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COMPARATIVE STUDY OF LENGTH-WEIGHT RELATIONSHIP, SIZE STRUCTURE AND FULTON'S CONDITION FACTOR FOR PRUSSIAN CARP FROM DIFFERENT ROMANIAN AQUATIC ECOSYSTEMS

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Abstract

Length-weight relationship, Fulton's K condition factor and the size structure were assessed for unsexed Prussian carp, Carassius gibelio (Bloch, 1782) caught from three different Romanian aquatic ecosystems: Cişmigiu Lake (Bucharest, October 2014), Brăneşti 3 Lake (Ilfov County, May 2015) and Sâi River (Teleorman County, April 2015).
Positive allometric growth was estimated for specimens sampled from Cişmigiu Lake and Sâi River, while Prussian carp from Brăneşti 3 Lake exhibited a negative allometric growth pattern.
Some physico-chemical parameters (pH, total dissolved solids, nitrite, nitrate, ammonium, phosphate, electrical conductivity, total hardness) were also recorded, in order to estimate the impact of water quality on C. gibelio population from Cişmigiu and Brăneşti 3 lakes. Both lentic ecosystems were found to be within the suitable range for well being of fish.
To our knowledge, this paper provides first published information on length-weight relationship of a fish species inhabiting the freshwater ecosystems Sâi River and Brăneşti 3 Lake.

***Key words**: Prussian carp, length-weight relationship, length distribution, condition factor, physico-chemical parameters, water quality.*

INTRODUCTION

Carassius gibelio (Bloch, 1782), known as Prussian carp or gibel carp is an important freshwater species for recreational fishing in Europe (Marinović et al., 2015). A dominant species in stagnant and slow-running water, this fish could change the flow of nutrients in the entire ecosystem (Tsoumani et al., 2006; Lorenzoni et al., 2010; Kirankaya and Ekmekçi, 2013).
There are only few studies regarding the biology of Prussian carp from Romanian waters, in terms of growth related to environmental factors (Cernisencu et al., 2007; Gheorghe et al., 2012). Sachidanandamurthy and Yajurvedi (2008) draw attention to the importance of studies regarding variation in fish growth parameters along with physico-chemical water quality parameters, to find out whether variation in growth and well being of fish are influenced by fluctuations in water quality.
Investigating length-weight relationship (LWR) offers information about the structure and function of fish population (Lemma et al., 2015).
On the other hand, condition factor represents an indicator reflecting the interactions between biotic and abiotic factors to the physiological condition of fish, being assumed that heavier fish shows a healthier physiological state (Lemma et al., 2015).
In addition, analyzing the size structure of a fish population could reveal many ecological and life-history traits, such the ecosystem health or stock conditions, even a basic description and length distribution having a great value for reference as well for comparison for future reports (Ranjan et al., 2005). Some

authors consider that length of the fish is more relevant than its age, since several ecological and physiological factors are more size-depended than age-dependent (Kalaycı et al., 2007).

The parameters for LWR and the type of growth were estimated before (Stavrescu-Bedivan et al., 2015) for the first time in *C. gibelio* specimens from an artificial lake from Bucharest. In the present paper, our purpose was to fulfill the following objectives: **(1)** to relate the biometric data obtained before for Prussian carp in Cişmigiu Lake with analysis of the water quality and **(2)** to compare length-weight relationship, Fulton's condition factor and growth pattern within the same species, sampled from different aquatic ecosystems, presenting different physico-chemical water parameters.

MATERIALS AND METHODS

Fish collection and measurements

A total of 262 Prussian carp individuals were collected from three different aquatic ecosystems, as follows: Cişmigiu Lake, an artificial lake from Bucharest (October 2014, n=94, by fish net) (Stavrescu-Bedivan et al., 2015), Brăneşti Lake 3, on the River Pasărea, tributary of the Dâmboviţa, Ilfov County (44° 26' 59.2" N, 26° 20' 05.7" E, May 2015, n=62, by recreational fishing) (Figure 1) and Sâi River, a tributary of the Danube, Teleorman County (43° 42' 52.8264" N, 24° 51' 2.2896" E, April 2015, n=106, by gill nets). After sampling, fish specimens were preserved frozen and analyzed in UASVM of Bucharest laboratory (Figure 2).

