 0.102	0.718
	II	36	13.0	18.7	16.11 ± 0.408	1.205
	III	14	17.0	21.5	19.00 ± 0.077	1.650
	IV	3	18.8	23.5	21.23 ± 4.773	1.922
	V	1	24.0	24.0	24.00	-
Combined sex	I	411	10.0	14.8	12.34 ± 0.089	0.911
	II	342	13.0	18.7	16.72 ± 0.107	1.009
	III	249	16.8	23.5	19.40 ± 0.192	1.541
	IV	35	18.2	24.8	22.25 ± 0.686	1.989
	V	8	24.0	25.8	24.98 ± 0.542	0.650
	VI	13	26.0	27.5	26.77 ± 0.245	0.405

LWR parameters were determined for females, males and for all specimens. Values for *b* for all LWR data were highly significant (t_{cal} = 2.196, $p < 0.05$ for females; t_{cal} = 1.166, $p < 0.05$ for males; t_{cal} = −2.342, $p < 0.05$ for all specimens). The estimated parameters and results of statistical analysis for both sexes are presented in Table 3.

Von Bertalanffy growth parameters of the *C. gibelio* population were as follows: L_∞ = 35.86 cm, k = 0.189 year^{-1}, t_0 = −1.238 years. The maximum asymptotic length was determined in females (Table 4).

Previous studies focused on the length distribution, age, L_∞, LWR parameters in different localities. The results of some studies are presented in Table 5.

Table 3

LWR parameters of *C. gibelio* for females, males and combined sexes

	Female	Male	Combined sex
n	809	249	1058
r	0.985	0.985	0.986
a	0.014	0.015	0.018
b	3.039	3.038	2.965
$b_{(SE)}$	0.018	0.033	0.014
t_{cal}	2.196	1.166	−2.342

Table 4

Von Bertalanffy growth parameters of *C. gibelio*

	n	K (year^{-1})	t_0 (year)	L_∞ (cm)
Female	809	0.177	−1.382	36.68
Male	249	0.178	−1.573	35.40
Combined sex	1058	0.189	−1.238	35.86

The studies determined the maximum length distributions in Lake Uluabat (total length) as 8.5–33.3 cm in Bursa (Emiroğlu 2008) and 9.0–33.0 cm in Lake Eğirdir (fork length) in Isparta (Balık et al. 2004). The maximum total length was 37.3 cm in Lake Trichonis; the maximum fork length was determined as 32.5 cm in Lake İznik (Tsoumani et al. 2006). The minimum total length was 6.8 cm in Lake Marmara (İlhan & Sarı 2013) and the minimum fork length was 7.1 cm in Lake Beyşehir (Çınar et al. 2007). In Lake Trichonis, Lake Vegoritis, the Danube River and many other populations, the maximum total length of members proved to be greater than in this study (Table 5). Many biotic and abiotic factors (e.g. sex, temperature, gonad maturity, size range, health, and condition of fish) can directly affect the LWR (Tesch 1971).

The maximum asymptotic length was 48.09 cm (fork length) in the Seyitler Reservoir (Bulut et al. 2013) and the minimum asymptotic length was 31.60 cm in the Buldan Reservoir (Sarı et al. 2008). Values from some other studies were: L_∞ = 41.46 cm (fork length) in the Topçam Reservoir (Şaşı 2015); L_∞ = 40.00 cm (fork length) in Lake İznik (Uysal et al. 2015); L_∞ = 38.90 cm in Lake Eğirdir (Özkök et al. 2007); L_∞ = 33.30 cm in Lake Eğirdir (Balık et al. 2004); L_∞ = 39.38 cm in the Danube River (Gheorghe et al. 2012), with the maximum total length and asymptotic length determined as L_{max} = 27.5 cm and L_∞ = 35.86 cm, respectively. These morphological parameters are smaller compared to the Danube River: L_{max} = 35.0 cm, L_∞ = 39.38 (Gheorghe et al. 2012), Lake Uluabat: L_{max} = 33.3 cm, L_∞ = 36.44 (Emiroğlu 2008) and the Seyitler Reservoir: L_{max} = 32.5 cm, L_∞ = 48.09 (Bulut et al. 2013). The results were obtained by using the total length. Differences in the values from other localities could result from

