

Growth Rate of *Barbus cyclolepis* (Cyprinidae) in the Middle Stream of the Maritsa River, Bulgaria

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Abstract: Altogether 847 specimens were studied to evaluate the growth rate and compensation growth of *B. cyclolepis* in the middle stream of the Maritsa River, Bulgaria. The population equation describing the relationship between the fish length and scale radius was $L' = 0.8335 + 0.3697S$, $r = 0.99$. The relation between the fish weight and length in the population was described with the equation $W' = 0.0144L^{3.0588}$, $r = 0.999$. Both relations were calculated also for each age group. The highest linear increment was recorded during the first year, while the weight increments increased with the increase in the fish weight. The linear and weight growth were described with Von Bertalanffy's growth equations: $L_t = 73.55 [1 - e^{-0.0394(t+0.178)}]$; $W_t = 9118 [1 - e^{-0.0362(t+0.2326)}]^{3.0588}$. The very low values of the growth coefficient k (0.0394 and 0.0362 for the length and weight growth, respectively) showed low growth rate. Low values of the coefficient of Hohendorf were received (0.03 for the linear growth and 0.2 for the weight growth). This shows that the population does not use well its growth potential. It was found that the compensation growth appeared in the third year.

Key words: *Barbus cyclolepis*, growth rate, compensation growth

Introduction

Barbus cyclolepis Heckel is a representative of the family Cyprinidae. It is a typical inhabitant of the middle stream of the rivers. *B. cyclolepis* is protected species according to the Bulgarian Biodiversity Act. Although it is not a commercial fish species, its stocks are under significant exploitation by the anglers.

Studies about the growth characteristics of the species are scarce. DIKOV, ZIVKOV (1985) compared the linear and weight growth of *B. cyclolepis* from Dospat Reservoir and Dzherman River. MARINOV (1989) presented data about growth of *Barbus* species in Bulgaria. The growth rate of *B. cyclolepis* in the Struma River was studied by BORISOV (1991). Data about the weight growth of the species were published by DIKOV *et al.* (1994). The growth rate of *B. cyclolepis* was also studied for the population in the Doirani River by VASILIOU, ECONOMIDIS (2005). The compensation growth of *B. cyclolepis* populations has never been studied.

The aim of this study is to evaluate the growth rate and the presence of compensation growth in *B. cyclolepis* in the conditions of the middle stream of the Maritsa River.

Material and Methods

A total of 847 specimens of *B. cyclolepis* were collected monthly (excluding in December) during the period September 2005 – June 2007 from the middle stream of the Maritsa River in the area between Popovitsa and Yabalkovo villages (Fig. 1). A 50 km stretch from the middle stream of the river was studied. The samples were collected by cast net fishing – mesh size of 10 mm and by an electrofishing gear Samus 725G at output frequency 45 Hz, output duration 0.35 milisec and output power 650 W. Electrofishing was done according to EN 14011:2004 (Water quality – Sampling of fish with

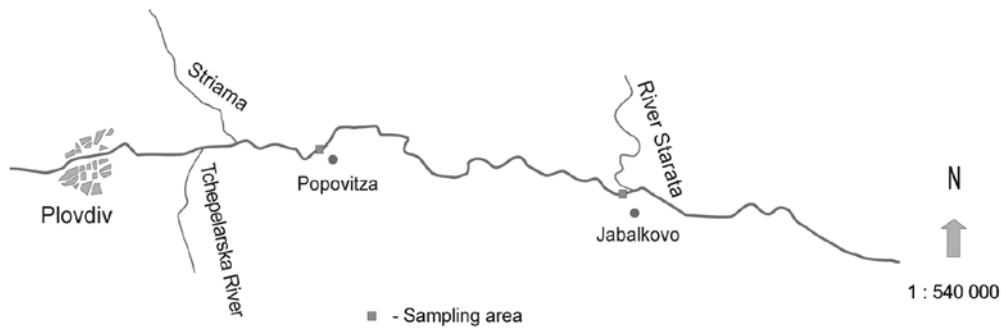


Fig. 1. Sampling area in Maritsa River

Table 1. Equations of the Length-Scale radius and Length-Weight relations for each age group

