

## MORPHOMETRIC CHARACTERISTICS AND LENGTH-WEIGHT RELATIONSHIP OF PUMPKINSEED SUNFISH (*LEPOMIS GIBBOSUS*) FROM THREE RESERVOIRS OF NORTH-EASTERN BOSNIA AND HERZEGOVINA

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### Summary

The aim of this paper is to analyse the morphometric characteristics, length-weight relationship and condition factor of pumpkinseed sunfish (*Lepomis gibbosus*) from three reservoirs (Modrac, Vidara and Sniježnica) from the area of north-eastern Bosnia and Herzegovina (B&H). The total sample was 61 individuals. The following morphometric parameters were measured: total length, standard length, forked length, head length, mouth width, mouth height, first gill arch length, intestine length and body mass. Length-weight relationship was described by the equation:  $W=a TL^b$ . Fulton's condition factor (K) was determined using the equation:  $K=100 (W/L^3)$ . Statistical analysis was performed using the ANOVA to determine differences in morphometric characteristics of individuals between the sites (populations). *L. gibbosus* from all three populations showed positive allometric growth, and the highest value of condition factor was fish from the reservoir Vidara. In accordance with this result, most of the morphometric characteristics of individuals from the reservoir Vidara were significantly higher compared to individuals from Modrac and Sniježnica reservoirs. This result leads to the conclusion that the *L. gibbosus* adapted best in Vidara reservoir.

**Key words:** *L. gibbosus*, reservoirs, length-weight relationship, allometric growth, condition factor

### INTRODUCTION

*L. gibbosus* is a very successful invasive freshwater fish species like other members of the family Cetrarchidae. At the end of the 19<sup>th</sup> century (1887), it was introduced to Europe as an aquarium fish. Today it inhabits almost all watercourses of the Adriatic and Danube basins (Adrović, 2008). *L. gibbosus* is numerous in the waters of Serbia inhabiting Danube and its tributaries, some canals and lakes. In Croatia, *L. gibbosus* inhabits almost all water bodies of the Danube and Adriatic basins, where it is a common species (Drava, Sava, Kupa and

Krapina rivers, Vrana Lake, Šarena Lakes) and competes with indigenous ichthyofauna (Piria *et al.*, 2017). A special problem is in the rivers of the Adriatic basin (Krka, Neretva, Cetina and Zrmanja rivers) where almost every watercourse is home to at least one endemic species that can be endangered by this species (Mihinjač *et al.*, 2019). It is also present in wetlands, which is confirmed by the fact that in the wetland Hutovo blato was the most numerous fish species in 2012 with 25.67% of the total catch (Tutman *et al.*, 2012). It is registered in the Jablanica reservoir in B&H, where it poses a great danger to indigenous fish species, due to its tendency to feed on the eggs of other fish (Trožić-Borovac *et al.*, 2003). This paper confirms its presence in the reservoirs of north-eastern B&H, such as Modrac, Vidara and Sniježnica.

The body of the *L. gibbosus* is flattened laterally and high (44-50% of the total length), so the maximum height fits about twice the total length of the body. It is 10 to 15 cm long on average, but it can reach a maximum length of 40 cm in its native area (Paulson and Hatch, 2002; Scott and Crossman, 1973). In European waters it is smaller (Copp *et al.*, 2002, 2004). Weight is from 200 to 400 g. The head is quite tall and long, 26.1 - 31.5% of the total body length. Several environmental parameters are known to affect *L. gibbosus* growth rate, including water quality, temperature, population density, and the presence of other fish species (Holtan, 1998). Depending on water quality, mature fish can reach 13 to 20 cm in length and weigh 0.23 kg to 0.34 kg (Holtan, 1998). Also, morphological differences are directly related to diet (Osenberg *et al.*, 1988; Mittelbach and Persson, 1998).

The aim of this paper is to analyse the morphometric characteristics, length - weight relationships and condition factor of *L. gibbosus* from three reservoirs (Modrac, Vidara and Sniježnica) in the area of north-eastern Bosnia and Herzegovina.

