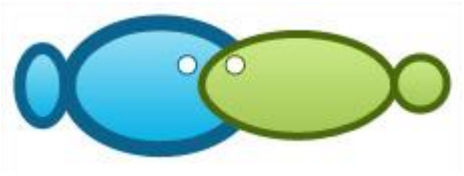

Length-weight relationship of the endemic dwarf carp (*Cyprinus carpio* L., 1758) living in thermal Lake Hévíz, Hungary

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Abstract. In this study, the length-weight relationships of an endemic common carp ecomorph in Lake Hévíz, Hungary, were determined. A slight negative allometric growth pattern was obtained, where the length (L) ranged from 9.3 cm to 26.3 cm, and weight (W) ranged from 24 g to 385 g. The growth of fish is linear, the condition decreasing with the increase of length. The b value proves that Lake Hévíz can provide a sufficient trophic basis for a moderate growth of the inhabitant carp population.
Key Words: *Cyprinus carpio,* LWR, growth, condition factor.

Introduction. Lake Hévíz (Hungary) is recognized as a nature conservation region covering an area of 4.44 ha containing hydrogen-carbonated water. During summer periods, the temperature of lake Hévíz waters may reach 35-39°C near the surface and does not fall below 26-29°C even in the coldest winter (Molnár et al 2019). The high temperature and the special chemical composition of the water resulted a particular fish fauna, with stable population of four species: *Gambusia holbrooki, Lepomis gibbosus, Herotilapia multispinosa* and an endemic carp (*Cyprinus carpio*, Lake Hévíz eco-morph), isolated from nearby populations (Bíró et al 2002; Specziár 2004). Specimens of this carp strain are slowly growing: 8–9-year-old carps had achieved a 23–29-cm body size and 400-450 g maximum live weight (Varga et al 2013). The dwarfish build may be a consequence of the adaptation to the extreme environment.

The main factors that influence the growth of fish are food availability, fish biomass, water temperature, oxygen level and water quality in general. In addition, the size, age and sexual maturity of the fish are important factors also affecting growth performance (Kuriakose 2017). Biomass production in Lake Hévíz is low (Ponyi 1995) and it was previously proven that fish can utilize the detritus as feed, the high environmental temperature producing a special fatty acid metabolism (Varga et al 2013).

The aim of this study was to investigate the growth pattern (length-weight relationship) and condition of the endemic carp population.

Material and Method. The study was based on measurements of 92 individuals of carp from lake Hévíz (Figure 1). Fish were collected between April 2007 and April 2018 by gill nets, during 5 periods of time. The total length (ruler, 1 mm accuracy) and the weight (digital scale 1 g accuracy) of the fish were determined. The nonlinear equation in the form of $W=aL^b$ (Le Cren 1951), which explains the length and weight relationship of the fish, was used in the present study. The linear transformation was made using a natural logarithm for the observed lengths and weights according to Zar (1974) as follows: Log

W = b logL + loga, where: W – weight of fish in grams, b – exponent value, L – length of fish in cm, a – constant.

The data used for length-weight relationship (LWR) were also utilized for calculating the condition factor ($K=100xW/L^b$) and the relative condition factor (K_n) of the fishes. The relative condition factor is given by the formula $K_n= W_m/W_c$, where Wm is the measured weight and Wc is the calculated weight.

The exponent (b value) in the LWR was tested for significance following Fisher's t- test (isometric or allometric growth). ANOVA (SPSS for Windows 13) was used to compare the sampling data (weights and lengths).

