Length-weight relationship and condition factors of white bream (*Blicca bjoerkna* (Linnaeus, 1758)) from the Kyiv Reservoir

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Abstract. This study was conducted to determine length-weight relationship (LWR), condition factor (K), and relative condition factor (Kn) of white bream *Blicca bjoerkna* (Linnaeus, 1758), inhabiting the Kyiv Reservoir (Upper Dnieper, Ukraine). Fishes aged 0+ to 19+ were analysed. Length-weight relationships were found to be W = 0.0439 × SL2.8442 (R^2 = 0.9845), W = 0.0320 × SL2.9284 (R^2 = 0.9736) and W = 0.0332 × SL2.9267 (R^2 = 0.9794) for females, males and combined sexes, respectively. A negative allometric growth (b < 3) was observed for all samples. Calculation of average K resulted as 2.74±0.11 for females, 2.60±0.11 for males and 2.68±0.12 for all specimens. Average Kn of these groups were found to be 1.03±0.04, 0.97±0.04 and 1.00±0.04, respectively. This study is the first reference on LWR equation parameters and Kn of *B. bjoerkna* in the Dnieper River.

Key Words: Dnieper River, Fulton's condition factor, Kyiv reservoir, length-weight relationship (LWR), relative condition factor, white bream (*Blicca bjoerkna*).

Introduction. Modern science uses a quantitative description of the relationship between length and weight of individuals in a fish population as a basic tool for assessing the natural populations (Ricker 1975; Froese 2006; Britton & Davies 2007). Simple equation W = a x SLb (Le Cren 1951) gave an opportunity to describe a certain population and provides the information about its condition using equation parameters a and b. Besides, these parameters allow comparing different populations of a certain species in regional or chronological aspects. These parameters provide an easy way to calculate weight data simply from length data that downgrade the volume of field work. Moreover, condition-oriented indices such as Fulton's condition factor (K), Le Cren's relative condition factor (Kn), could be the reference point of fish condition in the water body (Le Cren 1951; Froese 2006; Verreycken et al 2011; Froese et al 2014).

We focused our investigations on white bream *Blicca bjoerkna* (Linnaeus, 1758) because it is one of the most numerous and less investigated native benthivorous fish in freshwater bodies of Europe and abundant commercial fish species in the Dnieper River basin. This species is protected in Ukraine by the annual stocks assessing that prevents its overfishing. This is one of the main species in commercial catches, which constituted from 33.52 to 41.08% (38.01±0.94) in catches of small mesh size gillnets (30-50 mm) in the Kyiv Reservoir during 2017-2019 (Ainsworth et al 2021; Cooke et al 2021).

Therefore, the goals of this paper were: to calculate the a and b values of length-weight relationship (LWR) equation and condition factors of *B. bjoerkna* in the Kyiv Reservoir sampled during the fisheries monitoring programme; to compare our values with those published in FishBase and to provide the data from our fish surveys as reference values for FishBase (www.fishbase.org). Moreover, K and Kn indices will provide better understanding of fish conditions and give an opportunity to compare studied population with other parts of its areal.

Material and Method

Description of the study sites. The Kyiv Reservoir is the first reservoir in the cascade of six reservoirs located on the Dnieper River (Figure 1). Its total surface area is 922 km^2 the territories of the Kyiv and Chernigiv Oblasts in Northern part of Ukraine. It has a length of 110 km, maximum width of 12 km, average depth of 4.1 m, and maximum depth of 15 m (Osadchy & Hopchenko 2014).

Figure 1. Kyiv Reservoir (Google Earth).