## MATERIAL AND METHODS

The research was conducted in the period of summer and autumn 2019 in three sites, Modrac, Vidara and Sniježnica reservoirs. The fish were caught in cooperation with local fishermen (31 individuals from Modrac, 17 individuals from Vidara and 13 individuals from Sniježnica and the total sample were 61 individuals). Measurements of TL-total length; SL-standard length, FL-forked length, HL-head length, MW-mouth width, MH-mouth height, GAL-(first) gill arch length, IL-intestine length and W-body mass were performed. The allometric relationship between total body length (TL) and body mass (W) is shown by functional regression according to the formula (Ricker, 1975):  $\text{Log } W = \log a + b \log \text{TL}$  i.e. based on the exponential equation:  $W = a \text{TL}^b$ , where W is mass in grams, TL is total body length in cm, and *a* and *b* are constants. From the aspect of length-weight relationship, the coefficient *b* can have the following values:  $b = 3$  isometric growth,  $b > 3$ , positive allometric growth and  $b < 3$  negative allometric growth. Fulton's condition factor (K) is calculated based on the results of measuring the total length and mass of the fish, according to the formula (Froese, 2006):  $K = 100 (W/L^3)$  where W is mass of fish in grams and L is total body length in cm. In addition to descriptive statistics, analysis of variance (ANOVA) was performed, which tested the differences in the arithmetic means of three or more groups (samples), and tested the relationship of variability between and within groups of individuals. The Scheffe test was used to determine the stated differences of individuals within the observed sites.

## RESULTS AND DISCUSSION

### Morphometric characteristics

Values of investigated morphometric parameters of *L. gibbosus* from all three sites are given in tables 1, 2 and 3.

**Table 1.** Morphometric characteristics of *L. gibbosus* from Modrac reservoir; N=31 (AV - average value, SD = standard deviation, Min = minimum value, Max = maximum value, CV (%) = coefficient of variation)

Variables	AV	SD	MIN	MAX	CV
Total length (cm)	8.51	1.91	6.50	13.30	22.44
Standard length (%) of total body length	80.51	4.39	65.00	88.46	5.45
Head length (%) of total body length	22.47	4.52	14.71	35.00	20.13
Mouth width (%) of head length	37.03	14.81	15.00	72.73	40.00
Mouth height (%) of head length	46.38	15.05	25.00	81.82	32.45
Forked length (%) of total body length	88.81	4.87	71.28	96.15	5.48
First gill arch length (%) of head length	45.54	11.67	26.32	75.00	25.63
Body mass (g)	15.20	12.04	7.00	51.00	79.19

**Table 2.** Morphometric characteristics of *L. gibbosus* from Vidara reservoir; N=17 (AV - average value, SD = standard deviation, Min = minimum value, Max = maximum value, CV (%) = coefficient of variation)

Variables	AV	SD	MIN	MAX	CV
Total length (cm)	10.54	1.23	7.80	12.10	11.67
Standard length (%) of total body length	82.27	2.99	79.80	89.74	3.63
Head length (%) of total body length	17.63	1.37	14.88	20.41	7.79
Open mouth width (%) of head length	38.25	9.20	23.53	55.56	24.06
Open mouth height (%) of head length	51.57	9.36	35.00	71.43	18.15
Forked length (%) of total body length	85.72	3.79	81.00	97.44	4.42
First gill arch length (%) of head length	69.77	12.75	50.00	92.86	18.23
Body mass (g)	28.35	10.21	18.00	51.00	36.01

**Table 3.** Morphometric characteristics of *L. gibbosus* from Sniježnica reservoir; N=13 (AV - average value, SD = standard deviation, Min = minimum value, Max = maximum value, CV (%) = coefficient of variation)

Variables	AV	SD	MIN	MAX	CV
Total length (cm)	6.66	0.82	5.90	8.20	12.28
Standard length (%) of total body length	80.82	4.73	73.85	91.67	5.85
Head length (%) of total body length	19.06	2.87	15.25	23.73	15.08
Open mouth width (%) of head length	31.18	4.58	23.08	41.67	14.69
Open mouth height (%) of head length	49.03	13.51	35.71	77.78	27.55
Forked length (%) of total body length	82.59	4.89	76.92	91.67	5.92
First gill arch length (%) of head length	50.87	19.44	28.57	90.00	38.21
Body mass (g)	6.46	2.30	4.00	10.00	35.60