Each individual of *Carassius gibelio* was measured for total length (TL ± 1 mm) and weighted (TW ± 1 g). The length-weight relationship (LWR) was expressed as: $TW=aTL^b$, where coefficient *a* (intercept) describes the rate of change of weight with length and coefficient *b* (slope) provides information about isometric or allometric growth pattern (Froese, 2006). The relationships between the length and the weight of fish in each study area were assessed through linear regression (Log TW=Log a + b Log TL).

Positive allometric pattern of growth occurs when b>3, while negative allometric or hypoallometric growth is indicated by low values of b (< 3) (Froese et al., 2011; Karachle and Stergiou, 2012). The slope and intercept were estimated by the least-square method, using PAST (Paleontological Statistics Software) version 3.04.

Fulton's condition factor (K), showing the degree of well-being of the fish in their habitat (Nehemia et al., 2012) was calculated using the equation: $K = (TW/TL^3)*100$.

Size intervals for total length distribution of *C. gibelio* caught in study area were established and adapted in accordance with Innal (2012).

Some physico-chemical water quality parameters were assessed in samples from Cişmigiu and Brăneşti Lakes.

Figure 1. Fishing on Brăneşti 3 Lake

Figure 2. Prussian carp specimens from Sâi River, prior to biometric analysis

Water sampling

Water samples were collected from Cişmigiu Lake (three sampling points) and Brăneşti Lake (three sampling points) at the same moment with fish collection. Water samples were taken at about 45 cm below surface layer in plastic bottles. The samples were subsequently stored at 4°C for as short a time as possible before analysis to minimize physical and chemical changes. Chemical analyses were conducted within 48 hours of collection. The samples were allowed to stay until they reached room temperature before analysis.

Chemical analyses

The chemical analyses analysis of water samples were was performed by using methods similar to those recommended for drinking water (Mănescu et al., 1994). The assessment of all species was performed in triplicates and the presented results are the average of three similar values of each sample determinations. The concentrations of phosphate, nitrate, ammonium and nitrite species were determined by spectrophotometric means. Phosphate was quantified as molybdenum blue, for nitrate was used phenoldisulphonic method, for ammonium determination was used Nessler reagent and nitrite was achieved using Griess reaction. The pH was determined potentiometrically, after the water samples reached room temperature. Total hardness was assessed by complexometric method using as titrant a solution of Na_2EDTA 0,05N meanwhile chemical oxygen demand (COD) was determined by manganometry.

Electrical conductivity is a good indicator of total salinity of water and sometimes it is used to evaluate in a rough manner the total dissolved solids (TDS); it has been observed that usually TDS (mg/L) represents about half of the conductivity (μs/cm) (Stone et al., 2013). TDS was achieved using gravimetric method.

Apparatus

Prior to the analysis, all instruments were calibrated according to manufacturer's recommendations.

Spectrophotometric measurements were carried out using Metertek SP830 Plus apparatus meanwhile pH was measured by using Inolab WTW pH-meter with combined glass electrode. The conductivity of water samples was determined using Hach SensIon7 apparatus.

RESULTS AND DISCUSSIONS

In a previous study (Stavrescu-Bedivan et al., 2015), were recorded biometric data for *Carassius gibelio* sampled from **Cişmigiu Lake**: TL (min. 3.7 - max. 10.8 cm, with a mean of 5.28 cm) and TW (min.1.00 - max 23.00 g, with average of 3.39 g). The linear regression of the log-transformed values was calculated as: Log (TW)=3.63L Log (TL) - 2.26 (r^2=0.913, 95% CL of the parameters *a* and *b*); the corresponding nonlinear equation was calculated as: $TW=0.0055 \times TL^{3.6303}$. Growth type for Prussian carp juveniles from this artificial lake was determined as positive allometric (*b*>3); K has a value of 1.62 (min. 0.85- max.2.55).

