Seasonal Changes in the Condition Factor and Gonado-Somatic Index of *Carassius gibelio* From the Kopački rit Nature Park, Croatia

Sezonske promjene kondicijskoga i gonadosomatskog indeksa *Carassius gibelio* u parku prirode Kopački rit, Hrvatska

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SEASONAL CHANGES IN THE CONDITION FACTOR AND GONADO-SOMATIC INDEX OF *Carassius gibelio* FROM THE KOPAČKI RIT NATURE PARK, CROATIA

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SUMMARY

This study's objective was to explore some of the annual Prussian carp's (Carassius gibelio) biological characteristics (sex ratio, length–weight ratio, and gonado-somatic index - GSI) in the Kopački Rit Nature Park in Croatia. The Prussian carp is an invasive fish species originated from Asia, which became widely distributed throughout Europe and is believed to be responsible for a decline in the number of indigenous fish, invertebrate, and macrophyte populations in different areas. The fish sampling was conducted from September to November 2017 and from February to July 2018, respectively, using electrofishing. A total of 475 fish individuals were caught and measured for the total length, standard length, body height, and body weight. Males made up 34.31% of the population of Prussian carp. The mean value of Fulton condition factor (FC) of Prussian carp in Kopački Rit was 1.77 ± 0.28. Overall, the FC value had a relatively small amplitude, but it exhibited a clear seasonal variability. The average GSI values of females (9.91 ± 5.34) were higher than those of males (3.58 ± 1.37) during the observed period. The average GSI values indicate that the majority of females are spawning in the late April and May, which are also the same periods when other cyprinid species are spawning, allowing the Prussian carp to exploit its gynogenesis strategy.

Keywords: Nature Park, Invasive Aquatic Species, Carassius gibelio, sex ratio, adaptability, weight-length relationship, GSI

INTRODUCTION

Prussian carp (*Carrasius gibelio* Bloch, 1782) is a benthopelagic, potamodromous fish that feeds on detritus, zooplankton, zoobenthos, and macrophytes (Specziar et al., 1997). The species was introduced to Europe from Asia in the 17th century, but the definite data on its original distribution in Europe are not available (Rylková et al., 2013). It is believed that Prussian carp was introduced to Europe with East Asian cyprinids (Takada et al., 2010), and those accidental escapes from aquaculture resulted in the occurrences in open waters (Kalous et al., 2012). Soon, Prussian carp became widely distributed throughout Europe, and many European countries reported its findings in open waters in the late 1950s and early 1960s — for example, Greece in 1950 (Leonardos et al., 2008) and Serbia and Slovenia in 1962 (Plančić, 1967; Povž and Šumer, 2005). Prussian carp is well known for its invasiveness, and it is considered to be one of the most hazardous fish species for native fish communi-

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ties (Crivelli, 1995; Kalous et al., 2004, Tsoumani et al., 2006; Leonardos et al., 2008). A major biological trait responsible for the invasiveness of the Prussian carp is its reproduction. The Prussian carp has a dual mode of reproduction that is, a bisexual and an asexual one, and a form of parthenogenesis called gynogenesis, which requires the presence of sperm of other cyprinid species to activate (but not fertilize) their own eggs (Lusková et al., 2010; Innal, 2012, Prozybyl et al., 2020). The successfulness of invasion was also possible due to its unusual tolerance of a wide spectrum of ecological conditions (Vetemaa et al., 2005; Grabowska and Przybylski 2015). The Prussian carp can survive and thrive under adverse environmental conditions where other species rarely succeed. Therefore, it can easily become one of the dominant species in stagnant and slow-running waters and may change the flow of nutrients in the entire ecosystem (Paulovits et al., 1998), thus also influencing the fish fauna. Kopački Rit Nature Park is located in Eastern Croatia, being a triangular area between the rivers Danube and Drava and one of the largest internal deltas of the Danube River. Shallow waters and submerged vegetation characterize this area, making it suitable for nursery and a spawning ground for freshwater fish. Recent ichthyological research in Kopački Rit Nature Park indicated that Prussian carp became a dominant fish species (Opačak et al., 2015; 2016; 2017), but little information is available about the status of the population in the Nature Park for the purpose of management of this alien species. Information about the condition factor and length–weight relationship is both valuable and the widely used tools, important in studying the fish biology, conservation, and sustainable management. These variables are influenced by various ecological and biological factors, and they are often used to record a response of a specific organism toward a particular factor and providing understanding of general well-being of fish, its growth, survival, maturity, and reproduction (Jakovlić and Treer, 2001; Bakota et al., 2003; Prpa et al., 2007). The aim of this study was to present the data on some biological characteristics (sex ratio, length–weight relationship, and gonado-somatic index) during the year of the Prussian carp in the Kopački Rit Nature Park.

