



Growth and Condition of Vimba Bream *Vimba vimba* (L., 1758) (Actinopterygii: Cyprinidae) from Commercial Fisheries in the Danube River near Belgrade, Serbia

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Abstract: Vimba bream individuals ($n = 157$), obtained from commercial catches in 2016 and 2017 near Belgrade, were analysed to obtain information on growth and condition of this species. The total body length of sampled fish ranged from 248 to 440 mm, while the body weight ranged from 139 to 889 g. Five age classes (from 4+ to 8+) were present in the sample, with predominance of individuals aged 6+. Back-calculated annual length growth was the highest in the first year of life. The total body length defined according to the parameters of the von Bertalanffy growth curve could be calculated at any given time t using $L_t = 75.07 \times (1 - e^{-0.06 \times (t+1.73)})$, and the length-weight relationship – using $\log W = 0.010 + 3.02 \times \log TL$. The asymptotic standard body length was $SL_\infty = 63.86$ cm and the phi-prime growth performance index was $\phi' = 2.53$. The highest mean values of Fulton's condition factor were observed in spring of 2016, followed by spring of 2017, and in individuals aged 7+. The seasonal and age-related differences in condition were statistically significant. The lack of data, the degree of endangerment in some European countries, the status of important species for the river continuity restoration and commercial exploitation of this species, emphasise the need for future research.

Key words: back-calculated length; length-weight relationship; von Bertalanffy curve; Fulton's condition factor

Introduction

The vimba bream *Vimba vimba* (L., 1758) (Cyprinidae) is a benthopelagic species (HAMAČKOVA et al. 2009) inhabiting waters of central and eastern Europe (KOTTELAT & FREYHOF 2007). It is a potamodromous fish (HAMAČKOVA et al. 2009) living in various types of waterbodies (KOTTELAT & FREYHOF 2007). It can be classified as a medium distance migrant and one of the more important species in river continuity restoration and modelling (ICPDR 2015). Besides migratory populations, there are also

some stationary sub-populations in both rivers and lakes (POPOVIC et al. 2013). Vimba bream is omnivorous and its diet includes various food items, such as molluscs, macrophytes, oligochaetes, gammarids, chironomids, plankton, fish fry and detritus (BUBINAS & VAITONIS 2003, OKGERMAN et al. 2013, SUBOTIĆ et al. 2019).

This species is categorised as least concern (LC) by the IUCN, with an unknown population trend (FREYHOF & KOTTELAT 2008); however, regional threats to this species have been observed. LUSK et al. (2004) recognised the vimba bream as

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vulnerable (VU) in Czech waters, while it is critically endangered (CR) in Polish waters (WITKOWSKI 1999). In Serbia, this species has been categorised as LC (SIMONOVIĆ 2001).

MUELLER et al. (2018) compared the CPUE (catch per unit effort) in 1990s and 2000s with historical data for various fish species and observed a decline in the vimba bream CPUE in the German segment of the Danube River. A study by KOVAČ (2015) suggested a decline in the relative density of the vimba bream from the Upper to the Lower Danube River. As for the Serbian section of the Danube River, the data on abundance/biomass of the vimba bream are available from various fishery management programs. In the last few surveys, vimba bream constituted less than 5% of the total fish stock in both abundance and in biomass (ANONYMOUS 2016, 2017). The decline in the vimba bream stock could be attributed to several factors, such as bad fishing practices, habitat alteration, introduced fish species and water pollution (BACKIEL 1985, CILBIZ et al. 2015). Due to local threats, projects on artificial reproduction, rearing and stocking have been developed in some countries (HAMAČKOVA et al. 2009, BORON & SZLACHCIAK 2011). However, regardless of reports on regional threats, this species is abundant in the Tisza River in Hungary (HARKA & BANARESCU 1999). Even though it is commercially exploited in Serbia (SMEDEREVAC-LALIĆ 2013), there are no current data on population parameters, fisheries management or conservation status for the vimba bream in Serbian waters.