| Age (years) | Equations of the relation L – S for each age group | Equations of the relation W – L for each age group |
|-------------|--|--|
| 1 | $L_1 = 1.6439 + 0.4474 S_1, r = 0.98$ | $W_1 = 0.0129L_1^{3.1384}, r = 0.99$ |
| 2 | $L_2 = 0.8084 + 0.4119 S_2, r = 0.97$ | $W_2 = 0.0159L_2^{3.0137}, r = 0.99$ |
| 3 | $L_3 = 0.3164 + 0.383 S_3, r = 0.99$ | $W_3 = 0.0143L_3^{3.0615}, r = 0.99$ |
| 4 | $L_4 = 2.298 - 0.4532 S_4, r = 0.98$ | $W_4 = 0.0136L_4^{3.0733}, r = 0.99$ |
| 5 | $L_5 = 3.438 - 0.4788 S_5, r = 0.97$ | $W_5 = 0.0144L_5^{3.0645}, r = 0.99$ |
| 6-8 | $L_{6-8} = 4.5723 - 0.507 S_{6-8}, r = 0.92$ | $W_{6-8} = 0.0228L_{6-8}^{2.8856}, r = 0.99$ |

electricity). The cast net fishing covered the whole width of the river.

Standard length ($SL \pm 1mm$), total weight ($TW \pm 1g$), and gutted (somatic) weight ($W \pm 1g$) were measured for each specimen. The age was determined by the scales at magnification of 17.5x with a Projector Dokumator, Lasergeret (Carl Zeiss, Jena). Length and weight at age were back calculated and the received values were used to calculate Von Bertalanffy's growth parameters (BERTALANFFY 1938). To assess whether the growth potential of the population was well used the coefficient of Hohendorf was applied (HOHENDORF 1966). Compensation growth was studied on the generations 2000 and 2001 by applying the methodology of ZIVKOV (1980, 1982).

To compare the growth rate among populations, they were arranged in ascending order of the length of the highest age group. On comparing two populations of different ages, the length of the highest age group of the youngest population was compared (ZIVKOV 1972, ZIVKOV *et al.* 1999). The parameters: $k, L_\infty / W_\infty, t_0$ from Von Bertalanffy's equation, ω – parameter (GALUCCI, QUINN 1979), and ϕ – parameter (PAULY 1979, MUNRO, PAULY 1983, PAULY, MUNRO 1984) were also used to compare the growth rate of the populations.

Calculations were made with the use of Excel and MASO software products.

Results and Discussion

The relationship between L and S in the studied population is described by the equation $L' = 0.8335 + 0.3697S, r = 0.99$. The L-W relation is presented with the equation $W' = 0.0144L^{3.0588}, r = 0.999$. The L-S and L-W equations for each age group are given in Table 1. Based on these equations, the average length (Table 2) and weight (Table 3) for each generation and age group were back calculated.

The generation 1999 had the slowest growth rate as each year the length and weight values were lower than the average recorded for the population. The generation 2002 had the highest growth rate. The uneven growth rate of the different generations is due to the change of the hydrological characteristics of the river over the years. Throughout year 2002 there was a high water level, which was the reason for the better start and the highest growth rate of the respective gender. The weak start of the fish from year 2005 is due to the high average values of the monthly runoff in years 2005 and 2006 (<http://www.moew.government.bg>).