MATERIAL AND METHODS

The Prussian carps were captured during September–November 2017 and February–July 2018 in the lakes of Sakadaš, Bijelo, and Kopačko, by a single-pass boat-based electrofishing using the AGK EL65 II electrofisher. During the research, 475 individuals of Prussian carp were caught. For each fish, a total weight (W, g) and total length (TL, cm) were measured, respectively, by the Ref-meter Octo electronics scale to the nearest 1 g and by the ichthyometer to the nearest 0.5 cm. For fish euthanasia, anesthetic overdose with clove oil concentration of 140 mg l^{-1} clove oil were used (Woody et al., 2002). The individual fish were placed in a vessel with 2.0 liters of riverine water, and the clove oil was administrated. Two minutes subsequent to an opercular movement cessation, the fish did not manifest a reaction to handling and were removed from the water and decapitated prior to further analysis. A reproductive state was assessed macroscopically, and the weight of the gonads was recorded to nearest 0.01 g by ALJ 250-4AM Sysmex. The length-weight relationship ($W = \alpha TL^{b}$) was determined and tested for an isometric or allometric growth using the t-test (Pauly, 1984). Fulton's condition factor ($FC = W\ L^{-3}\ 100$) was calculated from the weight-length relationship (see Froese, 2006), with the intention of describing the "condition" of that individual fish. Also, the gonado-somatic index (GSI) [(GW / W) 100], which is commonly used as an index of reproductive activity in fish, (Wootton, 1998) was calculated monthly.

RESULTS AND DISCUSSION

In total, 475 individuals were caught between September 2017 and July 2018 (Table 1). The total length of the sampled fish ranged between 16 and 46 cm. A length-weight ratio (Figure 1) amounted to $TW = 0.0147\ TL^{3,051}$ ($r^2 = 0,99$, $n = 475$). The slope was not significantly higher than the theoretical value of 3 (t-test, $t = 1.581$, $P = 0.113$), indicating an overall isometric growth for a species. The sex of the fish could be determined at 16 cm for females and 18 cm for males.

Table 1. Total length (TL, cm), total weight (TW, kg), gonado-somatic index (GSI), and condition factor (FC) of Prussian carp

Tablica 1. Totalna dužina (TL, cm), ukupna masa (TW, kg) gonado-somatski indeks (GSI) i kondicijski indeks (FC) babuške

