Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2013) 37: 636-640

doi:10.3906/vet-1206-10

Comparison of growth and reproduction of mirror carp and scaled carp introduced into Gelingüllü Reservoir, Yozgat, Turkey

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Received: 08.06.2012 • **Accepted:** 28.01.2013 • **Published Online:** 13.11.2013 • **Printed:** 06.12.2013

Abstract: Carp have been translocated and introduced outside of their natural range in many countries. In Turkey, mirror carp (a warm-water fish) has generally been introduced into man-made reservoirs for fishery management, regardless of geographic location and climatic conditions. During the previous decade, controversy has arisen concerning the adaptation and spawning of carp, and the success of such introduction practices in Central Anatolia, which is characterized by typical cold continental weather conditions. Concurrently, based on some irregular observations, scaled carp was reintroduced as an alternative to mirror carp. Long-term monitoring studies on the growth and reproduction of mirror carp and scaled carp introduced into reservoirs are necessary for effective fishery management. This study aimed to compare the growth and reproduction of mirror carp and scaled carp populations in Gelingüllü Reservoir. A total of 796 mirror carp and 285 scaled carp were caught between June 2002 and July 2005. Scaled carp reached up to 61.9 cm in fork length (FL) at age 8+ whereas mirror carp could reach to a maximum of 71.5 cm in FL at age 9+. The data show that mirror carp had a better growth rate and higher fecundity than scaled carp. Introduction of mirror carp may be recommended for fishery management applications under continental climate conditions.

Key words: Central Anatolia, *Cyprinus carpio*, fish introduction, nonnative fish, fecundity

1. Introduction

Introduction of fishes to freshwater ecosystems for fishery management is a common practice in many countries (1). The choice of species for culture depends on many factors, such as regional climatic conditions, vacant niche, biological characteristics of the preferred fish (i.e. growth rate, reproductive success, and disease resistance), and consumer preference (1–3). *Cyprinus carpio*, which has 4 basic domestic forms (scaled carp, line carp, mirror carp, and leather carp), is probably the oldest cultured and most domesticated fish in the world (4). Today, carp is an important fish for commercial fisheries in natural waters and aquaculture settings, and it is widely used for transfer and introduction (1–2).

Reservoirs that are the result of dams built for various purposes, including hydroelectric power generation, agricultural and domestic water supply, and flood control, are stocked with commercially valuable fish species to provide opportunities for employment. There has been a tendency to introduce mirror carp into many reservoirs in order to develop aquaculture, but monitoring of fishery practices after such introductions is lacking in Turkey, as in many other countries. Following the carp introduction a short and high productive period has been observed, but later a sharp decrease in fishery production appeared in many reservoirs in Turkey (personal communication with DSI authorities). Ekmekçi (5) also reported that after short periods of productive practice following the impoundment, fishery of carp becomes unfavorable. The success of mirror carp reproduction and growth is a contentious topic. Governmental organizations responsible for fish introductions recently reported a preference for scaled carp over mirror carp; however, quantitative and comparative data on introduced mirror carp and scaled carp populations are currently unavailable.

Gelingüllü Reservoir in Yozgat, Turkey (Central Anatolia) (39°36′30″N, 35°032′02″E) was impounded by the end of 1993 to provide water for agriculture. The reservoir is at an altitude of 1000 m a.s.l. in a region with continental climatic conditions. According to mean temperature values of the region between 1997 and 2003, the maximum and minimum air temperatures were 19.6 °C in August and –2 °C in January. Due to the difficult climatic conditions, fishing is possible only between March and November. The native ichthyofauna of the area consists of *Capoeta baliki*, *Capoeta sieboldii*, *Squalius cephalus*, *Chondrostoma nasus*, *Alburnus* sp., *Alburnoides*