The highest average value of TL for *L. gibbosus* is noticed in Vidara reservoir ( $10.54 \pm 1.23$  cm) followed by Modrac reservoir ( $8.51 \pm 1.91$  cm). The lowest average TL was recorded for *L. gibbosus* from reservoir Sniježnica ( $6.66 \pm 0.82$  cm). The "longest" individual was caught in Modrac reservoir (13.30 cm). The highest average SL of *L. gibbosus* was in Vidara reservoir, while the maximum SL was recorded for fish from Modrac reservoir. The values of FL and the GAL are significantly higher in fish from Vidara reservoir compared to individuals from the other two sites. Also, FL and GAL are significantly higher in *L. gibbosus* from Modrac reservoir compared to those from Sniježnica reservoir. The average value of W of *L. gibbosus* from all three sites is 16.67 g. The highest average value of W was recorded for fish from Vidara reservoir (28.35 g) and the lowest for fish from Sniježnica reservoir (6.46 g). The individual with the largest W (51 g) was also from Modrac and Vidara reservoirs (Tables 1, 2 and 3).

*L. gibbosus* is on average from 10 to 15 cm long (Page and Burr, 1991; Booy *et al.*, 2015), it can reach a maximum length of 40 cm in its native area (Page and Burr, 1991). *L. gibbosus* from Jablanica reservoir are from 8 to 15 cm long, rarely 30 cm (Trožić-Borovac *et al.*, 2003; Mihinjač *et al.*, 2019). It weighs from 200 to 400 g, and the largest recorded body mass is 630 g (Mihinjač *et al.*, 2019). In Northern Ireland, *L. gibbosus* grow up to average length of 10-15 cm and reach a maximum weight of 300 g (Booy *et al.*, 2015). The average total body length of *L. gibbosus* from our research is 8.57 cm and is the closest to the values for TL of fish from the Jablanica reservoir.

The lowest coefficient of variation (CV) for *L. gibbosus* was determined for the SL (Modrac 5.45%; Vidara 3.63% and Sniježnica 5.85%) and FL (Modrac 5.48%, Vidara 4.42% and Sniježnica 5.92%). The highest CV was recorded for the MW (Modrac 40.00%; Vidara 24.06% and Sniježnica 14.69%) and the MH (Modrac 32.45%; Vidara 18.15% and Sniježnica 27.55%) (Tables 1, 2 and 3).

Table 4 shows the values of the measures of the central tendency and dispersion of *L. gibbosus* by the sites. The values of arithmetic means differ on all variables of morphometric characteristics.

**Table 4.** Descriptive indicators for *L. gibbosus* from all three sites (AM=arithmetic mean, SD=standard deviation, SEM=standard error of the mean, Min=minimum value, Max=maximum value)

Variables	Reservoirs	AM	SD	SEM	MIN	MAX
Standard Length	Modrac	6.87	1.69	0.30	5.00	11.50
	Vidara	8.65	0.96	0.23	6.80	9.90
	Sniježnica	5.38	0.67	0.19	4.60	6.50
Head length	Modrac	1.93	0.65	0.12	1.00	3.60
	Vidara	1.85	0.22	0.05	1.30	2.20
	Sniježnica	1.26	0.18	0.05	0.90	1.40
Mouth width	Modrac	0.66	0.22	0.04	0.30	1.00
	Vidara	0.71	0.18	0.04	0.40	1.00
	Sniježnica	0.39	0.08	0.02	0.30	0.50
Mouth height	Modrac	0.84	0.21	0.04	0.50	1.20
	Vidara	0.88	0.26	0.06	0.00	1.20
	Sniježnica	0.60	0.10	0.03	0.50	0.80
Forked length	Modrac	7.55	1.72	0.31	5.70	12.50
	Vidara	9.01	0.98	0.24	7.00	10.20
	Sniježnica	5.52	0.87	0.24	4.70	7.00
First gill arch length	Modrac	0.87	0.31	0.06	0.40	1.50
	Vidara	1.29	0.27	0.07	1.00	1.90
	Sniježnica	0.62	0.15	0.04	0.40	0.90
Digestive length	Modrac	8.20	2.93	0.53	4.50	16.00
	Vidara	9.21	1.47	0.36	6.50	12.00
	Sniježnica	3.71	0.80	0.22	2.50	5.50