The results recorded for sampling station **Brăneşti Lake 3** are: TL (min. 16.5 - max. 27 cm, with a mean of 20.35 cm), TW (min. 8.8 - max 41.00 g, with average of 16.14 g), Log (TW)=2.66L Log (TL) - 1.28 (r^2=0.879, 95% CL), $TW=0.0523 \times TL^{2.6569}$, K=1.87 (min. 1.51-max. 2.38). In this natural lake, *Carassius gibelio* indicated negative allometric growth ($b < 3$).

In **Sâi River**, data recorded for Prussian carp specimens were: TL (min. 5.9 - max. 31.5 cm, with average of 11.46 cm), TW (min. 20 - max. 648 g, with average of 49.67 g), Log (TW)=3.24 L Log (TL) - 2.06 (r^2=0.99, 95% CL), $TW=0.0087 \times TL^{3.249}$, K=1.58 (min.0.93-max. 2.34). The results showed positive allometric type of growth for Prussian carp from Sâi River.

Length distribution of *Carassius gibelio* specimens caught in all sampling points is given in Figure 3.

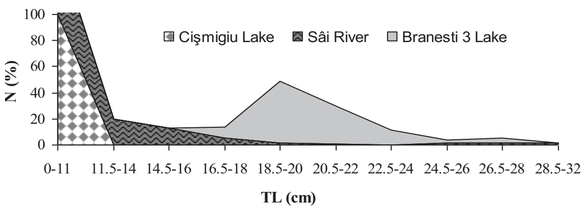

Figure 3. Length distribution of Prussian carp in each study site

In Cişmigiu Lake, all fish caught (100%) were shorter than 11 cm. In Brăneşti 3 Lake, 87.09% of Prussian carp were 18.5-24 cm. Among specimens caught in Sâi River, 72.64% were shorter than 14.5 cm. Only 4.84% (Brăneşti 3 Lake) and 5.65% (Sâi River) of sampled *C. gibelio* were longer than 24 cm.

The equations of the length-weight relationship in the study area are given in Figures 4-6.

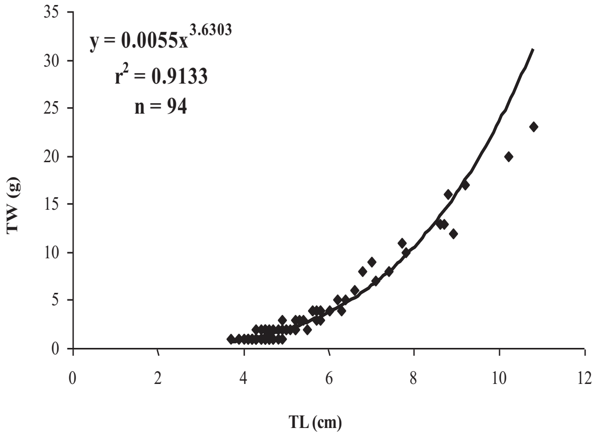

Figure 4. LWR of the Prussian carp in Cişmigiu Lake (Stavrescu-Bedivan et al., 2015)

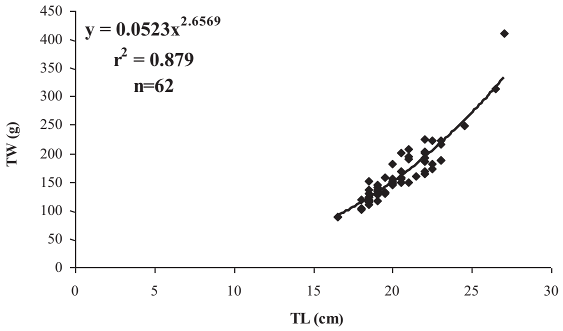

Figure 5. LWR of the Prussian carp in Brăneşti 3 Lake

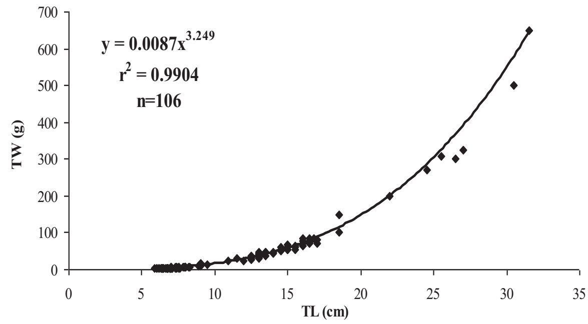

Figure 6. LWR of the Prussian carp in Sâi River

The parameters of the LWR might be affected by various factors including season, sex, differences in the length range of the caught specimens, population density, sexual maturity age, habitat, food quality or quantity, fish health or environmental conditions (Innal, 2012; Lemma et al., 2015; Marinović et al., 2015; Moradinasab et al., 2012).