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bipunctatus, *Rhodeus amarus*, *Barbus tauricus*, *Cobitis simplicispinna*, and *Oxynoemacheilus brandtii.* After the dam was constructed, mirror carp, a warm-water culture fish, was regularly introduced into the reservoir between 1994 and 2001 to provide employment opportunity, as routinely practiced in other reservoirs in Turkey (Table 1). The growth of the mirror carp population was monitored during the initial period of introduction into the Gelingüllü Reservoir by Ekmekçi (5), Ekmekçi and Kırankaya (6), and Kırankaya and Ekmekçi (7), who reported that the population had a very high growth rate, despite the cold weather conditions, which may have been due to the general characteristics of the initial period of newly built reservoirs (8). After 2001, both scaled carp and mirror carp were introduced into the reservoir; as such, the present study aimed to simultaneously compare their growth and reproduction in the same environment. We think that the present findings will be useful for future fisheries management practices in Turkey, as well as in similar environments around the world.

2. Materials and methods

Fish specimens were collected between June 2002 and July 2005, using gill nets with mesh size varying from 25 × 25 mm to 100 × 100 mm.

The fork length (FL) and weight (W_t) of each specimen were determined to the nearest 1 cm and 0.1 g, respectively. Relative body condition (K_r) was calculated using the formula of Le Cren (9): $K_r = W_t / aL^b$ where W_t is the whole body weight (g), L is the fork length (cm), and a and b are the parameters of the length–weight relationship. Age was determined based on scales (10) and annuli were identified according to the criteria given by Bagliniere and Le Louarn (11) and Stainmetz and Müller (12).

Linear regression was used to assess the growth pattern and the length–weight relationship (13). Sex was determined by macroscopic examination of gonads. The spawning period was determined based on monthly variation in the gonadosomatic index (GSI). The GSI was calculated for males and females separately using the equation $GSI = (W_G / W_t) \times 100$, where W_G is gonad weight and W_t is whole body weight.

Fecundity was estimated by the gravimetric method with ovaries preserved in 10% formaldehyde solution (14,15). Subsamples were obtained from the anterior, middle, and posterior parts of mature ovaries. The absolute fecundity (AF) was estimated as $AF = W_G \times D$, where W_G is gonad weight and D is number of the oocytes per gram of ovarian tissue (15). Relative fecundity (RF) was calculated using the equation $RF = AF / W_t$ (15).

Differences in FL, W_t, and K_r between mirror carp and scaled carp of the same age were statistically analyzed using the Mann–Whitney U test. Comparison of the slopes of the length–weight regression (b) between mirror carp and scaled carp were tested using Student's t-test (16). Variation in the sex ratio was analyzed using the chi-square test (16). SPSS 16.0 for Windows was used for all statistical analyses.

3. Results

Using the same fishing equipment, 796 mirror carp and 285 scaled carp were collected from the Gelingüllü Reservoir. The age composition of the mirror carp was 0–IX, versus I–VIII for the scaled carp (Figure 1). The dominant mirror carp age groups in the catch were I, II, and III, with rates of 21.9%, 32.9%, and 23.1%, respectively, versus II, III, and IV in scaled carp population, with rates of 18.3%, 36.8%, and 18.2%, respectively.

Mean FL, W_t, and K_r values of fish specimens in the same age group were statistically compared to evaluate growth performance. FL was 8–71.5 cm for mirror carp and 10.5–61.9 cm for scaled carp. In mirror carp and scaled

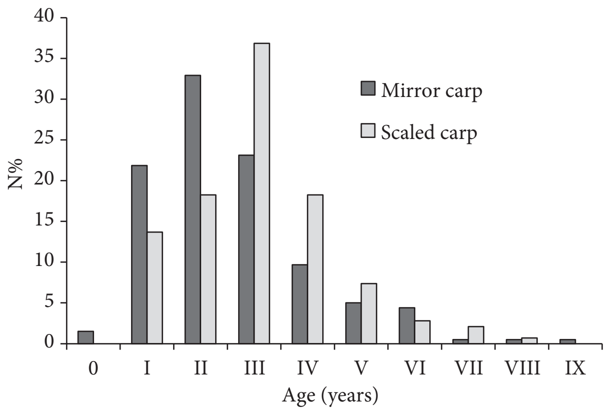

Figure 1. Age distribution in mirror carp and scaled carp in Gelingüllü Reservoir.