Data on growth and condition of the vimba bream from the Danube River in Serbia are reported in this article. Due to its undefined status as well as its commercial value in Serbia and in view of the local threats in some European countries, such data are important for the sustainable management and maintenance of fish stocks of this species.

Materials and Methods

Vimba bream individuals ($n = 157$) were obtained from commercial catches in the Danube River near Zemun (municipality of Belgrade), between 1170th and 1189th river km, from March 2016 to May 2017. Fishing was conducted by drift gill-nets with a mesh size of 50 mm. Total length TL of sampled fish was measured to the nearest 0.1 cm and body weight W (digestive tract and gonads included) – to the nearest g. Previous reports confirm that scales can be used for age validation in vimba bream (HLIWA & MARTYNIK 2002, LUSK et al. 2005, CZERNIEJEWSKI et al. 2011, OKGERMAN et

al. 2011), considering that they are relatively large and of proportional shape. Scales were taken from the region between the lateral line and the dorsal fin. Fish age was determined based on the number of scale annuli. Readable scales (not damaged and not regenerated) were cleaned in alcohol, mounted on microscope slides, photographed using a stereo microscope and subsequently analysed with an image analysis software (ImageJ). All scales were read by three independent readers.

Length back-calculation was done according to the equation of Monastyrsky (FRANCIS 1990):

$$Ln = (Sn/S^b) \quad (1),$$

where Ln was the total length at age n , Sn was the scale radius at age n , S was the scale radius at time of catch and b was the slope from the body length-scale radius regression.

The Beverton's model was used for fitting of the von Bertalanffy growth curve (RICKER 1975). The von Bertalanffy growth equation was estimated using the finite difference diagram of Walford. Growth curves were generated with the Simply Growth program (©PISCES Conservation Ltd, 2002), which estimates parameters by non-linear regression using the Levenberg-Marquardt method. The length-weight relationship was also calculated with the Simply Growth program.

To test the overall growth performance and to overcome the problem of correlation between growth parameters k and L_∞ , the phi-prime index (ϕ') was calculated (MUNRO & PAULY 1983, PAULY & MUNRO 1984):

$$\phi' = \log_{10} k + 2 \log_{10} L_\infty \quad (2),$$

where k was the Brody's growth coefficient and L_∞ was the asymptotic length.

Fulton's condition factor K was calculated using the following equation (RICKER 1975):

$$K = WL^{-3} \times 100 \quad (3).$$

Additionally, all calculations were done with the standard body length for comparisons with other studies where standard length (SL) was used. Conversion of the total (TL) to standard length was performed according to the FishBase (FROESE & PAULY 2019), using the following equation:

$$TL = 0.000 + 1.179SL \rightarrow SL = TL/1.179 \quad (4).$$

To test for seasonal differences of Fulton's con-

Table 1. The number of sampled vimba bream individuals in each analysed age class, with minimum, mean (\pm SD) and maximum values of the total body length (cm) and weight (g). Estimated weight increments (%) are also included.

Age	n = 157	Total length (cm)		Weight (g)		
		Min-Max	Mean \pm SD	Min-Max	Mean \pm SD	Increment (%)
4+	2	25.0–25.5	25.2 \pm 3.54	175–203	188 \pm 19.94	-
5+	49	24.8–31.5	28.5 \pm 16.23	139–365	254 \pm 52.89	35
6+	72	26.3–37.0	30.2 \pm 26.37	189–628	306 \pm 84.11	20
7+	25	29.1–41.0	33.7 \pm 29.86	288–779	467 \pm 123.25	52
8+	9	32.6–44.0	36.9 \pm 42.38	346–889	571 \pm 198.49	22

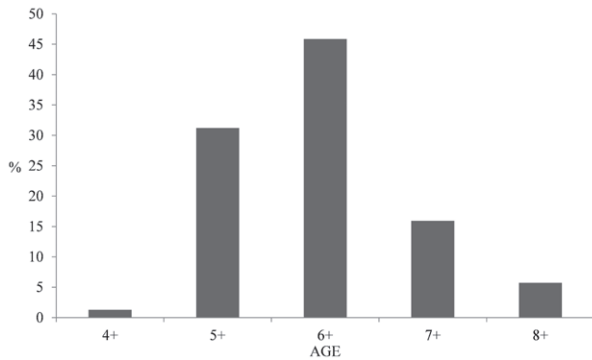


Fig. 1. Age frequency distribution of sampled vimba bream.

dition factor, a one-way ANOVA with Brown-Forsythe F test was applied. Post-hoc intergroup comparisons were performed using the Games-Howell post-hoc test.