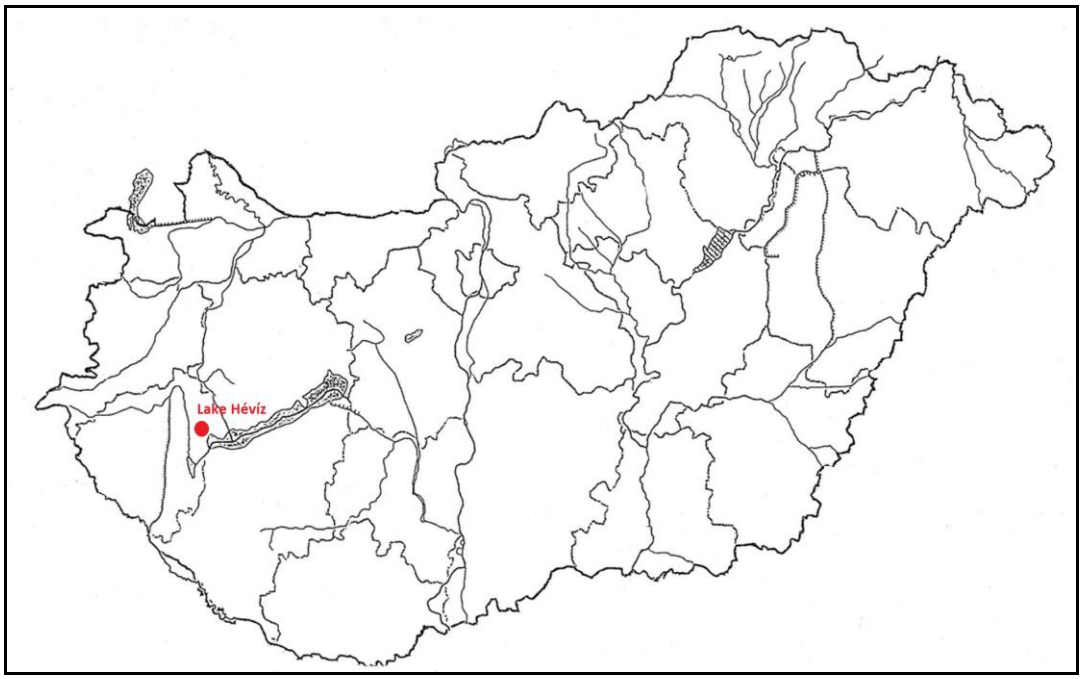

Figure 1 Location of Lake Hévíz.

Results and Discussion. Table 1 presents the measured data. Comparing the five sampling dates, no significant differences were revealed in the length and weight of the fish (ANOVA, $p>0.05$)

Table1

Measured length and weight, the condition factor (K) and the relative condition (K_n) of Hévíz carp

	Minimum	*Maximum*	*Mean*	*SD*
Length (cm)	9.3	26.3	19.2	3.7
Weight (g)	24	385	205.6	85.8
K	1.65	3.59	2.72	0.34
K_n	0.44	1.3	1.03	0.13

If there is no change in the body shape of a fish during growth, the weight increases as a third power of the length. The growth is isometric, and the exponent b is equal to 3. Negative allometry refers to the fish becoming slimmer (in the longitudinal profile) with length increase, the weight increasing in a slower rate than the length, with $b<3$. Positive allometric growth implies that the weight of the fish increases faster than the length, and it is indicated by a b value higher than 3 (Riedel et al 2007).

The calculated LWR of Hévíz carp was $W=0.068L^{2.683}$ ($r^2=0.966$). The constant (a) and the exponent (b) values, and the transformed logarithmic equation are presented in Table 2. The logW - log L relation is illustrated in Figure 2. The high determination

coefficient (r^2) for LWR of Hévíz carp indicates that length increases with increasing weight, but the b value was significantly lower than 3 (Fisher's t-test, $p<0.05$). Thus, the growth of the fish shows negative allometry, not satisfying the cube law. It can be stated that the weight of the carp in Lake Hévíz increases in a lower proportion than the cube of its length.

Table 2

Estimated parameters of length-weight relationship for Hévíz carp

N	*a*	*b*	*Logarithmic equation*
92	0.068	2.683	logW = -1.1675 + 2.683logL (r^2 = 0.966)

Note: N - number of fish; a - constant; b - exponent; W - weight; L - length.

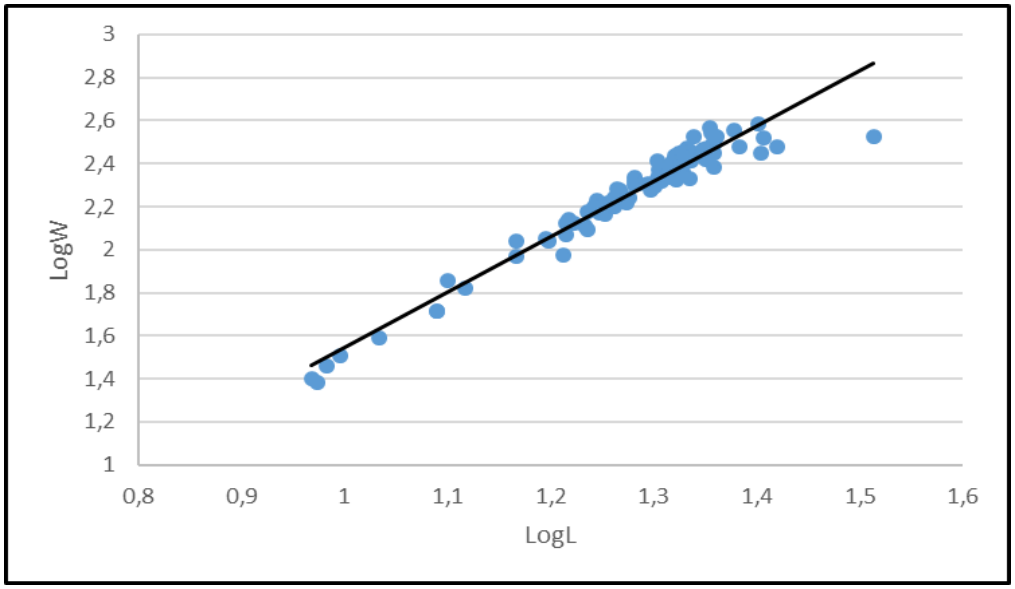

Figure 2. Length-weight relationship of Hévíz carp (*Cyprinus carpio*); L - length; W - weight.