Table 1. Fish stocking program of Gelingüllü Reservoir (M: mirror carp, S: scaled carp; data from General Directorate of State Hydraulic Works - DSI).

Year	1994	1995	1996	1997	1999	2000	2001	2001	2002	2003	2004
	M	M	M	M	M	S	M	S	S	S	S
Int. fish amount (×1000)	200	100	150	200	150	200	100	20	100	100	100

carp populations, FL growth exhibited linear change with age, based on the equations FL = 6.71 t + 11.6 and FL = 6.36 t + 9.85, respectively (Figure 2). The mean FL length in mirror carp was about 3–4 cm longer than in scaled carp and the difference was significant in all age groups (Mann–Whitney U test, P < 0.05).

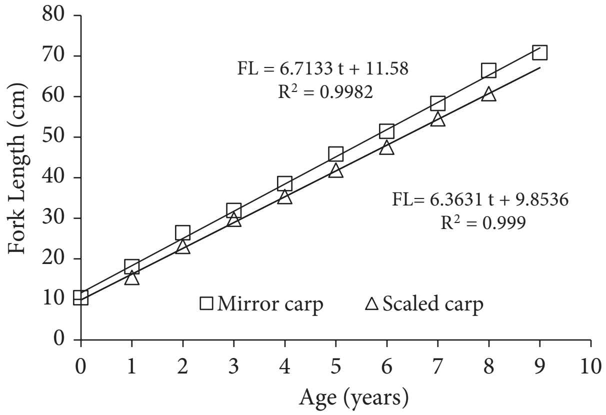

Figure 2. Age–length relationship of mirror and scaled carp (FL: fork length, t: age).

The minimum W_t values for mirror carp and scaled carp populations were 13.3 g and 19.7 g, respectively. Mirror carp attained a maximum W_t of 12.5 kg, versus 4.22 kg for scaled carp. In each age group mirror carp were 1.5–2 times heavier than scaled carp (especially above age group III) (Figure 3). Statistical analysis showed that the difference in W_t between mirror carp and scaled carp populations was significant (Mann–Whitney U test, P < 0.05). Furthermore, the age–weight growth curves showed that mirror carp in Gelingüllü Reservoir had a higher growth rate than scaled carp (Figure 3).

The length–weight relationship estimated for mirror carp and scaled carp was $W_t = 0.0283 \times FL^{2.98}$ ($r^2 = 0.96$) and $W_t = 0.0272 \times FL^{2.96}$ ($r^2 = 0.98$), respectively. The standard error of coefficient *b* was 0.022 for mirror carp and 0.028 for scaled carp. There was not a significant difference in coefficient *b* between the mirror carp and scaled carp populations (Student's t-test: t = 0.50, P > 0.001). The calculated *b* exponents significantly differed from 3, which indicated isometric growth.

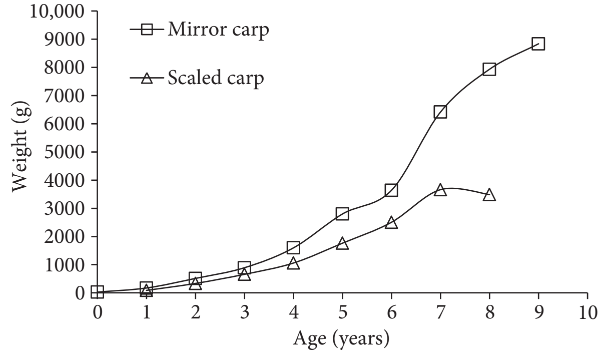

Figure 3. Age–weight relationship of mirror and scaled carp.

Mean K_r varied between 0.91 to 1.13 in mirror carp and 0.90 to 1.20 in scaled carp. K is an important indicator of growth performance and was significantly higher, in all age groups, in mirror carp than in scaled carp age groups (Mann–Whitney U test, P < 0.05) (Figure 4).