Results

The total body length of the sampled fish ranged from 24.8 cm to 44.0 cm (mean \pm SD = 30.60 \pm 3.45 cm), while body weight was from 139 g to 889 g (mean \pm SD = 329.8 \pm 130.9 g; Table 1). The age of the sampled fish ranged from 4+ to 8+, with the highest percentage of individuals (46%) in the 6+ age class (Fig. 1).

Annual length growth (length-at-age) was back-calculated using the growth models of Monastyrsky and von Bertalanffy (Table 2). The greatest relative growth increment was observed in the first year of life.

The total body length of the sampled fish, defined according to the parameters of the von Bertalanffy growth curve (Fig. 2), could be calculated at any given time as: $L_t = 75.07 \times (1 - e^{-0.06 \times (t+1.73)})$. The estimated phi-prime growth performance index (ϕ') was 2.53. The asymptotic length using the standard body length was $SL_\infty = 63.86$ cm.

The relationship between TL and weight was estimated as $\log W = 0.010 + 3.02 \times \log TL (R^2 =$

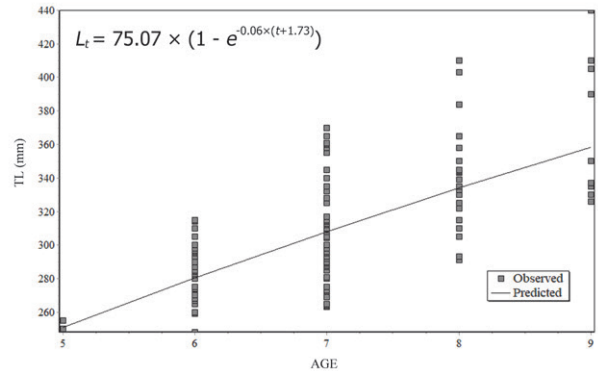


Fig. 2. Von Bertalanffy growth curve of sampled vimba bream

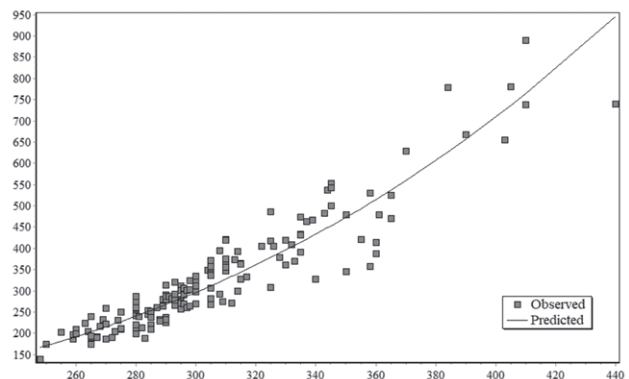


Fig. 3. Length-weight relationship curve of sampled vimba bream.

0.88, $p < 0.01$), which indicated an almost isometric growth (Fig. 3).

