



Reproductive characteristics of an invasive species *Carassius gibelio* (Bloch, 1782) in Ataturk Dam Lake, Turkey

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ABSTRACT

In this study, sex composition, spawning period, fecundity and sexual maturity of the gibel carp, *Carassius gibelio* (Bloch, 1782), an invasive species in the Atatürk Dam Lake, on Euphrates River, Turkey were studied. *C. gibelio* specimens were analysed from Ataturk Dam Lake and the percentage of the males and females was 45.55% and 55.45% respectively out of the 110 specimens studied, ranging between age groups I -VI. The age at first maturity was three years for both females and males. The diameter of the egg was smallest in September, with a mean of 0.62 mm, while the mean egg diameter in June was greatest, at 1.54 mm. The absolute fecundity ranged from 1054 to 22548. Reproduction of gibel carp in Atatürk Dam Lake in Turkey was characterised by a young age at first maturity and high spawning capacity that would facilitate population expansion in aquatic environments.

Keywords: *Carassius gibelio*, Fecundity, Gonado-somatic index, Reproduction

Introduction

Investigations on the reproductive characteristics of fish and understanding the reproductive details of a species is central to the development of successful strategies for sustainable fisheries (Unlu, 1991; Ali and Kadir, 1996; Muchlisin, 2014) and for evaluating the impacts of environmental variability on the dynamics of fish populations (Schlosser, 1990; Tarkan *et al.*, 2009). In addition, information on the reproductive biology of the candidate species is fundamental to the development of aquaculture (Tesch, 1968; Priyadharsini *et al.*, 2013). Consequently, many undescribed species are in potential danger of extinction because of incomplete taxonomy, unrecognised congeneric variation and/or lack of studies on reproductive characteristics (Brophy, 2004).

Carassius gibelio (Bloch, 1872) belonging to the family Cyprinidae has been a subject of a long debate regarding its validity and origin (Yerli *et al.*, 2014). This is a potamodromous species and tolerant to marginal habitats (Kukuradze and Mariash, 1975; Riede, 2004; Docherty *et al.*, 2017). It is also an invasive species and is widely known in Turkey as Israeli carp and thought to be a result of hybridisation or even thought to be a native to far east of Central Europe, introduced to Europe (Ilhan and Sari, 2013; Yerli *et al.*, 2014). It has wide distribution

in Turkey (Ozulug *et al.*, 2004; Innal and Erk'akan, 2006; Gaygusuz *et al.*, 2007; Tarkan *et al.*, 2012; Yerli *et al.*, 2014; Tarkan *et al.*, 2017; Gulsah and Ozulug, 2017). This species is hazardous for native fish communities in Turkey (Gozlan *et al.*, 2010; Aydin *et al.*, 2011; Tarkan *et al.*, 2017) and has become one of the dominant species which may change the flow of nutrients in the entire ecosystem (Paulovits *et al.*, 1998; Yilmaz *et al.*, 2004).

Ataturk Dam was commissioned in 1990 for irrigation and hydroelectric purposes. It is one of the largest man-made dams in Turkey, which occupies an area of approximately 817 km², making the lake the biggest artificial reservoir in Turkey (Oymak *et al.*, 2011). For its large size and ecological properties, it has very high potential for fisheries. There are 28 species and subspecies belonging to 8 families in Ataturk Dam Lake (Bozkurt, 1994; Oymak *et al.*, 2001). However, the number of native species in the lake decreased after the introduction of *C. gibelio* through restocking of carp fry (Leonardos *et al.*, 2008; Emiroglu *et al.*, 2012).

Studies of *C. gibelio* in Turkey, are limited and information on its reproductive performance is scarce (Balik *et al.*, 2004; Tarkan *et al.*, 2009; Emiroglu *et al.*, 2011; Emiroglu *et al.*, 2012; Tarkan *et al.*, 2012; Kirankaya and Ekmekci, 2013). Likewise, there is no scientific study

on reproduction of *C. gibelio* population in the Atatürk Dam Lake, till date.