Table 5

Length distributions, L_∞, maximum age, LWR parameters and the correlation coefficient in different studies from Turkey

Localities	Author	Length (cm)	L_∞ (cm)	Max age	*a*	*b*	*r*
Lake Eğirdir	Balık et al., 2004[FL]	9.0–33.0	33.30	VI	0.016	3.15	0.99
	Bostancı et al. 2007[b]	8.2–28.1	-	-	0.015	3.17	0.98
	İzci 2004[CA]	-	-	VI	0.021	3.05	-
	Özkök et al. 2007	-	38.90	-	0.016	3.12	-
Lake Bafra	Bostancı et al. 2007[a]	16.9–30.0	-	VII	0.026	2.97	0.97
Lake Beyşehir	Çınar et al. 2007[FL]	7.1–27.4	36.20	V	0.013	3.18	0.94
Lake Uluabat	Emiroğlu 2008[*]	8.5–33.3	36.44	VII	0.016	3.03	0.85
Lake İznik	Uysal et al. 2015[FL]	7.8–32.2	40.00	VI	0.015	3.12	0.99
Lake Ladik	Yazıcıoğlu 2013	13.4–26.5	-	-	0.016	3.14	0.99
Buldan Reservoir	Sarı et al. 2008	9.7–25.5	31.60	VI	0.031	2.87	0.98
Seyitler Reservoir	Bulut et al. 2013[*FL]	14.8–32.5	48.09	VII	0.027	2.93	0.81
Topçam Reservoir	Şaşı 2015[FL]	23.8–29.5	41.46	VI	0.036	2.88	0.99
Lake Vegoritis (Greece)	Tsoumani et al. 2006	16.2–33.2	-	-	0.009	3.25	0.98
Lake Trichonis (Greece)	Tsoumani et al. 2006	28.0–37.7	-	-	0.004	3.38	0.97
Danube River	Gheorghe et al. 2012	15.0–35.0	39.38	-	0.029	2.84	0.95
Lake Marmara	İlhan et al. 2014	10.0–27.5	-	-	-	-	-
	İlhan & Sarı 2015[*]	6.8–27.5	-	-	0.017	2.97	0.99
	Balık et al. 1991[CA]	-	36.05	VI	0.054	2.80	0.93
	This study[*]	10.2–27.5	35.86	VI	0.018	2.95	0.99

*CA: *Carassius auratus*, FL: fork length, a: intercept, b: regression coefficient

different sampling methods, length–weight and age distribution, age composition differences and different habitats.

Two studies on *C. gibelio* growth were carried out in the same location, i.e. Lake Marmara. The total length varied between 6.8–27.5 cm and 10.2–27.5 cm in İlhan & Sarı (2015) and Lake Marmara in the present study, respectively. The asymptotic length reached by *C. gibelio* in Lake Marmara was 36.05 cm (Balık et al. 1991) and 35.86 cm as determined in this study. The results of the total length distribution and asymptotic length are almost similar to those of our study.

LWRs were highly significant, with most r^2 values being > 0.93 (except the Seyitler Reservoir and Lake Uluabat) and the slope growth parameters of *C. gibelio* varied from 2.80 (Lake Marmara) to 3.38 (Lake Trichonis) in all studies (Table 5). The highest values of the *b* parameter were 3.25 and 3.38 in Lake Trichonis and Lake Vegoritis, respectively. These lakes are deeper than the other lakes, 58 and 75 m, respectively. Slope values were less than 3.00 in Lake Bafra (Bostancı et al. 2007a), the Buldan Reservoir (Sarı et al. 2008), the Seyitler Reservoir (Bulut et al. 2013) and Lake Marmara (İlhan et al. 2015). In the present study, slope values were within the normal range. The results of the present study are similar to previous studies. The parameter *b* is directly affected by the ecosystem where the fish are found (Erdoğan et al. 2014).