Thus, the value of parameter b is directly affected by the habitat in which the fish lives (Erdogan et al., 2014) and may vary with the trophic state of the water (Tsoumani et al., 2006).

In Brăneşti 3 Lake and Sâi River, the exponent b was within the expected range of 2.5-3.5. The slope value recorded for the Prussian carp exceeded even the maximum value reported by FishBase (www.fishbase.org) only in Cişmigiu Lake (b = 3.6303) (Figure 4), but this is because most of the sampled specimens had a very small length range. Similar results were obtained by Treer et al. (2010), for *Carassius gibelio* from a Croatian Lake.

In a previous survey (Stavrescu-Bedivan et al., 2015), we assumed that this high value of slope in LWR for *C. gibelio* from Cişmigiu Lake might suggest the presence of an oligotrophic water. This supposition is now confirmed by performed chemical water analyses and reported herein. This was confirmed by water quality parameters calculated in the present study.

The negative allometric growth (b=2.6569) for fish from Brăneşti 3 Lake could be attributed to trophic state of the water, assuming the results of the chemical analysis. In addition, it was reported that Brăneşti 3 Lake is an unhygienic fishing pond, as on its banks and in the water there is quite a lot of rubbish (www.baltidepescuit.ro/balta-branesti-3.html).

Our results are in agreement with the findings of Tsoumani et al. (2006), who showed significant negative correlation between the trophic state of the water and b values. However, Prussian carp is a resistant species to anthropogenic pollution, as Zhelev et al. (2015) reported.

The lower value of b in the case of *C. gibelio* from Brăneşti 3 Lake can also be influenced by the number of caught fish specimens, since the small sample size can also influence the LWR parameters (Leonardos et al., 2008).

Length-weight relationship indicated that Prussian carp populations caught in all studied ecosystems show allometric growth. Similar findings were reported for *Carassius gibelio* from Danube (Gheorghe et al., 2012) and Taşaul Lake (Cernisencu et al., 2007).

Differences in condition factor for the same species in various habitats may be attributed to water quality parameters, as earlier studies mentioned (Khallaf et al., 2003; Sachidanandamurthy and Yajurvedi, 2008; Nehemia et al., 2012). The Fulton's condition of *C. gibelio* sampled in study area has values between 1.58 and 1.87. Hence, fish specimens from Brăneşti 3 Lake suggest a better well-being that that in other water bodies, although this lake seems to have a poor water quality comparing to Cişmigiu Lake (Tables 1 and 2).

Also, from the total of three sampled aquatic ecosystems, Brăneşti 3 Lake seems to hold the best Prussian carp population, in terms of distribution of length frequencies. As Ranjan et al. (2005) suggested, the absence of very large specimens from a water resource might indicate that fish is target of anglers and fishermen.

Although length-frequency distribution of *C. gibelio* has already been subject of several papers (Innal, 2012; Kirankaya and Ekmekçi, 2013; Marinović et al., 2015; Zhelev et al., 2015), there is still scarce literature available on this topic for Prussian carp from Romanian ichtyofauna.

Physico-chemical parameters for water samples collected from Cişmigiu Lake and Brăneşti Lake are presented in Tables 1 and 2, respectively. Also, for comparison in Table 3 are presented the parameters and quality classes according to Order 161/2006.

The conductivity and pH values of water samples collected from Cişmigiu Lake present very significant correlation with total hardness, the calculated correlation parameters being r=0.950*** and r=0.992***, respectively. (Figure 7).

The coefficients resulted after conductivity-total hardness and pH-total hardness correlations (r=0.774*** and r=0.770***, respectively) indicate a very significant correlation between subjected parameters (Figure 8).