Gibel carp is becoming the most dominant species in many aquatic environments with high adaptation to different ecological conditions (Lusk *et al.*, 2010). For this reason, the reproductive success of populations in different environments need to be investigated and monitored. The purpose of this study was to describe the reproductive characteristics including sex ratio, age at sexual first maturity, spawning time, gonado-somatic index, ova diameter and fecundity of *C. gibelio* from the Atatürk Dam Lake, the biggest reservoir in Turkey and to make comparisons among the different localities within the lake.

Materials and methods

Samples of *C. gibelio* were collected from January to November 2009 at monthly intervals from Atatürk Dam Lake near Kahta and Samsat Town of Adiyaman in Turkey (Fig. 1).

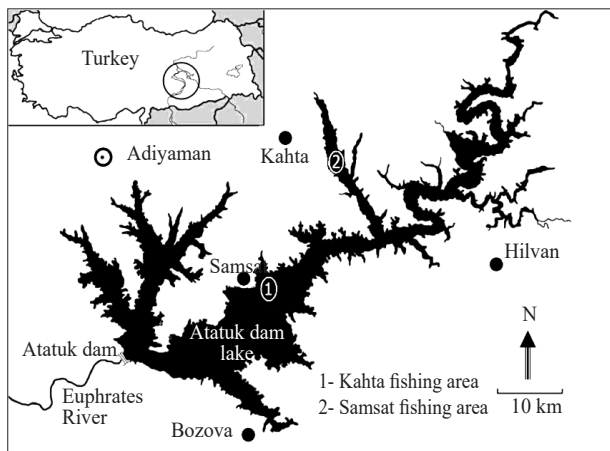


Fig. 1. Map of the study area (Oymak *et al.*, 2011)

Overall, 110 specimens (61 females and 49 males) of *C. gibelio* were collected using gillnets of various mesh sizes (18x18 mm, 24x24 mm and 30x30 mm). The fish were brought to the laboratory in an icebox the same day. Specimens were tagged after biometric data on sex; fork length (FL) and weight (W) measurements were recorded (Table 1). FL was measured to nearest 1 mm and weight to nearest 1 g. The age of the specimens were identified by checking the scales according to the criteria described by Polat (1987). For this purpose, approximately 10 scales were taken from the mid-body behind the pectoral fins of each individual sampled. The scales were mounted between two glass microscope slides and they were assessed by Kindermann Microfiche Reader. Sex was determined by examination of the gonads either visually

for the larger individual samples or with the aid of a binocular stereo microscope for the smaller samples.

The gonads were separated and weighed to the nearest 0.01 g. The monthly gonado-somatic index (GSI) was calculated according to the equation as established by Wootton (1990): $GSI = \text{Gonad weight (g)} / \text{Body weight (g)} \times 100$. Sex ratio was estimated for all fish caught and comparisons of sex ratio based on the expected 1:1 ratio were made by Chi-square test at confidence level of 95%. Maturity of samples was detected by visual inspection of the gonads in the samples caught in months close to the reproductive period.

The age at which 50% of fish were mature was considered as the age at first maturity for both sexes (Oymak *et al.*, 2011). The average length of fish at this age was evaluated to be the length at first maturity. To determine the fecundity of *C. gibelio*, the number of eggs produced by individual fish was calculated by the gravimetric method from ovaries which had been preserved in 4% formalin solution (Laevastu, 1965) so as to enumerate the total number of eggs in the particular ovary. From each ovary, 20 ova were chosen at random and the mean diameter for each egg was manually measured to the nearest mm. The relative fecundity (Fr) was expressed by dividing the absolute fecundity by the fish body weight (Bagenal, 1978). The relationship between fecundity (F) and fork length (FL, mm), body weight (W, g) and gonad weight (GW, g) of fish were determined by using the power regression equation $F = aX^b$, where F = Fecundity, X = Standard length of fish (mm) or weight of fish (g), a = Regression constant and b = Regression coefficient. The relationship was log transformed into a straight line, as $\text{Log } Y = a + b \text{ Log } X$ (Wootton, 1990).