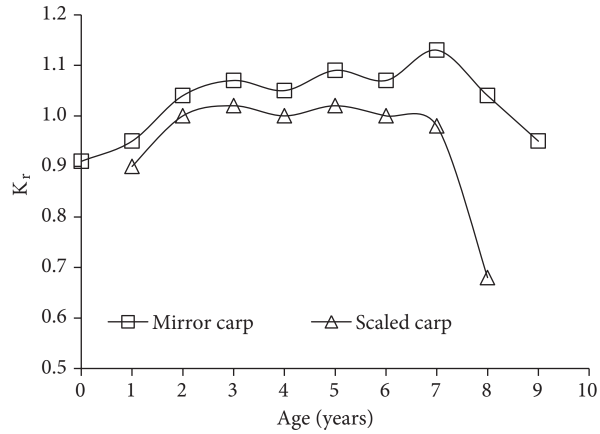

Figure 4. Relative condition (K_r) of mirror and scaled carp for different age groups.

The mirror carp sample was 57% female and 43% male, whereas scaled carp sample was 51% female and 49% male. The male:female sex ratio was 0.76:1 for mirror carp and 0.97:1 for scaled carp. The male:female ratio for the mirror carp population varied significantly from the expected 1:1 ($\chi^2 = 10.6$, P < 0.05).

The GSI of female mirror carp attained a maximum value of 12.02 in April and gradually decreased to 8.23 until July, whereas in August, the minimum value was recorded as 1.24 (Figure 5). The maximum GSI value of scaled carp was 11.03 in March and gradually decreased in April and May (9.17 and 8.8, respectively); the minimum value was 0.53 in July (Figure 5). The GSI of male mirror carp varied from 8.9 in March to 3.19 in August, and in male scaled carp this value varied from 7.7 to 1.87 during the period between March and August. According to GSI data, the spawning period was from April to August in mirror carp and from April to July in scaled carp.

AF increased with age in both fish populations, but was higher in mirror carp, varying from 44,226 (at age III) to 1,687,961 (at age IX) in mirror carp and from 22,395 (at age III) to 1,031,563 (at age VI) in scaled carp (Table 2). Additionally, during the early maturation period (at ages III and IV), the number of mirror carp eggs was 2- to 3-fold higher.

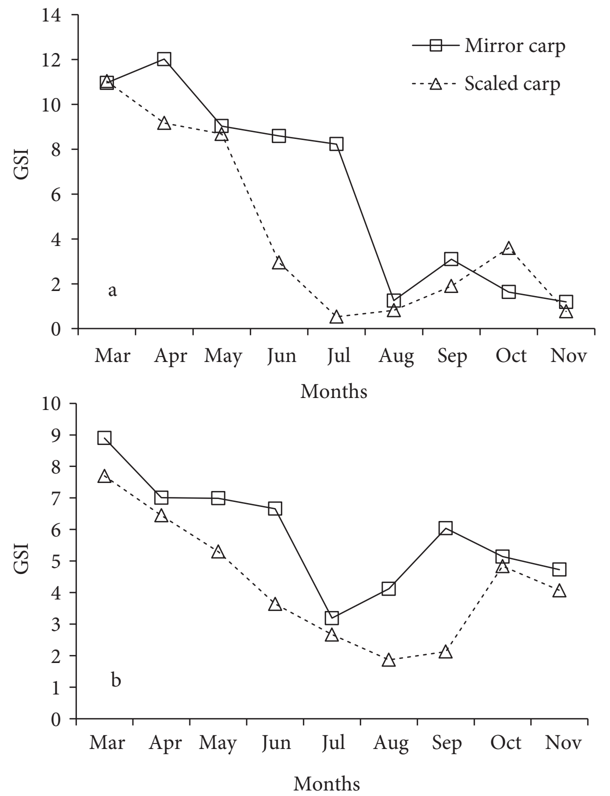

Figure 5. GSI cycles of female (a) and male (b) mirror carp and scaled carp.

Table 2. Absolute fecundity (AF) and relative fecundity (RF) of mirror carp and scaled carp in different age groups.