Table 1. Physico-chemical parameters for water collected from Cişmigiu Lake

Parameters / Results	SP1	SP2	SP3	Av.	Quality class
pH	6.85	6.53	7.00	**6.79**	-
Conductivity (µS/cm)	829	784	841	**818**	-
Total hardness (mg $CaCO_3$/L)	22.38	18.79	23.57	**21.58**	-
COD (mg O_2/L)	7.91	8.71	7.83	**8.15**	**II**
N-NH_4^+ (mgN/L)	1.69	1.63	1.44	**1.58**	**IV**
N-NO_2^- (mg N/L)	0.015	0.017	0.014	**0.015**	**II**
N-NO_3^- (mg N/L)	0.415	0.375	0.475	**0.421**	**I**
P-PO_4^{3-} (mg P/L)	<DL	<DL	<DL	**-**	**-**
Total dissolved solids (TDS) (mg/L)	389	410	413	**404**	**I**

SP- sampling point; Av. - average; DL - detection limit

Table 2. Physico-chemical parameters for water collected from Brăneşti 3 Lake

Parameters / Results	SP1	SP2	SP3	Av.	Quality class
pH	7.68	7.58	7.84	**7.70**	-
Conductivity (µS/cm)	1132	1105	1156	**1131**	-
Total hardness (mg $CaCO_3$/L)	26.27	24.93	27.84	**26.34**	-
COD (mg O_2/L)	9.53	9.3	8.98	**9.27**	**II**
N-NH_4^+ (mgN/L)	4.28	4.41	4.5	**4.39**	**V**
N-NO_2^- (mg N/L)	0.068	0.076	0.078	**0.074**	**IV**
N-NO_3^- (mg N/L)	1.83	2.13	1.89	**1.95**	**II**
P-PO_4^{3-} (mg P/L)	<DL	<DL	<DL	**-**	-
Total dissolved solids (TDS) (mg/L)	558	542	531	**543.66**	**II**

SP- sampling point; Av. - average; DL - detection limit

Table 3. Quality classes for surface waters according to Order 161/2006

Parameters / Classes	**I**	**II**	**III**	**IV**	**V**
pH	6.5-8.5				
COD (mg O_2/L)	5	10	20	50	>50
N-NH_4^+ (mgN/L)	0.4	0.8	1.2	3.2	>3.2
N-NO_2^- (mg N/L)	0.01	0.03	0.06	0.3	>0.3
N-NO_3^- (mg N/L)	1	3	5.6	11.2	>11.2
P-PO_4^{3-} (mg P/L)	0.1	0.2	0.4	0.9	>0.9
Total dissolved solids (TDS) (mg/L)	500	750	1000	1300	>1300

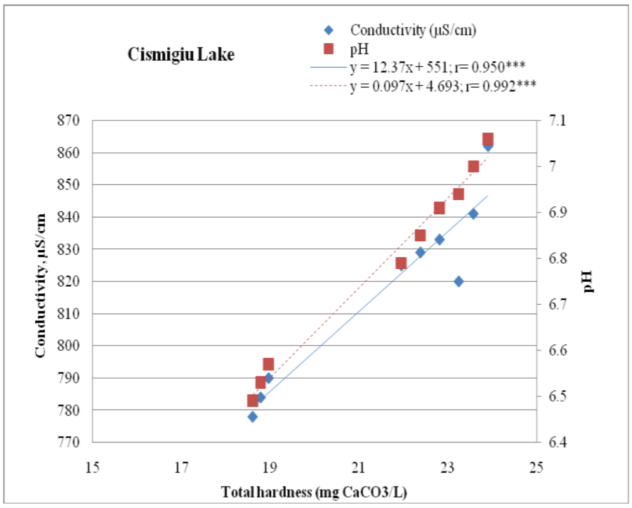

Figure 7. Correlations between conductivity and pH values with total hardness of water samples from Cişmigiu Lake

Desirable pH range for optimal growth of most fish species is 6.5-9.0, levels below 6.5 leading to a decrease of reproduction (Stone et al., 2013).