The value of SL was significantly higher ( $p < 0.05$ ) in Vidara reservoir compared to the other two sites. Also, the value of SL is significantly higher in Modrac reservoir compared to those from Sniježnica reservoir. Statistically significant differences were also recorded for the HL, MW, MH and IL and these morphometric characteristics of *L. gibbosus* are significantly higher for fish from Modrac and Vidara reservoirs compared to individuals from Sniježnica reservoir.

#### The univariate analysis of variance

Significance of differences between morphometric characteristics of *L. gibbosus* was determined by F-test and the results are shown in Table 5. Based on the obtained results it can be concluded that (at the level of statistical significance 0.01) there are significant differences in all variables of morphometric characteristics between the three observed sites.

**Table 5.** Results of the univariate analysis of variance (SS-sum of squares, df- degrees of freedom, MS-mean square)

Variables	Group	SS	df	MS	F-test	p <0,01
Standard length	Between	81.10	2.00	40.55	22.19	<b>.000</b>
	Within	105.97	58.00	1.83		
Head length	Between	4.29	2.00	2.15	9.05	<b>.000</b>
	Within	13.76	58.00	0.24		
Mouth width	Between	0.86	2.00	0.43	12.06	<b>.000</b>
	Within	2.07	58.00	0.04		
Mouth height	Between	0.67	2.00	0.34	7.90	<b>.001</b>
	Within	2.48	58.00	0.04		
Forked length	Between	90.10	2.00	45.05	23.06	<b>.000</b>
	Within	113.33	58.00	1.95		
First gill arch length	Between	3.66	2.00	1.83	24.38	<b>.000</b>
	Within	4.35	58.00	0.08		
Digestive length	Between	251.45	2.00	125.73	24.30	<b>.000</b>
	Within	300.05	58.00	5.17		
	Within	10.50	58.00	0.18		

Since the results of the univariate analysis of variance showed that there are statistically significant differences in the morphometric characteristics of *L. gibbosus* between the observed sites, the Scheffe test was applied and the results are shown in Table 6.

**Table 6.** Scheffe test results (SE-standard error)

Variables		Difference	SE	p	
Standard length	Modrac	Vidara	-1.78 *	0.41	<b>.000</b>
		Sniježnica	1.49 *	0.45	<b>.006</b>
	Vidara	Modrac	1.78 *	0.41	<b>.000</b>
		Sniježnica	3.27 *	0.50	<b>.000</b>
	Sniježnica	Modrac	-1.49 *	0.45	<b>.006</b>
		Vidara	-3.27 *	0.50	<b>.000</b>
Head length	Modrac	Vidara	0.08	0.15	.865
		Sniježnica	,67 *	0.16	<b>.001</b>
	Vidara	Modrac	-0.08	0.15	.865
		Sniježnica	,59 *	0.18	<b>.007</b>