LWR in fish is affected by many factors, such as health, season, diet, sex, gonad maturity and habitat (Cox & Hinch 1997). Thus, LWR provides very important information about the habitat of fish (Pauly 1993), and it helps the proper management of a fish population (Anene 2005).

Investigating the LWR for common carp in natural waters evinced similar results widely. Natural carp population's b value was found to be 2.845 in the lower Danube (Gheorghe et al 2011); in middle and southern Iraq, b varied between 1.03 and 2.75 (Al-Jebory et al 2018); in the southern Caspian Sea, b was 2.901 (Segadhat et al 2013) and in Kenya, b was 2.3484 and 1.9455 for males and females, respectively (Aera et al 2014) showing a negative allometric growth.

Moreover, Treer et al (2003) demonstrated a slightly negative allometric growth in the LWR (b=2.86) of a natural carp population of Lake Vransko, Croatia (introduced in 1948), an oligotrophic standing water with prolonged feeding seasons and mild climate conditions (Piria et al 2016).

The condition factor (K) refers to the wellbeing of fish, and it is also useful in the monitoring of the feeding intensity, age, and growth rates in fish, being strongly influenced by both biotic and abiotic environmental factors (Ahmed et al 2013). K value of the Hévíz carp population (Table 1) in this respect is similar to other well-nourished Hungarian wild type carps, showing a mean value of K=2.8 (Hancz et al 2002).

According to our results, the condition of the Hévíz carp is decreasing with the increase of length (Figure 3). The regression between K and length is negative. A similar trend was observed for a carp population in oligotrophic waters (Treer et al 2003). In

case of a negative allometric growth, the condition evolves to the opposite direction from that length onward. This tendency can be explained by subpar environmental conditions (e.g. lack of feed, nonoptimal temperature, etc.) for the bigger fish (Treer et al 2003).

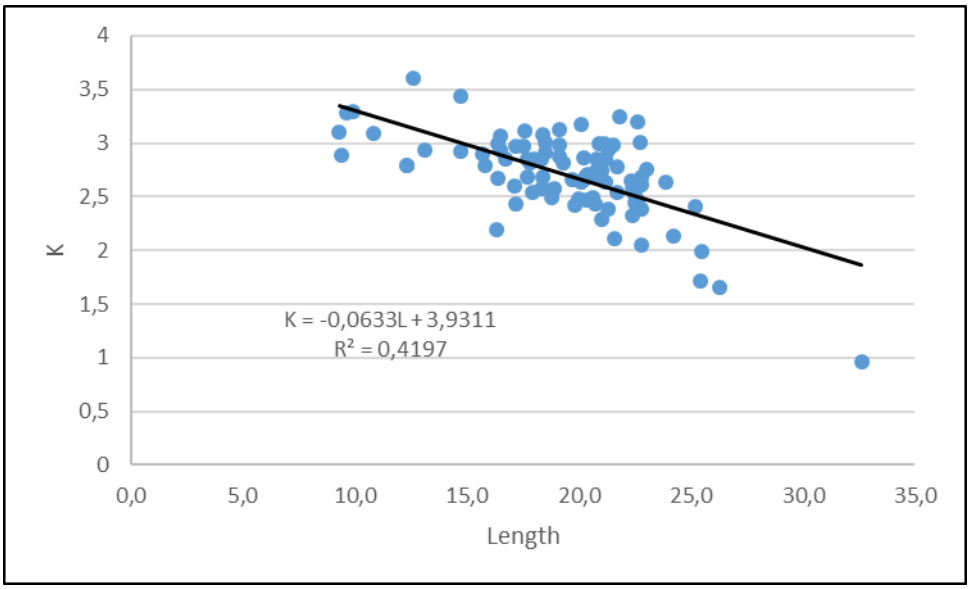

Figure 3. Condition factor (K) – Length (L) relationship of Hévíz carp (*Cyprinus carpio*).

Relative condition factor (K_n) is the ratio between observed and calculated weight of the fish. K_n values depend on physiological features of fish, such as maturity, spawning, environmental factors and food availability (Ujjania et al 2012). K_n helps detect the long term effects causing sustained physiological stress in the segment of fish population (Swingle & Shell 1971). A K_n value higher than 1 is indicative of the general wellbeing of fish, whereas K_n lower than 1 indicates that the fish is in a bad condition (Singh & Nautial 2017). K_n values of the Hévíz carp varied between 0.4 and 1.3, the average value being 1.03 (Table 1). This indicates that the fish population is not affected by any critical factors.

Conclusions. The growth in length of Hévíz carp is similar compared to other natural carp populations (original and introduced natural populations, as well). The growth is linear and constant. The condition, according to the K value obtained, is decreasing with the increase of length. The b value proves that Lake Hévíz can provide a sufficient trophic basis for a good growth of the inhabitant carp population. Results confirmed that the fish is well adapted to the constant high temperature coupled with special food availability (oligotrophy) and water chemical composition.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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