The mean value of Fulton's condition factor based on TL was 1.11 ± 0.13 , while the mean value based on the estimated SL was 1.81 ± 0.22 . The differences between seasons were statistically significant ($F = 24.943$; $p < 0.001$): the highest mean value was observed in spring of 2016 (1.23 ± 0.09), followed by spring of 2017 (1.10 ± 0.08 ; Fig. 4). The post-hoc test showed that spring of 2016 was statistically different to all other seasons, except for winter of 2016. The highest mean value of Fulton's condition factor was observed in age class 7+ (1.20) and the lowest in age

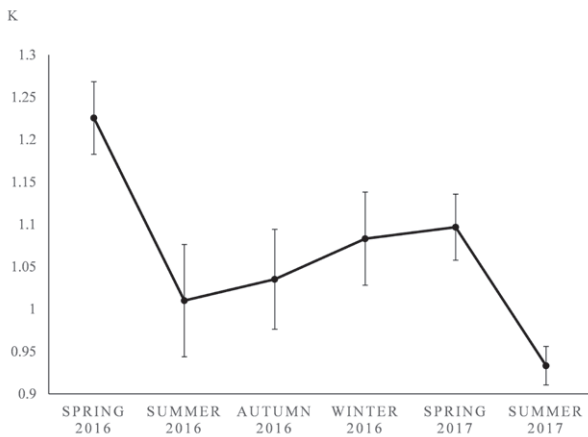


Fig. 4. Seasonal fluctuations of Fulton's condition factor in sampled vimba bream (mean values \pm SD).

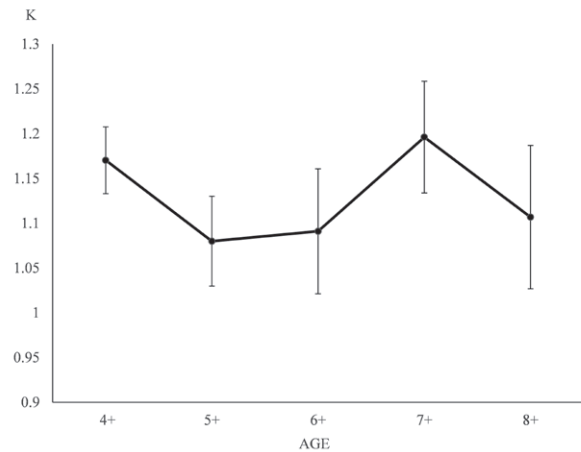


Fig. 5. Age-related fluctuations of Fulton's condition factor in sampled vimba bream (mean values \pm SD).

Table 2. Back-calculated length-at-age of sampled vimba bream.

Age	Total length (cm) \pm SD								
	L1	L2	L3	L4	L5	L6	L7	L8	L9
4+	10.1 \pm 2.64	15.0 \pm 3.55	18.4 \pm 4.01	21.1 \pm 4.58	25.2 \pm 3.54				
5+	11.2 \pm 1.70	15.8 \pm 1.71	19.7 \pm 1.59	23.0 \pm 1.75	25.5 \pm 1.98	28.6 \pm 1.62			
6+	11.0 \pm 1.57	15.3 \pm 1.84	18.8 \pm 2.10	22.4 \pm 2.31	25.2 \pm 2.49	28.1 \pm 2.66	30.2 \pm 2.64		
7+	10.9 \pm 1.64	15.2 \pm 1.85	18.7 \pm 1.98	22.3 \pm 2.14	25.5 \pm 2.18	28.4 \pm 2.40	31.2 \pm 2.48	33.8 \pm 2.99	
8+	11.3 \pm 1.62	15.6 \pm 1.61	18.8 \pm 2.02	22.2 \pm 2.17	26.4 \pm 2.45	28.9 \pm 3.00	31.4 \pm 3.73	34.1 \pm 4.04	36.9 \pm 4.24
TL MON	10.9 \pm 0.48	15.3 \pm 0.31	18.9 \pm 0.51	22.2 \pm 0.71	25.6 \pm 0.48	28.5 \pm 0.36	30.9 \pm 0.61	33.9 \pm 0.22	36.9
Increment (cm)		4.47	3.47	3.33	3.40	2.91	2.44	2.99	2.99
Increment (%)		41	23	18	15	11	9	10	9
TL BERT	11.3	15.3	19.0	22.4	25.4	28.3	30.8	33.2	35.3
Increment (cm)		4.04	3.69	3.37	3.08	2.82	2.58	2.36	2.15
Increment (%)		36	24	18	14	11	9	8	6

class 5+ (1.08; Fig. 5). The age-related differences in the condition factor were also statistically significant ($F = 4.04$; $p = 0.04$) as well as the differences between ages 6+ and 8+ and 7+ and 8+.