Data collection and analysis. Samplings in the Kyiv Reservoir were conducted during commercial fishing seasons (June-December) of 2017, 2018 and 2019 within the framework of annual monitoring fish surveys of Institute of Fisheries of National Academy of Agrarian Sciences (IF NAAS) in the Dnieper Reservoirs. The same sites were sampled during each year. Geographical coordinates of each sampling site were registered using a GPS receiver (Garmin Dakota 10). Ethic permission for investigations was proved by scientific fishing licenses of Kyiv state fishery inspections because fish specimens, protected by commercial fishery rules, were removed from the wild. The fish were caught using 24 commercial gill nets: 70.0 m length, 3.0 m high. Their mesh size was 30, 36, 40, 45, 50, 55, 60, 65, 70, 75, 80, 90 mm in twos each mesh size (Ozinkovska et al 1998). We use all these gill nets simultaneously in order to omit errors mentioned by Froese (2006). These gillnets were used 15 days in September-October for each year. Therefore, 360 gill net catches for each year or 1440 gill net catches within four years of the study period were examined. Fishes were usually processed at the fisheries posts of IF NAAS (species identification (Kottelat & Freyhof 2007), wet weight (precision balance VTD-6EL (Ukraine)), length measurements (standard measuring bar of IF NAAS with one mm accuracy)). Fish of smaller size were caught with a push-net (10 m × 1 m × 1 mm mesh size). The area of seine hauls depended on the water depth and bank steepness and ranged from approximately 10 to 100 m^2, which was measured visually using the seine length as a reference, according to standard methodology (Ozinkovska et al 1998). The age of the fish was determined from scales collected in March and April. The growth rate of bream was estimated by growth zones on scales and found from back-calculated lengths (Bagenal & Tesch 1978) in combination with Petersen's method (De Bont 1967).

A total of 1250 specimens with a standard length of 12.0-30.0 cm were weighed. The length and weight were measured with the accuracy of 1.0 cm and 1.0 g, respectively. Sexes were identified by macroscopic examination of the gonads (Bagenal & Tesch 1978). Age estimation was based mainly on the annual ring structure of scales. Several scales were taken from every white bream, from the left side of the body, from the first row above the lateral line and below the insertion of the dorsal fin. The scales were examined under dissecting microscope. In addition, to confirm the determinations made on scales, random sample of 120 *B. bjoerkna* of 12.0 to 30.0 cm SL (40 individuals each year), results of independent readings of the age of scales were compared with readings of hard rays from dorsal fins that were clearly legible. In 118 cases, the results of readings were identical, so it was assumed that the age determination based on scales was reliable (Pravdin 1966).

The LWRs were determined for males, females and combined sexes according to the equation $W = a \times SL^b$ given by Le Cren (1951) where *W* is the total wet weight (g), SL is the standard length (cm), and *a* and *b* are parameters of the LWR equation. These parameters were estimated by the least squares regressions method and, then, subjected to logarithmic transformation $\log(W) = \log(a) + b \times \log(SL)$. Standard error was calculated for the slope (*b*). The hypothesis of isometric growth was tested through Student's *t*-test, with values of $p < 0.05$ considered significant.

A t-test was used for comparison of *b* value obtained in the linear regression with isometric value (Sokal & Rohlf 1987):

$$t_s = \frac{(b-3)}{S_b}$$

where: t_s is the t-test value, *b* is the slope and S_b is the standard error of the slope (*b*).

The obtained t-test values were compared with the respective tabled critical values that allowed to determine the *b* values significance, and their inclusion in the isometric range ($b = 3$) or allometric range (negative allometric; $b < 3$ or positive allometric; $b > 3$). The degree of correlation between the variables was computed to determine R^2. The parameter *b* of LWR was compared for significant difference between sexes in same seasons and among seasons by analysis of covariance (ANCOVA) (Zar 1998).

Fulton's condition factor (*K*) was calculated using the equation (Bagenal & Tesch 1978):

$$K = 100 \times \frac{W}{SL^2}$$

The equation used for relative condition factor was:

$$K_n = \frac{W}{a \times SL^b}$$

where: *a* and *b* are the exponential form of the intercept and slope, respectively, of the logarithmic length-weight equation (Le Cren 1951). In our calculations we used sex separated and pooled samples.