The recorded average annual linear increments for the population are presented in Table 2. They are within the range of lowest reported for the populations of *B. cyclolepis*. The highest increment was observed during the first year. During the second year, there was a significant drop of the linear increments

Table 2. Back calculated average fish lengths (L, cm) in the different generations and age groups of *B. cyclolepis* and average length increments; L' – fish length calculated by the use of the population equation; L'' – fish length calculated by the use of the equation for each age group

| Gender (years) | Age group | Back calculated fish lengths (L, cm) at the end of each vegetation period | | | | | | | | | | | | | | | | n | | | | | | | | | | | | | | |
|-------------------------|-----------|---|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------|------------------|-------------------|--|--|-----|--|-----|--|-----|--|-----|--|-----|--|
| | | L ₀ ' | L ₀ '' | L ₁ ' | L ₁ '' | L ₂ ' | L ₂ '' | L ₃ ' | L ₃ '' | L ₄ ' | L ₄ '' | L ₅ ' | L ₅ '' | L ₆ ' | L ₆ '' | L ₇ ' | L ₇ '' | | L ₈ ' | L ₈ '' | | | | | | | | | | | | |
| 2006 | 0+ | 1.9 | 2.9 | | | | | | | | | | | | | | | | | 8 | | | | | | | | | | | | |
| 2005 | I-II | 1.6 | 2.6 | 3.1 | 4.4 | 5.1 | 5.6 | | | | | | | | | | | | | 33 | | | | | | | | | | | | |
| 2004 | II-III | | | 4.3 | 5.8 | 6.7 | 7.3 | 9.3 | 9.1 | | | | | | | | | | | 144 | | | | | | | | | | | | |
| 2003 | III-IV | | | 3.3 | 4.6 | 7.5 | 8.2 | 10.0 | 9.8 | 10.8 | 9.9 | | | | | | | | | 257 | | | | | | | | | | | | |
| 2002 | IV-V | | | 3.9 | 5.3 | 7.0 | 7.7 | 10.1 | 9.9 | 12.5 | 12.0 | 15.3 | 15.2 | | | | | | | 244 | | | | | | | | | | | | |
| 2001 | V | | | 3.5 | 4.9 | 6.6 | 7.3 | 9.7 | 9.5 | 12.2 | 11.7 | 14.1 | 13.8 | | | | | | | 126 | | | | | | | | | | | | |
| 2000 | VI | | | 3.5 | 4.9 | 6.5 | 7.2 | 9.4 | 8.9 | 11.8 | 11.1 | 14.1 | 13.8 | 15.5 | 15.5 | | | | | 30 | | | | | | | | | | | | |
| 1999 | VII | | | 3.1 | 4.4 | 5.4 | 5.9 | 8.0 | 7.7 | 10.6 | 9.7 | 12.5 | 11.6 | 14.6 | 14.3 | 16.0 | 16.2 | | | 4 | | | | | | | | | | | | |
| 1998 | VIII | | | 3.1 | 4.3 | 4.5 | 4.9 | 7.1 | 6.8 | 11.6 | 10.8 | 13.8 | 13.3 | 15.6 | 15.7 | 18.2 | 19.3 | 20.4 | 22.3 | 1 | | | | | | | | | | | | |
| Average lengths (L, cm) | | 1.8 | 2.8 | 3.5 | 4.8 | 6.2 | 6.8 | 9.1 | 8.8 | 11.6 | 10.9 | 14.0 | 13.6 | 15.2 | 15.2 | 17.1 | 17.7 | 20.4 | 22.3 | 847 | | | | | | | | | | | | |
| Empirical lengths (cm) | | 3.0 | | | 4.7 | | | 7.1 | | | 9.9 | | | 13.7 | | | 16.3 | | | 21.8 | | | | | | | | | | | | |
| Increments (t'; t'') | | 3.5 | | | 4.8 | | | 2.7 | | | 1.9 | | | 2.4 | | | 2.7 | | | 1.3 | | | 1.6 | | 1.9 | | 2.5 | | 3.3 | | 4.6 | |