Discussion

Back-calculated standard lengths-at-age of vimba bream individuals in this study were comparable to those recorded by CZERNIEJEWSKI et al. (2011) for the Oder River estuary. Yearly length increments were similar in all age classes except for the 1+ fish: the growth increment between the first and the second year of life was 15–16% greater in individuals from the Danube River than from the Oder River. Individuals caught in the Dyje/Thaya River (Czech Republic) had even greater (\approx 60%) increment between the first and the second year of life (LUSK et al. 2005). PATIMAR & SAFARI

(2010) observed a drastically smaller back-calculated length-at-age (fish grew to only 3 cm TL in the first year of life) and greater yearly increment (139% growth increment between the first and the second year).

Individuals from the Danube River attain a greater asymptotic length ($SL_{\infty} = 63.9$ cm; $TL_{\infty} = 75.1$ cm) compared to fish sampled from other areas:

(i) from other waterbodies in Europe, where $TL_{\infty} = 52.0$ cm (FROESE & BINOHLAN 2003);

(ii) from the Caspian Sea, where $TL_{\infty} = 32.6$ cm for males and $TL_{\infty} = 36.0$ for females (PATIMAR & SAFARI 2010) or $FL_{\infty} = 23.3$ cm for males and $FL_{\infty} = 24.5$ mm for females (TARIDASHTI et al. 2017);

(iii) from Turkey, where $FL_{\infty} = 28.9$ cm for males and $FL_{\infty} = 24.7$ cm for females (OKGERMAN et al. 2011).

Low values of the Brody growth coefficient ($k = 0.06$) indicate a slow growth of the vimba bream

in this part of the Danube. A slow rate of growth leads to larger asymptotic size (CHARNOV 1993). On the other hand, k is inversely proportional to the analysed range of lengths. The estimated high value of L_{∞} and low k have been expectable, since the sampled individuals from the Danube River were much larger (from 24.8 to 44.0 cm TL); it is due to gear selectivity, which is mandatory for commercial fishermen. The length range of fish from other studies is 12.7–22.9 cm TL in PATIMAR & SAFARI (2010), 8.0–24.0 cm FL in TARIDASHTI et al. (2017) and 9.1–22.9 cm FL in OKGERMAN et al. (2011). The abundance of larger and older individuals in the analysed catches in the Danube River could indicate that this part of the Danube River has favourable environmental conditions for the growth of the vimba bream. This can lead to lower mortality, which results in a shift towards larger maximum sizes (WOOTTON 1990). The low fishing pressure on *Vimba vimba* in this part of the Danube River (JOVIČIĆ et al. 2014) can also result in the presence of large individuals in the catch. However, the phi-index for the vimba bream in the Danube River is lower than indices obtained by FROESE & BINOHLAN (2003) for other waterbodies of Europe and by PATIMAR & SAFARI (2010) for the SE Caspian Sea.

The differences in growth parameters and back-calculated lengths can be explained, in part, by the different length and age ranges of the analysed fish. In studies where samples are fishery-dependent, the lack of small, young fish is expected, which can cause problems when estimating the growth curve for the youngest ages. Due to lack of young fish (< 4+) in the present study, the resulting back-calculated lengths-at-age for young age classes should be interpreted with caution. CZERNIEJEWSKI et al. (2011) included fish from a wider age range (from 3+ to 11+) and LUSK et al. (2005) back-calculation was based on fish of a wider length range, mainly of 4+ and 5+ ages. PATIMAR & SAFARI (2010) conducted the research on young vimba individuals with smaller lengths.