Results and discussion

Length and weight of monthly samples

The number, fork length and body weight of the 110 specimens of *C. gibelio* collected monthly from Atatürk Dam Lake during the study are given in Table 1. The length and body weight were in the range 80 - 252 mm and 9 - 328 g respectively.

Sex ratio, age and size at first maturity

From the total 110 specimens collected, 61 were females and 49 males, with an overall sex ratio of 1: 0.80 (female to male). The difference between the number of females and males was not significant ($\chi^2 = 1.309$, $p > 0.05$) from the expected 1:1 ratio.

The results showed that six age groups for both females and males were represented in the current study

Table 1. Number (n), length and weight (mean±SD) of *C. gibelio* sampled monthly during the study period between January and November 2009 from the Atatürk Dam Lake

Month	Female				Male			
	n	Fork length (mm)	Weight (g)	n	Fork length (mm)	Weight (g)		
		Mean±SD	Mean±SD		Mean±SD	Mean±SD		
January	5	190.0±6.12	161.8±17.08	3	140.8±92.41	137.3±24.58		
February	4	189.0±9.87	150.5±32.62	2	111.0±94.87	80.0±14.14		
March	8	174.4±21.95	118.1±43.81	2	105.7±89.81	75.0±9.90		
April	6	97.7±14.39	18.7±8.07	7	103.8±50.93	33.1±31.11		
May	5	151.8±52.10	87.0±85.25	2	73.3±65.25	20.0±11.31		
June	6	197.5±8.38	136.0±19.56	4	140.2±79.10	97.8±52.45		
July	9	189.4±17.78	127.8±31.52	11	156.3±49.51	85.8±35.39		
August	2	187.5±3.54	114.5±0.71	4	168.8±92.13	172.0±7.87		
September	5	194.4±16.79	143.2±45.05	4	147.4±85.44	122.8±57.35		
October	6	192.2±31.81	164.5±84.61	6	152.3±69.36	150.8±76.91		
November	5	190.8±30.31	166.0±84.37	4	165.2±91.94	184.0±72.54		

(Table 2). The highest frequency of fish caught occurred at 5 years age (63.9% for females and 42.9% for males). t-test analysis revealed that the age differences were not significant between females and males ($t = 0.6182$, $df = 5$, $p > 0.05$).

Table 2 shows the summary of age at sexual maturity based on the results obtained from the gonad examination of *C. gibelio* collected in this study. It was observed that all of the females with 95 mm and males with 90 mm fork length and those older than three years were mature individuals.

Spawning season

In order to determine the spawning season of *C. gibelio*, the mean gonado-somatic index and mean egg diameter were calculated monthly (Fig. 2 and 3). The results revealed that the peak GSI values of 16.77 and 5.06 respectively for females and males were observed in the month of May. The lowest mean value for females was found in November (GSI = 2.72) and for males in August (GSI = 1.06). The mean GSI values were found to diminish from November until the new spawning season.

The mean egg diameter, measured monthly from January to November 2009, was highest in May with a mean of 1.54 and lowest in September with a mean of 0.62 mm when the ovaries contain only oocytes which would develop the following year. As shown in Fig. 2 and 3, there is a strong relationship between GSI values and egg diameter with month. This trend of GSI values and seasonal development in ova size showed that the spawning took place in May and continued until late June in the population.

Fecundity

Absolute fecundity was estimated in adult females during the study. Individual values of the absolute fecundity varied in a wide range from 1054 to 22548 with a mean of 9202 ± 5727 ($n = 58$) in *C. gibelio*. The relative fecundity was 5.67 to 379.38 eggs with a mean of $96.89 (\pm 91.31)$ per gram of body weight.