Results

Age and length of different age groups. In autumn 2017-2019 the white bream population of the Kyiv Reservoir consisted of fishes aged 1+ to 13+. Age classes ranged from 1 to 12 years, with a predominance of ages 4-6 in catches. Fish aged 4 (16.0-20.0 cm SL) dominated in the sample. During two years, a white bream in the Kyiv Reservoir reached a standard body length of 12 cm (Table 1), that is less than in Kremenchuk reservoir (Didenko 2008), however within 13 seasons, white bream had an average body length of 29-30 cm.

Table 1

Standard length (SL) of different age groups of *B. bjoerkna* in the Kyiv Reservoir

Age	Female			Male		
	n	*Mean SL±SE (cm)*	*Min-Max (cm)*	*n*	*Mean SL±SE (cm)*	*Min-Max (cm)*
1	90	10.30±0.59	09.00-12.00	90	9.87±0.61	08.00-11.00
2	90	14.20±0.39	13.00-15.00	90	14.00±0.50	12.00-15.00
3	90	15.81±0.33	15.00-17.00	90	15.39±0.39	13.00-16.00
4	90	17.96±0.43	16.00-20.00	90	17.37±0.31	17.00-19.00
5	63	19.89±0.34	18.00-21.00	37	19.49±0.49	18.00-21.00
6	50	21.63±0.40	21.00-23.00	49	20.08±0.44	19.00-22.00
7	35	23.00±0.38	22.00-24.00	39	22.92±0.43	22.00-24.00
8	35	24.92±0.38	24.00-26.00	37	24.60±0.27	24.00-25.00
9	43	27.00±0.43	26.00-29.00	34	26.50±0.35	26.00-27.00
10	46	27.88±0.50	27.00-29.00	38	27.75±0.23	27.00-28.00
11	13	28.80±0.29	28.00-29.00	–	–	–
12	11	29.50±0.58	29.00-30.00	–	–	–

Length-weight relationships and condition factors. A total of 1250 individuals of *B. bjoerkna* (656 females and 594 males) were used for the study. Average SL and wet weight values of all measured fish were 20.22±2.02 cm and 246.62±74.66 g for mixed samples, 21.35±2.08 cm and 292.31±79.37 g for females and 18.87±1.72 cm and 191.78±57.94 g for males, respectively.

Although weight depends largely on the stomach content, the LWR can be used as an indicator of fish condition as well (Froese 2006). According to our calculations, the LWR of *B. bjoerkna* can be expressed by the regression equations: $W = 0.0439 \times SL^{2.8442}$ ($R^2 = 0.9845$) for females, $W = 0.0320 \times SL^{2.9284}$ ($R^2 = 0.9736$) for males and $W = 0.0332 \times SL^{2.9267}$ ($R^2 = 0.9794$) for combined sexes. Data for separate years on SL and weight were presented in Table 2.

Isometric growth (I) implies that there is no change of body shape as an organism grows and that weight increases as the third power of length, i.e., the allometric parameter (*b*) is 3.0. Negative allometric growth (A-) implies the fish becomes slenderer as it is getting longer and is indicated by $b < 3.0$. Positive allometric growth (A+) implies the fish becomes relatively stouter or deeper-bodied as it increases in length and is indicated by $b > 3.0$. The coefficient *a* might be directly interpretable as the weight of a fish in grams when it is one centimeter in length (Riedel et al 2007). *B. bjoerkna* showed negative allometric growth (A-) in all calculations.

The calculated condition factors of *B. bjoerkna* showed that Fulton's condition factor (*K*) values of *B. bjoerkna* ranged between 2.04 and 3.66 with an average of 2.68±0.12 for pooled samples, 2.14-3.66 with average 2.74±0.11 for females and 2.04-3.28 with average 2.60±0.11 for males. Similarly, the values of relative condition factors (K_n) were found to be 0.76-1.35 (1.00±0.04), 0.81-1.35 (1.03±0.04) and 0.76-1.20 (0.97±0.04), respectively. Data for separate years were presented in Table 3.