Table 3. Back calculated average fish weights (W, g) in the different generations and age groups of *B. cyclolepis* and average weight increments. W' – fish weight calculated by the use of the population equation; W'' – fish weight calculated by the use of the equation for each age group

| Gender (year) | Age group | Back calculated fish weights (W, g) at the end of each vegetation period | | | | | | | | | | | | | | | | n | | | | | | | | | | | | | | | | | |
|-----------------------|-----------|--|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|-------|------------------|-------------------|--|--|------|--|--|------|--|------|--|------|--|------|--|------|--|
| | | W ₀ ' | W ₀ '' | W ₁ ' | W ₁ '' | W ₂ ' | W ₂ '' | W ₃ ' | W ₃ '' | W ₄ ' | W ₄ '' | W ₅ ' | W ₅ '' | W ₆ ' | W ₆ '' | W ₇ ' | W ₇ '' | | W ₈ ' | W ₈ '' | | | | | | | | | | | | | | | |
| 2006 | 0+ | 0.1 | 0.4 | | | | | | | | | | | | | | | | | 8 | | | | | | | | | | | | | | | |
| 2005 | I-II | 0.1 | 0.3 | 0.5 | 1.3 | 2.1 | 2.8 | | | | | | | | | | | | | 33 | | | | | | | | | | | | | | | |
| 2004 | II-III | | | 1.2 | 3.2 | 4.8 | 6.4 | 13.2 | 12.3 | | | | | | | | | | | 144 | | | | | | | | | | | | | | | |
| 2003 | III-IV | | | 0.5 | 1.6 | 6.7 | 9.0 | 16.4 | 15.5 | 21.0 | 15.8 | | | | | | | | | 257 | | | | | | | | | | | | | | | |
| 2002 | IV-V | | | 0.9 | 2.4 | 5.6 | 7.5 | 17.1 | 16.2 | 32.9 | 28.5 | 60.0 | 60.7 | | | | | | | 244 | | | | | | | | | | | | | | | |
| 2001 | V | | | 0.7 | 1.9 | 4.7 | 6.3 | 15.0 | 14.1 | 30.6 | 26.0 | 47.6 | 44.9 | | | | | | | 126 | | | | | | | | | | | | | | | |
| 2000 | VI | | | 0.7 | 1.8 | 4.5 | 6.0 | 13.7 | 11.5 | 27.2 | 22.3 | 47.2 | 44.3 | 63.0 | 62.5 | | | | | 30 | | | | | | | | | | | | | | | |
| 1999 | VII | | | 0.5 | 1.4 | 2.5 | 3.3 | 8.2 | 7.4 | 19.9 | 14.7 | 32.5 | 26.6 | 52.5 | 49.3 | 69.3 | 70.7 | | | 4 | | | | | | | | | | | | | | | |
| 1998 | VIII | | | 0.4 | 1.3 | 1.5 | 1.9 | 5.8 | 5.1 | 25.7 | 20.7 | 43.9 | 40.2 | 64.5 | 64.5 | 103.1 | 116.1 | 146.6 | 177.2 | 1 | | | | | | | | | | | | | | | |
| Average weight (W, g) | | 0.1 | 0.3 | 0.7 | 1.9 | 4.0 | 5.4 | 12.8 | 11.7 | 26.2 | 21.3 | 46.2 | 43.3 | 60.0 | 58.8 | 86.2 | 93.4 | 146.6 | 177.2 | 847 | | | | | | | | | | | | | | | |
| Empirical weight (g) | | 0.4 | | | 2.3 | | | 6.5 | | | 17.9 | | | 48.4 | | | 73.3 | | | 186.0 | | | | | | | | | | | | | | | |
| Increments (t'; t'') | | 0.7 | | | 1.9 | | | 3.4 | | | 3.5 | | | 8.7 | | | 20.0 | | | 22.0 | | | 13.8 | | | 15.4 | | 26.2 | | 34.6 | | 60.4 | | 83.9 | |

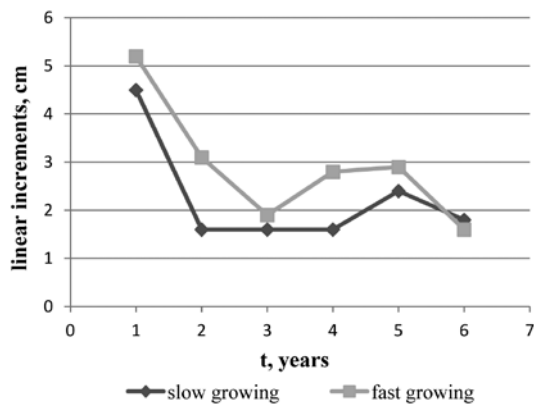


Fig. 2. Changes in the annual linear increments in fish with different initial lengths from generation 2000