Month and year / *Mjesec i godina*	Sex / *Spol*	N	Mean TL±SD (Range) / *Prosjek TL±SD (raspon)*	Mean TW+SD (Range) / *Prosjek TW+SD (raspon)*	Mean GSI+SD (Range) / *Prosjek GSI+SD (raspon)*	Mean FC+SD (Range) / *Prosjek FC+SD (raspon)*
Sept. 2017 / rujan, 2017.	male / mužjaci	16	28.25±5.66 (21.0-37.0)	0.44±0.25 (0.15-0.96)	2.99±0.36 (2.00-3.41)	1.78±0.25 (1.59-2.60)
	female / ženke	30	32.13±7.40 (20.0-46.0)	0.70±0.45 (0.18-1.67)	5.72±1.68 (3.07-9.57)	1.83±0.25 (1.38-2.53)
Oct. 2017 / listopad, 2017.	male / mužjaci	17	28.88±6.67 (18.0-44.0)	0.54±0.42 (0.11-1.53)	3.11±0.40 (2.20-3.95)	1.91±0.29 (1.58-2.53)
	female / ženke	33	30.0±6.62 (20.0-44.0)	0.62±0.49 (0.13-2.20)	7.29±1.67 (2.78-9.72)	1.93±0.35 (0.94-2.58)
Nov. 2017 / studeni, 2017 .	male / mužjaci	18	27.03±4.73 (18.0-36.0)	0.40±0.15 (0.09-0.56)	2.13±0.84 (0.93-3.81)	1.93±0.31 (1.20-2.42)
	female / ženke	34	32.43±4.04 (21.0-39.0)	0.70±0.28 (0.16-1.40)	8.05±1.3 (5.58-12.42)	1.96±0.21 (1.61-2.55)
Feb. 2018 / veljača 2018.	male / mužjaci	21	27.93±6.94 (19.0-39.0)	0.46±0.32 (0.09-1.00)	2.48±1.58 (0.62-5.62)	1.75±0.28 (1.27-2.26)
	female / ženke	40	32.59±6.12 (22.0-42.5)	0.69±0.37 (0.18-1.42)	10.56±4.79 (0.32-18.70)	1.80±0.27 (1.21-2.41)
March 2018 / ožujak 2018.	male / mužjaci	20	28.68±6.57 (18.5-42.0)	0.46±0.32 (0.09-1.23)	3.41±0.62 (2.51-4.66)	1.68±0.31 (1.29-2.41)
	female / ženke	34	30.54±5.80 (20.0-43.0)	0.54±0.33 (0.01-1.40)	14.21±2.94 (6.66-18.59)	1.73±0.33 (1.12-2.65)
April 2018 / travanj 2018.	male / mužjaci	18	31.81±7.52 (18.0-44.0)	0.64±0.45 (0.07-1.54)	4.47±0.72 (1.97-5.06)	1.68±0.33 (1.17-2.42)
	female / ženke	38	32.59±4.30 (23.5-43.0)	0.63±0.25 (0.21-1.51)	19.05±2.10 (13.33-22.57)	1.76±0.22 (1.40-2.34)
May 2018 / svibanj 2018.	male / mužjaci	16	29.72±5.45 (20.0-36.0)	0.46±0.24 (0.12-0.86)	4.11±0.89 (1.94-5.21)	1.61±0.15 (1.48-2.0)
	female / ženke	37	29.36±5.43 (16.0-41.0)	0.46±0.25 (0.07-1.15)	8.58±6.44 (2.13-24.73)	1.66±0.25 (1.11-2.28)
June 2018 / lipanj 2018.	male / mužjaci	18	27.19±5.84 (18.0-38.0)	0.37±0.21 (0.09-0.81)	5.81±1.06 (3.24-7.38)	1.64±0.14 (1.48-1.92)
	female / ženke	36	33.39±6.30 (22.0-45.0)	0.65±0.32 (0.16-1.31)	8.25±2.72 (4.26-19.87)	1.61±0.18 (1.34-2.09)
July 2018 / srpanj 2018.	male / mužjaci	19	29.53±7.62 (18.0-43.0)	0.52±0.37 (0.08-1.29)	3.89±0.69 (2.41-5.47)	1.69±0.25 (1.19-2.20)
	female / ženke	30	33.15±6.56 (24.0-44.0)	0.72±0.40 (0.20-1.50)	5.43±1.64 (3.19-8.94)	1.77±0.21 (1.45-2.28)
Sep 2017 – July 2018 / rujan 2017. – srpanj 2018.	male / mužjaci	163	28.76±6.43 (18.0-44.0)	0.48±0.32 (0.07-1.54)	3.58±1.37 (0.62-7.38)	1.74±0.28 (1.17-2.60)
	female / ženke	312	31.80±5.97 (16.0-46.0)	0.63±0.36 (0.07-2.2)	9.91±5.34 (0.32-24.73)	1.78±0.28 (0.94-2.65)
	total / ukupno	475	**30.75±6.29 (16.0-46.0)**	**0.58±0.35 (0.07-2.2)**	**7.74±5.33 (0.32-24.73)**	**1.77±0.28** (0.94-2.65)

Males made up 34.31% of the population, resulting in a sex ratio of 1:1.91, indicating that the transformation process from a single-sex to a mixed-population type had been going on for some time. Until the 1970s, it was thought that the majority of European Prussian carp populations were almost exclusively composed of the triploid females and that gynogenesis was the only reproductive strategy. Then, a small number of males was discovered in Poland (Skóra 1971), Croatia (Kajgana, 1996), Hungary (Tóth et al. 2005), Estonia (Vetemaa et al. 2005), and the Czech Republic (Lusková et al. 2010). It is well known that the sex ratio in most species is close to one and that it may vary between species within a population in a given area, but it can also vary from one year to the next. Therefore, it is difficult to estimate a numerical proportion of Prussian carp males in the total population in the Danube River based on localized research. Previous research conducted in Kopački Rit reported that the proportion of males amounted to 39% (Opačak, 2016). Thus, it can be stated that the ratio of

males is higher than previously reported (23%) in a near proximity (Kajgana,1996), but it is still unclear whether the sex ratio will reach 1:1, like in the Amur River, or it will remain higher due to gynogenesis.