Table 3

Condition factors of *B. bjoerkna* in the Kyiv Reservoir, the Upper Dnieper, Ukraine

Year	Sex	n		Fulton's condition factor (K)		Relative condition factor (K_n)	
			R^2	Mean±SD	Min-Max	Mean±SD	Min-Max
2017	F	172	0.9733	2.42±0.10	2.04-2.89	1.06±0.04	0.9-1.31
	M	161	0.9831	2.40±0.10	2.00-2.79	1.05±0.04	0.9-1.21
	All	333	0.9540	2.41±0.11	2.00-2.89	1.06±0.08	0.9-1.31
2018	F	166	0.9832	2.75±0.09	2.16-3.26	1.01±0.03	0.93-1.56
	M	150	0.9854	2.10±0.12	1.17-2.96	0.97±0.06	0.56-1.44
	All	316	0.9897	2.19±0.15	1.17-3.45	1.01±0.07	0.56-1.56
2019	F	164	0.9811	2.72±0.09	2.39-3.08	1.01±0.03	0.89-1.17
	M	147	0.9728	2.65±0.11	2.38-3.09	1.01±0.04	0.90-1.01
	All	311	0.9419	2.68±0.10	2.38-3.09	1.01±0.04	0.89-1.17
All	F	656	0.9794	2.74±0.11	2.00-3.45	1.03±0.04	0.56-1.56
	M	594	0.9845	2.60±0.11	2.04-3.28	0.97±0.04	0.76-1.20
	All	1250	0.9736	2.68±0.12	2.00-3.66	1.00±0.04	0.56-1.56

Table 2

Length-weight relationships and growth type of *B. bjoerkna* in the Kyiv Reservoir, the Upper Dnieper, Ukraine

Year	*Sex*	*n*	*Standard length (cm)*		*Wet weight (g)*		*Equation parameters*					*Growth type*
			Mean±SD	*Min-Max*	*Mean±SD*	*Min-Max*	*a*	*b*	*SE (b)*	*t-test*	*p value*	
2017	F	172	20.36±5.68	13-29	259.97±79.13	60-610	0.0445	2.82773	0.0129	4.11	<0.005	*A-*
	M	161	18.38±1.75	13-27	173.6±49.87	60-430	0.0494	2.8028	0.0201	3.72	<0.005	*A-*
	F+M	333	19.63±2.17	13-29	228.42±72.63	60-610	0.0528	2.7507	0.0290	4.21	<0.005	*A-*
2018	F	166	20.34±1.68	12-29	246.84±59.62	40-620	0.0318	2.9388	0.0171	8.02	<0.0005	*A-*
	M	150	17.93±1.69	12-27	183.64±50.82	40-520	0.0500	2.7991	0.0199	3.56	<0.005	*A-*
	F+M	316	19.34±1.78	12-29	211.64±59.71	40-620	0.0324	2.9166	0.0206	4.23	<0.005	*A-*
2019	F	164	23.93±1.68	14-30	393.33±80.94	80-780	0.0247	2.9259	0.0181	6.79	<0.0005	*A-*
	M	147	19.8±1.64	15-28	222.5±63.53	85-570	0.0184	2.3499	0.0164	4.88	<0.005	*A-*
	F+M	311	21.71±1.96	15-30	301.35±83.81	80-780	0.0184	2.3499	0.0176	4.14	<0.005	*A-*
All	F	656	21.35±2.08	13-30	292.31±79.37	40-780	0.0332	2.9267	0.0150	8.38	<0.0005	*A-*
	M	594	18.87±1.72	12-28	191.78±57.94	40-570	0.0439	2.8442	0.0212	7.99	<0.0005	*A-*
	F+M	1250	20.22±2.02	12-30	246.62±74.66	40-780	0.03200	2.9484	0.0220	9.16	<0.0005	*A-*

Discussion

Age and length of different age groups. The age of *B. bjoerkna* ranged from 1+ to 12+ in this study. The older specimens have been found earlier in the Middle Dnieper. For example, available scientific papers demonstrate that earlier up to 18-year-old of *B. bjoerkna* individuals have been encountered in other some large reservoirs, such as the Kremenchuk Reservoir (Kirilyuk 1991; Didenko 2008). However, the life span of *B. bjoerkna* in other water bodies was the same or even less (Ilyina 1960; Ruygite 2008; Gerasimov & Komova 2015).