Absolute fecundity was significantly related to female body length and gonad weight, with the regression coefficient values of 0.680 (Table 3). Other relationships between fecundity with fish length and fish weight, although positive, were not significant ($p > 0.05$).

Table 2. Age group and the maturity percentage of females and males of *C. gibelio* from the Ataturk Dam Lake

Age group	Female					Male				
	n	IM	IM%	M	M %	n	IM	IM%	M	M %
I	-	-	-	-	-	-	-	-	-	-
II	2	2	100.0	-	0.0	2	2	100.0	1	25.0
III	5	1	20.0	4	80.0	6	2	33.3	4	67.7
IV	10	0	0.0	10	100.0	13	0	0.0	13	100.0
V	39	0	0.0	39	100.0	21	0	0.0	21	100.0
VI	5	0	0.0	5	100.0	7	0	0.0	7	100.0

n = Number of fish; IM = Immature; M = Mature

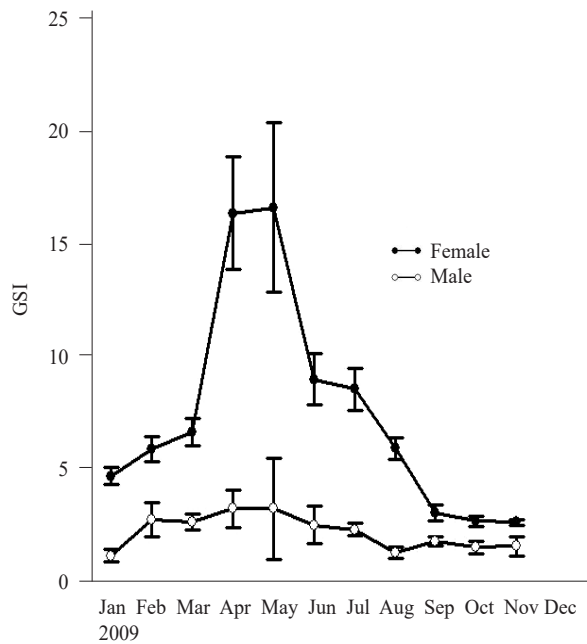


Fig. 2. Gonado-somatic index (GSI) of *C. gibelio* from the Ataturk Dam Lake

Table 3. Correlation coefficients and regression equation for relationships between absolute fecundity (F) and body length (FL), body weight (W) and weight of gonad (GW) of *C. gibelio* from the Ataturk Dam Lake

Relationship	n	Power regression	r	r ²	F	p
F-FL	58	F = 1108.919 FL ^{0.3614}	0.091	0.008	0.4679	0.4967
F-W	58	F = 6289.267 W ^{0.0292}	0.024	0.001	0.0311	0.8606
F-GW	58	F = 1139.725 GW ^{0.9542}	0.680	0.462	48.0524	0.0000

Fecundity of *C. gibelio* revealed that it was more related to gonad weight than to body length and body weight.

According to Tarkan *et al.* (2012) non-native gibel carp populations inhabiting different types of aquatic ecosystems in Turkey could be differentiated by their life history traits and growth patterns. Considered a typical invasive alien species, *C. gibelio* heavily depressed the occurrence and numbers of indigenous *C. carassius* populations and native cyprinid fish (Kukuradze and Mariash, 1975; Lusk *et al.*, 2010).