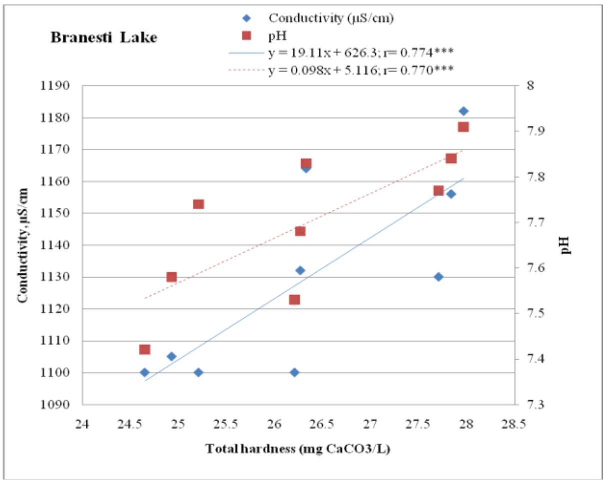

Figure 8. Correlations between conductivity and pH values with total hardness of water samples from Brăneşti 3 Lake

Dastagir et al. (2014) reported that a value pH lower than 8.4 indicate that the respiratory processes in a water resource are greater than the photosynthetic processes, while alkaline pH higher than 8.8 could produce death of the fish. In the present study, pH ranged from 6.79 in Cişmigiu Lake to 7.70 in Brăneşti 3 Lake.
Electrical conductivity it is recommended to be encountered in the range 60-2000 µs/cm (Stone et al., 2013), this requirement being fulfilled for all analyzed water samples.
Total hardness (as $CaCO_3$) of water for fish culture it is desirable to be found in the range 50-150 mg/L but values greater than 20 mg/L are considered to be acceptable (Stone et al., 2013). With values of 21.58 and 26.34 respectively, total hardness of the water was in desirable range in both analyzed lakes.
Ammonium level found in Cişmigiu Lake is 2.8 times lower than the level found in Brăneşti Lake. High values of ammonium are usually encountered in the spring and fall (Stone et al., 2013), related to the algal blooms. The increase in ammonia concentration in lake water may cause toxicity to aquatic organisms (Yang et al., 2011). Yet, toxicity of ammonia to fish varies with fish species, salmonids for example being more sensitive to this compound than other fish species (Stone et al., 2013), age or other quality parameters (Latha and Lipton, 2007). Goldfish, *Carassius auratus*, seems to have a greater resistance to ammonia (Schenone et al., 1982).
Jeppensen et al. (2000) showed that body weight of cyprinids decrease with the increase in phosphorus content of water samples. In present study, both analyzed lakes contain phosphate in levels lower than spectrophotometry may detect, which might suggest that water is suitable for optimal growth of the fish.
The total dissolved solids (TDS) fluctuated between 389 (Cişmigiu Lake) and 558 mg/L (Brăneşti 3 Lake). It has been documented that TDS vary in different waters depending upon the season, location or other factors (Dastagir et al., 2014) and high amounts of dissolved solids may indicate poor water quality.
In environmental chemistry, chemical oxygen demand (COD) is used to measure the amount of organic species in the water and to evaluate the quality of waters. COD is a measure of capacity of water to consume oxygen during decomposition of organics and oxidation of ammonia and nitrate (https://en.wikipedia.org/). From this point of view, the waters from Cişmigiu Lake and Brăneşti 3 Lake are similar and the chemical analyses allowed us to attribute them class II of quality.

CONCLUSIONS

The length-weight equations determined from regression of Log weight on Log length of Prussian carp indicated a positive allometric type of growth for specimens sampled in Cişmigiu Lake and Sâi River (which means that fish increase in body thickness) and a hypoallometric growth pattern for specimens in Brăneşti 3 Lake (which suggest that fish becomes more slender as it increase in weight).
Our results could be useful references for future comparative studies like *Carassius gibelio* biometric data registered by FishBase in various sites from Romania and worldwide.
Assuming the values of all the analyzed physico-chemical parameters, both studied lakes were found to be within the suitable range for well being of fish. Yet, the natural fishing pond Brăneşti 3 Lake from Ilfov County seems to have a poor water quality condition comparing to the artificial Cişmigiu Lake from Bucharest. However, *C. gibelio* from Brăneşti 3 Lake holds the best population in terms of length distribution, having also the best degree of health population from all studied areas in terms of fish condition.

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