The results of scale reading showed that there were some overlapping of individuals with same lengths, especially for the ages from 1+ to 6+. Consequently, age-length keys for females and males do not allow exact age determination of *B. bjoerkna* with 9-12 cm SL. Despite this fact, obviously that they give an idea about approximate age of certain length *B. bjoerkna* with one-year inaccuracy that can make easier age determination.

Length-weight relationships and condition factors. LWRs and relative condition factor for this fish species in this area have never been reported elsewhere before (www.fishbase.org). From our point of view, this situation is caused by the influence of Soviet ichthyologic school, when scientists only reported mean values of length and weight for certain age groups. Therefore, this study shows the first LWR and K_n data on this species in the Upper Dnieper.

Furthermore, LWRs of *B. bjoerkna* were reported on FishBase seven times for different populations (www.fishbase.org). According to traditional methodology, cyprinids should be measured using SL because of inaccuracies of total length (TL) caused by caudal fins breaking (Pravdin 1966), therefore we used it in our investigations. SL for *B. bjoerkna* was also reported for the Lake Balaton (Specziár et al 1997), and Berounka River (Hanel 1991).

However, it should be mentioned that in available scientific papers for *B. bjoerkna* authors reported not only SL but also TL. TL was reported for Lake Spanca, Marmara (Tarkan et al 2006) Europe (Blanck & Lamouroux 2007, Verreycken et al 2011). For this reason, we have to mention that length-length estimation is available in online services of Fishbase. Regression for *B. bjoerkna* is TL= 1.267 × SL (www.fishbase.org).

Fish growth in stocks is isometric when *b* value is 3.0. However, the growth depends on species, sex, age, seasons and feeding (Le Cren 1951; Bagenal & Tesch 1978) and may be lower or higher than 3 indicating negative and positive allometric growth, respectively. When the growth was evaluated in terms of length, it was found that the growth of males and females and for all specimens of *B. bjoerkna* in our investigations was negative allometric (*A*– ($b < 3$, $p < 0.05$) on pooled data as well as in separate years of investigation. To compare our data with available sources (fishbase), we should note that all authors reported negative allometric growth as well. Our findings accorded with the result obtained for the Gorkovsky Reservoir that could be explained by the same life conditions in these freshwater ecosystems.

Condition factors of a population may depend on not only its age and sex composition, but also on environmental elements and season (Pravdin 1966). Different authors use diverse condition factors. The main point is that *K* and K_n of *B. bjoerkna* have very different values therefore our main idea was to present information that will make possible to compare our data with other available ones. Fulton's condition factor (*K*) values for all specimens of *B. bjoerkna* ranged between 2.04 and 3.66 with an average of 2.68±0.12. Although the values for males and females varied insignificantly in different years with means of 2.60±0.11 and 2.74±0.11 respectively, but *K* was significantly ($p < 0.01$) smaller for males in all years. Minimum *K* value was observed for a male whereas maximum *K* value was noted for a female specimen. Besides this, relative condition factor (K_n) looked slightly the same as *K*. Average K_n for all specimens of *B. bjoerkna* was 1.00±0.04, the highest value (1.03±0.04) was noted for females and the lowest (0.97±0.04) for males. Although *K* and K_n calculated for *B. bjoerkna* were higher than in the references (Ilyina 1960; Kirilyuk 1991; Didenko 2008; Gerasimov & Komova

2015). Feeding activities, sexes, environmental factors and seasonal differences might be responsible for this difference.

Conclusions. This species in the Kyiv Reservoir has a certain commercial value, protected status by fishing rules and high pressure on population caused by fishing, human activities and habitat destruction. Findings of this study are very important for stock assessment and evaluation studies in future. Moreover, they will allow comparing current white bream population over time and among regions.

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