One of the LWR parameters, *a*, ranged from 0.004–0.054; the correlation coefficient varied within 0.81–0.99 in all studies. In this study, the parameter *a* was 0.18 and *r* was 0.99.

The condition factors for *C. gibelio* females and males ranged from 1.5 to 2 (Fig. 2). The minimum and maximum condition factors calculated for females were 1.56 in October and 1.82 in May, for males – 1.67 in September and 1.94 in January, respectively. The average condition factor was 0.177 for females and 0.178 for males. Fulton's condition factor for *C. gibelio* sampled in Romania (in three different water bodies: Lake Brăneşti, the Sâi River and Lake Cişmigiu) was between 1.58 and 1.87 (Stavrescu-Bedivan et al.

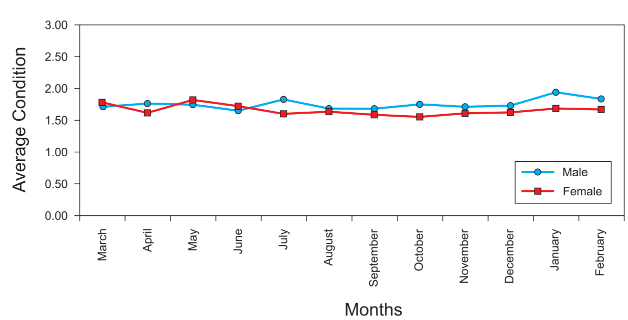

Figure 2

Average values of the condition factor for male and female individuals of *C. gibelio*

2015). Fulton's condition factor reflects the degree of well-being of fish in their habitat (Nehemia et al. 2012). Condition factors vary depending on the population as they are related to water quality parameters (Khallaf et al. 2003; Nehemia et al. 2012).

Conclusions

Since its introduction into natural lakes and reservoirs, *Carassius gibelio* has become the dominant fish there. According to the data of the Republic of Turkey Ministry of Agriculture and Forestry, fish catches of the lake amounted to 60.1 t in 2012. The target species of high economic value in the lake fishery are *C. carpio*, *Silurus glanis* and *S. lucioperca*. Therefore, the scrap species *C. gibelio* is also frequently fished (12.5 t in 2012) from the lake as a secondary catch, although it has low commercial value. The total potential of *C. gibelio* is very high, even though it is a kind of scrap catch in Lake Marmara. The presence of this species is therefore predicted to have a negative impact on fishing activities in the lake, where its population is likely to increase and continue to cause serious damage to the fishery.

There are growing concerns about the distribution and impact of *C. gibelio* in Turkey (Tarkan et al. 2012) as well as in Northern and Southern Europe (Vetemaa et al. 2005; Liasko et al. 2010), and the risk management strategies and control methods can be considered as inefficient. Negative effects of *C. gibelio* are likely to increase in the near future due to its adverse impact on native and endemic species by competing with the latter for food and habitat (Kottelat & Freyhof 2007). According to Tarkan et al. (2010), research on *C. gibelio* species should expand the database on the distribution, growth, reproduction and invasiveness, both in native and introduced populations, as well as on the potential impact of these introductions on food chains in aquatic ecosystems.

Furthermore, biological invasion is a major threat to endemic species. It is critically important that further studies should focus on negative impacts of invasive species on native species. The well-being of ecosystems could only be maintained by increasing the number of such studies, otherwise it is impossible to properly manage fishery activities in regions with unknown ecology.

Acknowledgements

We are grateful to the Republic of Turkey Ministry of Agriculture and Forestry for the legal permission for this research. We would like to express our appreciation to the Ege University Scientific Research Project Commission, which supported this study with BAP-Project No. 2011/SÜF/040.

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