In this study, 110 (61 females and 49 males) specimens of *C. gibelio* were caught from Ataturk Dam Lake, ranging from age group I to VI, in which, age group V represented the highest number of specimens obtained (females = 39 and males = 21) (Table 1). The results corroborate the studies conducted by Balik *et al.* (2004) in Turkey in which the specimens were represented by age group I to VI. More age groups were recorded in the study conducted by Emiroglu *et al.* (2012) in the Lake Uluabat (419 females and 153 males) where the age group ranged

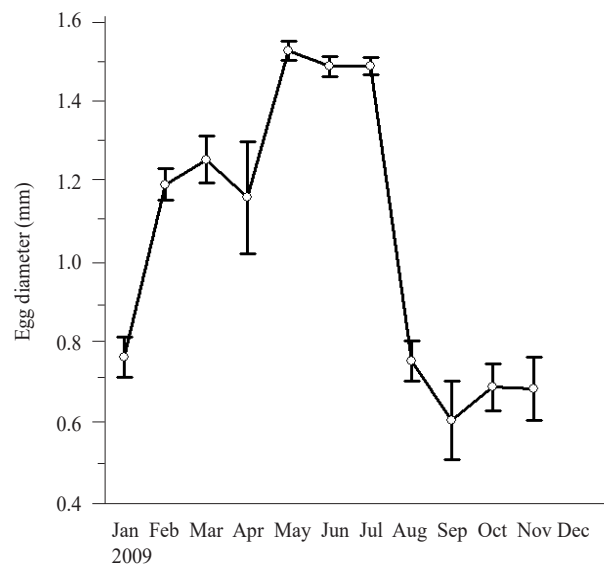


Fig. 3. Egg diameter of *C. gibelio* from the Ataturk Dam Lake

from I to XII. Likewise, Tarkan *et al.* (2012) reported age group from I to XI for a total of 1380 (1060 females and 320 males) individuals collected from 16 water bodies in Turkey. These variations could be attributed to either environmental changes, the length of time since introduction Tarkan *et al.* (2010), variations in fishing techniques during sampling activity, feeding habits of fish and the ecological characteristics of the lakes.

The age structure of *C. gibelio* at the sampling location in Ataturk Dam Lake indicates that most specimens leave the location and probably migrate into other locations not included in this current study during their first year of life. Another possible factor for the absence of age group I in our data may be due to water temperature which may directly or indirectly influence the food availability at the sampling locations.

In this study, most individuals spawned during May to June, while in Lake Egirdir, the most intensive period for reproduction was from April to July (Balik *et al.*, 2004) and in Lake Uluabat, from March to early May (Emiroglu *et al.*, 2012). In 16 water bodies in Turkey, the species spawned mainly from early April to late June (Tarkan *et al.*, 2012) and in Ikizcetepeler Dam Lake, their spawning period was mainly from early April and July (Erdogan *et al.*, 2014). The difference in some localities are thought to be due to climatic conditions, especially due to the higher temperature of water. In this study, the highest mean ova diameter was recorded in May (1.54 mm) and lowest in September with a mean of 0.62 mm. In Lake Uluabat, mean egg diameter was highest in March (0.98 mm) while it was lowest in July (0.69 mm) (Emiroglu *et al.*, 2012). Tarkan *et al.* (2012)

recorded highest mean egg diameter of 1.34 mm in May from 16 water bodies in Turkey. Egg size reported in our study is the highest which may be attributed to feeding. In this study, fecundity was estimated in females captured just prior to spawning and the number of eggs ranged from 1054 to 22548. Fecundity ranged from 42000 to 141000 in Lake Egirdir (Balik *et al.*, 2004) and in Lake Uluabat (Emiroglu *et al.*, 2012), it ranged from 1822 to 80,000 in 16 water bodies in Turkey (Tarkan *et al.*, 2012). These differences in the number of eggs are influenced by age, size and nutrition of fish (Wootton, 1990) and various physico-chemical factors (Schlosser, 1990; Schulte, 2014). Absolute fecundity was found to be linear with gonad weight which indicates that the number of eggs increases with ovary weight. Similar findings were reported by Emiroglu *et al.* (2012) for *C. gibelio* and by Ortega-Salas and Reyes-Bustamante (2006) for *C. auratus*.

Data obtained from this study could be used as baseline data for carrying out future investigations and may provide valuable information needed for monitoring and management of invasive species in aquatic environments.

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