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	Sniježnica	Modrac	-, 67 *	0.16	<b>. 001</b>
		Vidara	-, 59 *	0.18	<b>. 007</b>
Mouth width	Modrac	Vidara	-0.04	0.06	. 769
		Sniježnica	, 27 *	0.06	<b>. 000</b>
	Vidara	Modrac	0.04	0.06	. 769
		Sniježnica	, 31 *	0.07	<b>. 000</b>
	Sniježnica	Modrac	-, 27 *	0.06	<b>. 000</b>
		Vidara	-, 31 *	0.07	<b>. 000</b>
Mouth height	Modrac	Vidara	-0.05	0.06	. 755
		Sniježnica	, 23 *	0.07	<b>. 004</b>
	Vidara	Modrac	0.05	0.06	. 755
		Sniježnica	, 28 *	0.08	<b>. 002</b>
	Sniježnica	Modrac	-, 23 *	0.07	<b>. 004</b>
		Vidara	-, 28 *	0.08	<b>. 002</b>
Forked length	Modrac	Vidara	-1.46 *	0.42	<b>. 004</b>
		Sniježnica	2.03 *	0.46	<b>. 000</b>
	Vidara	Modrac	1.46 *	0.42	<b>. 004</b>
		Sniježnica	3.49 *	0.52	<b>. 000</b>
	Sniježnica	Modrac	-2.03 *	0.46	<b>. 000</b>
		Vidara	-3.49 *	0.52	<b>. 000</b>
First gill arch length	Modrac	Vidara	-, 42 *	0.08	<b>. 000</b>
		Sniježnica	, 25 *	0.09	<b>. 026</b>
	Vidara	Modrac	, 42 *	0.08	<b>. 000</b>
		Sniježnica	, 67 *	0.10	<b>. 000</b>
	Sniježnica	Modrac	-, 25 *	0.09	<b>. 026</b>
		Vidara	-, 67 *	0.10	<b>. 000</b>
Digestive length	Modrac	Vidara	-1.01	0.69	. 346
		Sniježnica	4.48 *	0.75	<b>. 000</b>
	Vidara	Modrac	1.01	0.69	. 346

		Sniježnica	5.49 *	0.84	.000
	Sniježnica	Modrac	-4.48 *	0.75	.000
		Vidara	-5.49 *	0.84	.000

Based on the obtained results shown in Table 6, it can be concluded that (at the level of statistical significance 0.05) the average SL of *L. gibbosus* is the highest in Vidara reservoir. Also, the SL of *L. gibbosus* is significantly higher in fish from Modrac reservoir compared to those from Sniježnica reservoir. Statistically significant differences were recorded on the variables HL, MW, MH and IL. The mentioned morphometric characteristics of *L. gibbosus* are significantly higher in individuals from Modrac and Vidara reservoirs compared to individuals from Sniježnica reservoir. No differences were recorded in the stated morphometric characteristics of *L. gibbosus* between Modrac and Vidara reservoirs. On the variables of FL and GAL, it can be concluded that (at the level of statistical significance 0.05) these two morphometric characteristics of the *L. gibbosus* are the largest in Vidara reservoir. Also, FL and GAL of the *L. gibbosus* are significantly higher in fish from Modrac reservoir compared to those from Sniježnica reservoir.

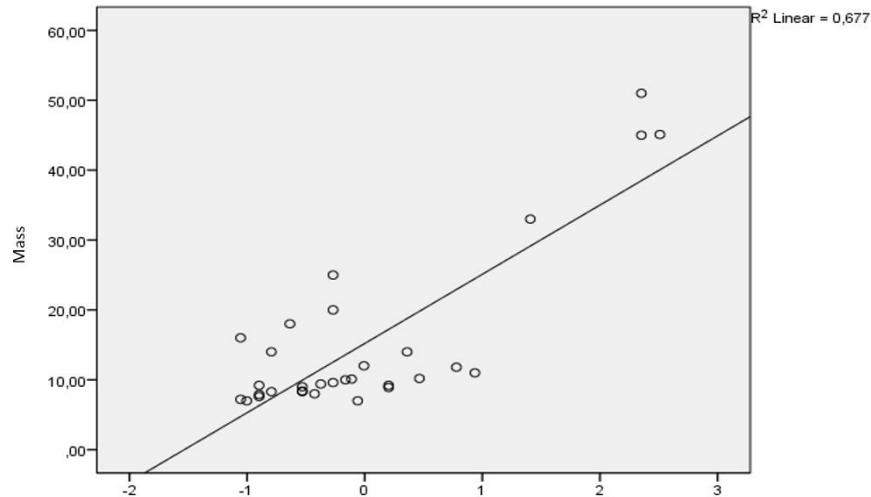
#### Length-weight relationship and condition factor

The function that best describes the length-weight ratio of *L. gibbosus* in Modrac reservoir logarithmically reads:  $\text{Log}W = -28,995 + 5,191\text{Log}L$  with a coefficient of determination of 0.67 ( $R^2 = 0.67$ ). Expressed as a percentage, this means that the obtained model explains 67% of the variance of the dependent variable. The correlation coefficient ( $r$ ) between the examined parameters is 0.82, which indicates a very large correlation. According to the obtained value of constant  $b$  of 5.19, it follows that *L. gibbosus* in Modrac reservoir has positive allometric growth and grows more in mass than in length (Table 7 and Figure 1).