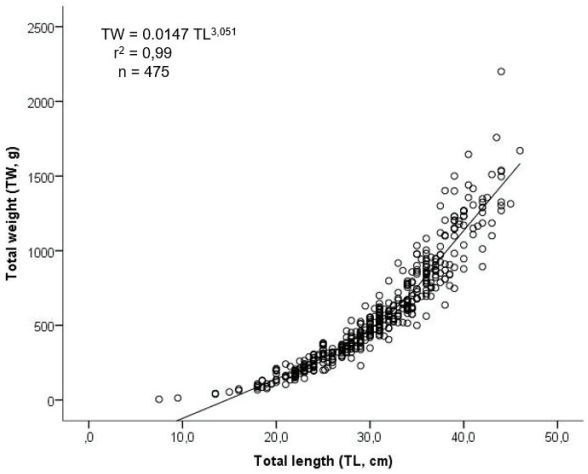

Figure 1. A relationship between the length (Total length, TL, cm) and weight (Total weight, TW, g) for Prussian carp in Kopački Rit Nature Park

Grafikon 1. Dužinsko-maseni odnos (totalna dužina, TL, cm, ukupna masa, TW, g) babuške u Parku prirode Kopački Rit

The minimum Fulton condition factor (FC) values for males were recorded in May (1.61 ± 0.15) and for females in June (1.61 ± 0.18), when the majority of them had already spawned. The maximum condition was recorded in late autumn for both sexes. Overall, the Fulton condition factor had a relatively small amplitude (Figure 2), but it exhibited a clear seasonal variability. The mean FC values of females were usually higher than those of males during the observed period, except in June. Fulton condition factor (Figure 2) manifested a rapid increase after spawning, from July to November. This improvement is the result of an abundant food source, such as zooplankton (Leonardos et al., 2008). During the hibernal months (November–February), the condition factor is declining due to acquiring energy from fat deposits, and in the early spring (March–April) the condition factor is further declining due spawning preparations. A difference in the mean FC values between the females and males can be explained as a result of gonado-somatic index (Balik et al., 2004). An average FC value for *C. gibelio* in Croatia is 1.791, based on nine populations (Treer et al., 2009), which positions the mean FC value (1.77 ± 0.28) of Prussian carp in Kopački Rit slightly below the national average. Overall, 201 caught individuals had FC values above 1.79, and in certain months the mean FC values exceeded national average (Fig. 2). This is not a surprise if the quality of the habitat is considered. Different mean FC values of different population of the same species indicate the state of sexual maturity, the timing and duration of breeding (Le Cren, 1951; Weatherly, 1972), available food sources, but also age and environmental conditions (Gomiero 2005).

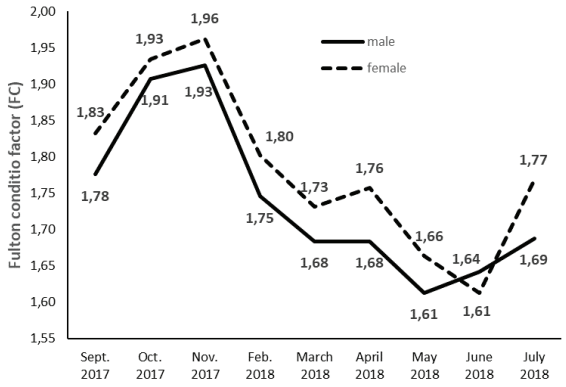

Figure 2. Variation of condition factor (mean) of *C. gibelio* in the Kopački Rit Nature Park, Croatia

Grafikon 2. Varijacija kondicijskoga indeksa (prosjek) babuške u Parku prirode Kopački rit, Hrvatska