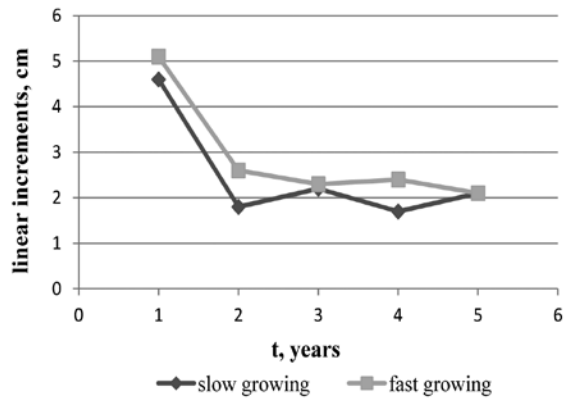


Fig. 3. Changes in the annual linear increments in fish with different initial lengths from generation 2001

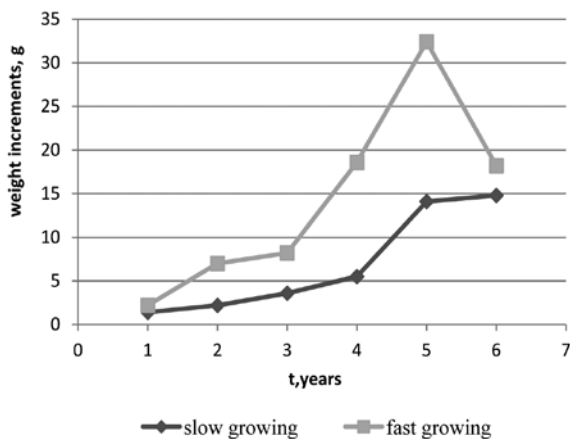


Fig. 4. Changes in the annual weight increments in fish with different initial weights from generation 2000

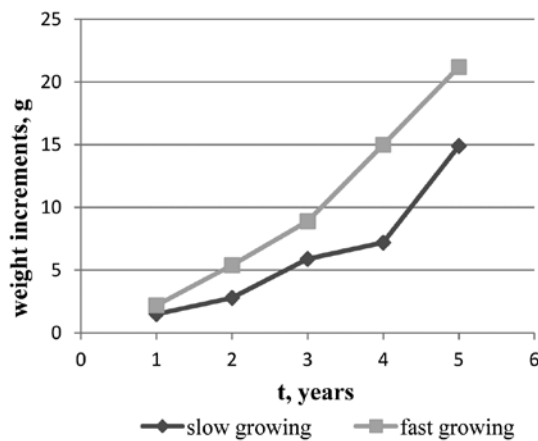


Fig. 5. Changes in the annual weight increments in fish with different initial weights from generation 2001

due to the sexual maturation of the female individuals (RAIKOVA-PETROVA, ROZDINA 2012). Similar drop of the increments was reported for other populations of the species and also for other fish species (ZIVKOV 1972, DIKOV, ZIVKOV 1985). The studied population had uneven alteration of the annual linear increments. The weight increments increased with the increase in the fish age. For the populations from Dospat Reservoir, the Dzherman River (DIKOV, ZIVKOV 1985), the Struma River (BORISOV 1991) and the Doirani River (VASILIOU, ECONOMIDIS 2005) the annual linear increments decreased with the increase in the fish age. The reason for the uneven change of the increments is the process of self-regulation (compensation growth) in the population.