**Table 7.** Condition factor (K) and parameters of length-weight growth ( $a$ ,  $b$ ), correlation coefficient ( $r$ )

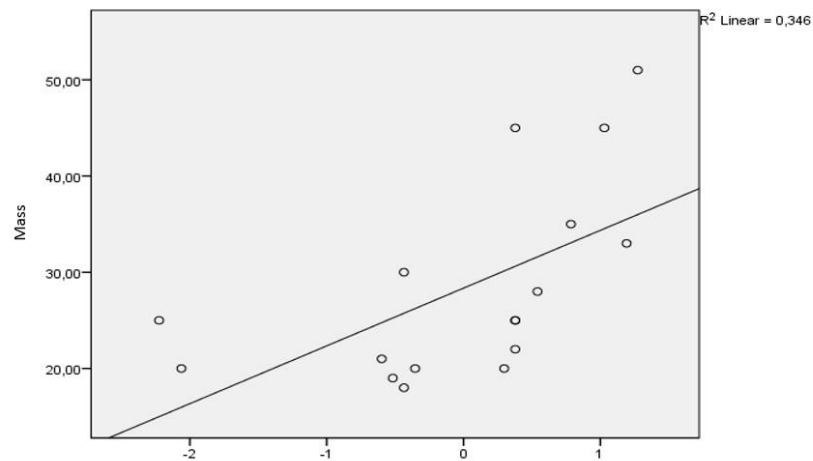
Locality	K ± SD	a	b	r
Modrac	2.37 ± 1.15	-28.99	5.19	0.82
Vidara	2.48 ± 1.08	-23.10	4.88	0.72
Sniježnica	2.19 ± 0.73	-55.79	6.95	0.91





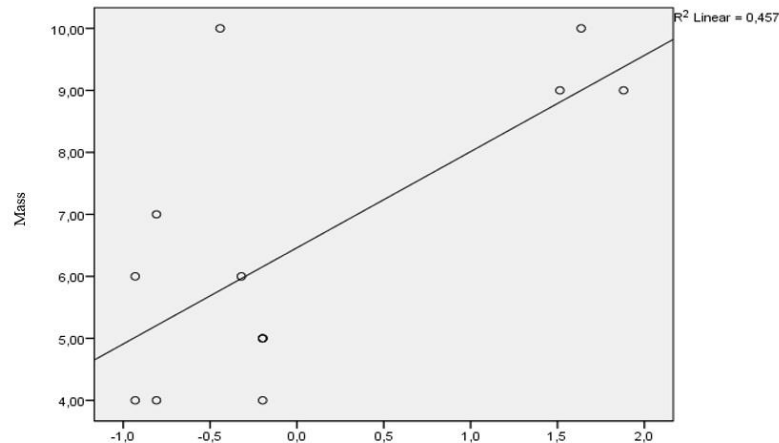
**Figure 1.** Length-weight relationship of *L. gibbosus* in Modrac reservoir

The function that best describes the length-weight ratio of *L. gibbosus* in Vidara reservoir logarithmically reads:  $\text{Log}W = -23,101 + 4,884\text{Log}L$  with a coefficient of determination of 0.34 ( $R^2 = 0.34$ ). Expressed as a percentage, it means that the obtained model explains 34% of the variance of the dependent variable. The correlation coefficient ( $r$ ) is 0.72, which indicates a significant correlation. According to the obtained value of constant  $b$  of 4.88, it follows that the *L. gibbosus* in Vidara reservoir has positive allometric growth and grows more in mass than in length (Table 7 and Figure 2).