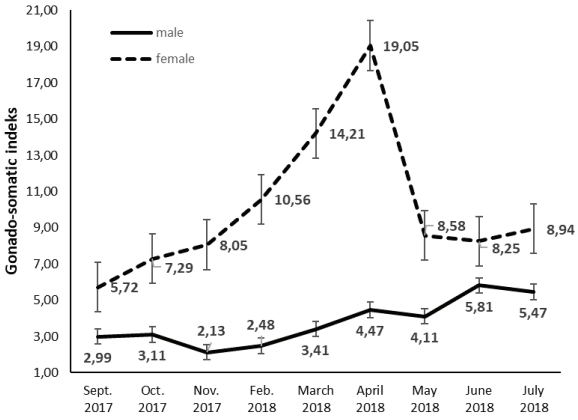

Figure 3. Gonado-somatic index cycles (mean ± SE) of *C. gibelio* in the Kopački Rit Nature Park, Croatia

Grafikon 3. Gonado-somatski indeks (prosjek ± SE) babuške u Parku prirode Kopački rit, Hrvatska

The average value of gonado-somatic index (GSI) of females (9.91±5.34) was higher than that of males (3.58±1.37) during the observed period (Table 1). A rapid increase in the average GSI values for females was observed from February to April, when it reached its peak value (Figure 3). The GSI follows gonadal maturation, reaching higher values at the ripe stage, and then decreasing after spawning (Petersen and Warner, 2002). The average GSI values indicate that the majority of females spawn in late April and May, which is also the same period when other cyprinid species are spawning, allowing the Prussian carp to exploit its gynogenesis strategy. The GSI value for males does not show the same variability as in females, but it is higher from April to June.

CONCLUSION

In Kopački Rit, *C. gibelio* males still constitutes a minor portion of the population, but it allows for dual mode of bisexual and unisexual reproduction, which in

turn allows rapid adaptations to the changing environmental conditions. Such adaptability made a successful invasion in Kopački Rit Nature Park possible, and, in the foreseen future, it will enable the maintenance of a stable population and a possible increase in abundance at the expense of other fish species, especially if the water levels in Kopački Rit continue to be at the lower end as a result of water management and a lack of abundant rainfalls. The FC values indicate a favorable habitat for this species; therefore, it is not surprising that it became the most represented species in Kopački Rit Nature Park. The GSI values indicate that females reproduce only once per year in a period from April to May. Given the biological characteristics of this species, available food sources, and the Kopački Rit environmental conditions, it seems that it will be very difficult to propose the management models for this alien fish species in order to reduce its abundance in the total ichthyofauna of the Kopački Rit Nature Park.

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SEZONSKE PROMJENE KONDICIJSKOGA I GONADOSOMATSKOG INDEKSA *Carassius gibelio* U PARKU PRIRODE KOPAČKI RIT, HRVATSKA

SAŽETAK

Cilj ovoga istraživanja bila je istražiti neke od bioloških karakteristika (omjer spolova, dužinsko-maseni odnos i gonadosomatski indeks) babuške (Carassius gibelio) tijekom jedne godine u Parku prirode „Kopački rit" u Hrvatskoj. Babuška je alohtona vrsta ribe uvezena iz Azije koja se od tada proširila diljem Europe te se vjeruje kako je odgovorna za opadanje autohtone populacije riba, beskralježnjaka i makrofita u pojedinim područjima. Ihtiološko uzorkovanje obavljeno je od rujna do studenoga 2017. te od veljače do srpnja 2018. s pomoću elektroribolova. Ukupno je ulovljeno 475 jedinaka, na kojima je izmjerena ukupna dužina, standardna dužina, visina tijela i masa. Mužjaci su činili 34,31 % populacije babuške. Prosječna vrijednost Fultonova kondicijskog faktora (FC) za babušku u Kopačkome ritu bila je 1,77 ± 0,28. Sveukupno, vrijednosti FC-a su imale relativno malo varijacija, ali ukazuju na jasnu sezonsku varijabilnost. Prosječne vrijednosti gonado-somatskoga indeksa (GSI) za ženke (9,91 ± 5,34) bile su veće negoli za mužjake (3,58 ± 1,37) tijekom promatranoga razdoblja. Prosječne vrijednosti GSI-ja ukazuju kako se većina ženka mrijesti krajem travnja i tijekom svibnja, što je isti period kada se mrijeste i ostale ciprinidne vrste, a to babuški omogućuje da se koristi svojom strategijom ginogeneze.

Ključne riječi: Park prirode, invazivne akvatične vrste, Carassius gibelio, odnos spolova, prilagodljivost, dužinsko-maseni odnos, GSI

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