Age	Mirror carp		Scaled carp	
	AF	RF	AF	RF
III	44,226	47.7	22,395	32.2
IV	163,630	97.3	57,930	52.1
V	304,211	99.9	161,460	84.1
VI	459,138	121.3	407,409	147.5
VII	1,015,822	158.4	1,031,563	267.8
VIII	1,591,383	200.6	-	-
IX	1,687,961	191.0	-	-

4. Discussion

Quantitative data on the growth and reproduction of mirror carp and scaled carp living in the same environmental conditions were simultaneously obtained. The age distribution in both populations showed that young fish were more abundant due to the regular introduction of fingerlings between 1994 and 2004. These findings illustrate the fishing pressure on both populations; when 100 × 100-mm mesh nets were used, only a few carp in age groups above V were caught.

The age structure of the populations was indicative of the reproductive success of the scaled carp and mirror carp populations in the reservoir. The specimens in the 0+ mirror carp age group were caught after the cessation of carp introduction (2004 and 2005), and as such were born in Gelingüllü Reservoir. Despite extensive effort to catch younger carp, only mirror carp in the 0+ age group were caught; we could not collect any 0+ scaled carp when mature females and males were present. These findings suggest that scaled carp either could not breed or that their eggs could not hatch in the reservoir, and as such the mirror carp could be considered to be more successful than the scaled carp.

Age–length and age–weight relationships suggested that mirror carp in Gelingüllü Reservoir had a higher growth rate than scaled carp. Additionally, K, an important indicator of growth performance (9), also indicated that the mirror carp in Gelingüllü Reservoir had better growth performance than scaled carp.

The estimated b values for mirror carp and scaled carp were 2.98 and 2.96, respectively. According to length–weight relationships, negative allometric growth was observed in both the mirror carp and scaled carp populations.

In the present study, sex ratios differed significantly from parity and females were dominant in mirror carp samples. Females with a body cavity occupied by large-mass gonads, especially during the spawning season, could not move rapidly; consequently, females that swam close to the lake shore to spawn were easily captured by our nets.

The spawning period was from April to August in mirror carp and from April to July in scaled carp, indicating that there was some overlap between spawning periods of mirror carp and scaled carp. Carp is a phytophilic spawning fish that lays sticky eggs on shallow vegetation in the littoral zone (4,17); however, reservoirs with a narrow littoral zone and steep sides provide limited aquatic vegetation and a land/water ecotone that is unstable due to water level fluctuation (18). In addition to providing a spawning substratum for carp, the littoral zone also serves as a nursing area for fry and is used by larvae, juveniles, and adults for feeding (19). According to the present findings, in Gelingüllü Reservoir there may been competition for spawning in the littoral zone due to the overlap of spawning times of mirror carp and scaled carp .

In the present study, AF was higher in mirror carp and this can be considered indicative of the reproductive success of mirror carp in Gelingüllü Reservoir. RF also suggested high reproductive success of mirror carp.

In conclusion, the present data on growth and reproduction show that mirror carp, a warm-water culture form, established a successful population in the Gelingüllü Reservoir. We think that the present findings can be used to inform fish introductions into other reservoirs located in regions with continental climatic conditions. It should be noted that successful introduction of species into newly impounded reservoirs is highly dependent upon reservoir ontogeny, as reported by Ekmekçi (5) and Ekmekçi and Kırankaya (6). Additionally, fish introduction into newly impounded reservoirs should be performed in consideration of the fact that such reservoirs are sensitive ecosystems due to their poorly developed, narrow littoral zone (8). The authorities responsible for fish introductions in Turkey have recently preferred to introduce scaled carp instead of mirror carp. However, the results of the present study showed that mirror carp may be a better choice for introduction practices in artificial freshwater bodies in Turkey. Thus, this study should be taken into consideration for decisions on further fish introduction practices.

Acknowledgments

The study was supported by the Research Center Office (Hacettepe University) and State Planning Organization (TC Prime Ministry) (No. 02K102 209-4) and was extracted from the PhD thesis of ŞG Kırankaya, submitted in 2007 and supervised by FG Ekmekçi.

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