**Figure 2.** Length-weight relationship of *L. gibbosus* in Vidara reservoir

The function that best describes the length-weight ratio of *L. gibbosus* in Sniježnica reservoir logarithmically reads:  $\text{Log}W = -6,172 + 1,897\text{Log}L$  with a coefficient of determination of 0.45 ( $R^2 = 0.45$ ). Expressed as a percentage, it means that the obtained model explains 45% of the variance of the dependent variable. The correlation coefficient ( $r$ ) between the examined parameters is 0.91, which indicates a very high correlation. According to the obtained value of the constant  $b$  of 6.95, it follows that *L. gibbosus* in Sniježnica reservoir has positive allometric growth and grows more in mass than in length (Table 7 and Figure 3).



**Figure 3.** Length-weight relationship of *L. gibbosus* in Sniježnica reservoir

The general condition of the fish can be displayed via  $K$ , as well as changes that occur depending on the location and physiological cycles in life fish (Treer and Piria, 2019). Prpa *et al.* (2007) state the data of the author Mrakovčić *et al.* (1997) according to which *L. gibbosus* from the river Krapina had  $K=1.96$  ( $b=3,082$ ), and  $R^2=0,999$  (Prpa *et al.*, 2007). The condition factor of *L. gibbosus* from Croatian reservoirs: from Fuka reservoir is  $K=1.74$ , from Osekovo reservoir is  $K=1.6$  and from Zakutak reservoir is  $K = 1.8$  (Piria *et al.*, 2017).

## CONCLUSIONS

Statistically significant differences of measured morphometric parameters of *L. gibbosus* were recorded for head length, mouth width, mouth height and intestine length. These morphometric characteristics were significantly higher in fish from Modrac and Vidara reservoirs compared to fish from Sniježnica reservoir. No differences were recorded in the stated morphometric characteristics between fish from Modrac and Vidara reservoirs. Forked length and the length of the first gill arch were significantly higher in *L. gibbosus* from Vidara reservoir compared to individuals from Modrac and Sniježnica reservoirs. Also, the stated morphometric characteristics were significantly higher in fish from Modrac reservoir compared to fish from Sniježnica reservoir. Considering that the Fulton condition factor of *L. gibbosus* from all three sites was  $> 1.4$ , it indicates the excellent condition of the populations in the observed reservoirs. Since the coefficient  $b$  in all three sites was  $> 3$ , it was determined that *L. gibbosus* have a positive allometric growth.

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### Sažetak

Cilj rada je analizirati morfometrijske karakteristike, dužinsko-masene odnose i faktor kondicije sunčanice (*Lepomis gibbosus*) iz tri hidroakumulacije (Modrac, Vidara i Sniježnica) iz sjeveroistočne Bosne i Hercegovine (BiH). Ukupan uzorak je iznosio 61 jedinku. Mjereni su sljedeći parametri: totalna dužina tijela, standardna dužina tijela, dužina glave, širina usnog otvora, visina usnog otvora, dužina ribe do početka repnog peraja, dužina prvog škržnog luka, dužina digestivnog trakta i masa tijela. Statistička analiza urađena je pomoću univarijantne analize varijanse (ANOVA) za utvrđivanje razlika morfometrijskih karakteristika sunčanice između tri lokaliteta (populacija). Dužinsko-maseni odnosi određeni su pomoću formule  $W=a TL^b$ , dok je Fultonov kondicioni faktor (K) određen pomoću formule  $K=100 (W/L^3)$ . Sunčanice iz sve tri populacije pokazuju pozitivan alometrijski rast, a najveću vrijednost kondicionog faktora imale su jedinke iz jezera Vidara. U skladu s tim većina morfometrijskih karakteristika jedinki iz jezera Vidara značajno je veća u odnosu na jedinke iz Modraca i Sniježnice što navodi na zaključak da se sunčanica najbolje adaptirala u jezeru Vidara.

**Ključne riječi:** *L. gibbosus*, hidroakumulacije, dužinsko-maseni odnosi, alometrijski rast, faktor kondicije

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