The exponent of the length-weight relationship ($b = 3.02$) indicates an almost isometric growth pattern. Several authors have reported a positive allometric growth ($b > 3$) for the vimba bream, e.g. in Turkey (TARKAN et al. 2006, ILHAN & SARI 2015). PRPA et al. (2007) has also reported, based on a literature review, a positive allometric growth for the vimba bream at two locations in Croatia. In one of the tributaries of the Danube River, the Timiș River, the vimba bream has shown a negative allometric growth (STAVRESCU-BEDIVAN et al. 2017). These differences in length-weight relationship (and growth

estimates, in general) could also reflect environmental conditions of the waterbody from where the sample was taken (TREER et al. 1999).

EGERICÍ et al. (2015) have observed lower average values of the Fulton's condition factor for the vimba bream in the Serbian part of the Danube River on several locations downstream of the sampling site near Zemun. However, these estimations have been done on a small sample ($n = 10$). Vimba bream individuals, caught in Croatia (PRPA et al. 2007) and Romania (STAVRESCU-BEDIVAN et al. 2017) also have lower values of Fulton's condition factor compared to fish caught near Zemun. It should be noted that the fish used in both of these studies were younger individuals with a narrow length and weight ranges and that the condition factor was calculated on a sample of smaller size. The significant drop in Fulton's condition factor between spring and summer in our study as well as its lowest values observed in summer could be attributed to the methodology we used. Since the measured body weight included internal organs, loss of gonad weight during the spawning season, which lasts from May to July (KOTTELAT & FREYHOF 2007), affected the results obtained for the summer condition.

The fishing pressure in the area of Belgrade is low and JOVIČIĆ et al. (2014) report that this species is at the bottom of the fisheries yield, both in terms of abundance and biomass. The vimba bream is categorised as a commercially exploited species of a lesser value (SMEDEREVAC-LALIĆ 2013), which could explain lower fisheries yields. However, some other species (such as the Prussian carp *Carassius gibelio* or the white bream *Blicca bjoerkna*) are also in the same category but provide larger yields (JOVIČIĆ et al. 2014). This could be due to a generally small abundance/biomass of the vimba bream in this part of the Danube River (ANONYMOUS 2017) or to the migratory behaviour of the species (KOTTELAT & FREYHOF 2007), making it not available to fishermen all year round and consequently not constituting a significant part of the total catch.

Knowledge about the biology of commercially-exploited species is one of the factors determining the minimal permitted length at catch (CABRERA et al. 2012). In Poland, the permitted size of caught vimba bream individuals is 30 cm (KUJAWA et al. 2011), with a gradual increase of the minimum landing size from 1940s to 2000s (PSUTY 2010). In Serbia, the minimum landing size for the vimba bream is 15 cm and fishing is permitted all year round (OFFICIAL GAZETTE OF RS No. 94/2018). The results of the back-calculated length-at-age in this study indicate that 15-cm individuals in the Danube River near

Belgrade are in their second year of life (1+). Considering that the first spawning of the vimba bream begins at 3–5 years of age (KOTTELAT & FREYHOF 2007), permitted fishing of immature individuals could generate a lot of pressure on populations. It would be beneficial if the minimum landing size is increased to at least 20 cm, which should ensure the sustainable fishing of this species in the Danube River in Serbia. A similar minimum landing size (19.3 cm) has been proposed by CILBIZ et al. (2015) for a lake in Turkey, while OKGERMAN et al. (2013) proposed that the minimum landing size should be 17.03 cm fork length and the minimum age – 4+ for another lake in Turkey. CILBIZ et al. (2015) have also suggested that fishermen should use gill nets with a mesh size of at least 50 mm.

Recreational fisheries can pose a problem for fish populations (COOKE & COWX 2004). There is a lack of data on recreational fisheries yield in Serbia and it should be noted that, unlike for some other fish species, the daily bag limit for recreational fisheries of the vimba bream is not specified (OFFICIAL GAZETTE OF RS No. 94/2018).

Global threat assessments are based on regional studies and evaluations (ARTHINGTON et al. 2016). Lack of data, endangerment in some European countries of having the status of important species for the river continuity restoration, all these highlight the need for a more comprehensive study of population ecology and future fisheries management of the vimba bream in the Serbian part of the Danube River.

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