There is a linear regression between the average fish length at age t year (L_t) and the average length one year later (L_{t+1}). The relation is described by the Ford-Walford equation (WALFORD 1946): $L_{t+1} = 4.3786 - 0.0321L_t$, $r = 0.998$. Based on this, the linear growth of *B. cyclolepis* can be described with

Von Bertalanffy's equation (1938): $L_t = 73.55[1 - e^{-0.0394(t+0.178)}]$. The asymptotic length of *B. cyclolepis* in the middle stream of the Maritsa River was 73.55 cm. High values of L_∞ (68.9 cm) with low values of k (0,0498) was also received for *B. tauricus* (ZIVKOV *et al.* 2003).

There is a linear regression between the average fish weight in the end of the t year (W_t) and the weight one year later (W_{t+1}). The relation is described by the equation $W_{t+1}^{1/3.0588} = 7.3608 + 1.3594 W_t^{1/3.0588}$, $r = 0.989$, $Sd = \pm 5.25$. Based on this, the weight growth of *B. cyclolepis* can be described with Von Bertalanffy's equation for the weight growth: $W_t = 9118 [1 - e^{-0.0362(t+0.2326)}]^{3.0588}$, $r = 0.995$, $Sd = \pm 4.56$. The obtained asymptotic weight for the conditions in the middle stream of the Maritsa River was 9118 g.

The acquisition of unrealistically high values of L_∞/W_∞ and respectively very low values of k is typical for populations with small initial lengths and presence of compensation growth (ZIVKOV 1999). The population of *B. cyclolepis* in the Maritsa River,

in comparison with the other populations of the species, has the lowest length in the first year (Table 4). The presence of compensation growth is illustrated in Fig. 2-5.

The values of the coefficient of HOHENDORF (1966) for the linear and weight growth are very low – 0.03 and 0.2, respectively. These values, much lower than 1, show that the studied population has not used well its growth potential. The low growth rate is also confirmed by the very low values of the coefficient of growth k (0.0394 and 0.0362 for the length and weight growth respectively).

Since data on the growth rate of *B. cyclolepis* are scarce, they were compared with the growth of species of the same genus with similar biology and ecological requirements.

Arranging the 11 populations of *B. cyclolepis* in ascending order of the fish lengths at the same

age we received that the population from the middle stream of the Maritsa River has one of the slowest growth rate. Only the population from the Doirani River, Greece has a lower growth rate (VASILIOU, ECONOMIDIS 2005) (Table 4).

The comparison of Von Bertalanffy's growth parameters k and L_{∞} / W_{∞} (HOCHENDORFF 1966, 1970, ALLEN 1976, MISRA 1980, 1986, MAKARA 1988, CERRATO 1990) between the different populations of the species (Tables 5 and 6) confirms the theory that the faster the growth rate is the smaller the length of the fish is, and the opposite. Given the eight times higher rate of linear growth in the Dzherman River, seven times – in Dospat Reservoir and three times – in the Doirani River, the asymptotic length of *B. cyclolepis* in the Maritsa River was 3.5 times higher than in the Dzherman River and around two times higher than in Dospat Reservoir and the Doirani River.

Table 4. Linear growth (in cm) in *B. cyclolepis* in different water bodies

| Water body and author/ Fish age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--|------------|------------|------------|-------------|-------------|-------------|-------------|-------------|------|
| Doirani River, VASILIOU, ECONOMIDIS (2005) | 5.2 | 7.6 | 9.6 | 11.5 | 13.4 | 15.3 | 17.3 | 18.4 | 19.2 |
| Maritsa River – our data | 4.8 | 6.8 | 8.8 | 10.9 | 13.6 | 15.2 | 17.7 | 22.3 | |
| Dzherman River, DIKOV, ZIVKOV (1985) | 5.4 | 9 | 12.6 | 15.2 | 16.7 | 18 | 18.5 | | |
| Mesta River, PENCZAK <i>et al.</i> (1985) | 5.5 | 8 | 10.7 | 13.8 | 17.8 | | | | |
| Chepinska River, MARINOV (1989) | 11.5 | 13.9 | 14.8 | | | | | | |
| Struma River, MARINOV (1989) | 6.5 | 11.9 | 15.4 | 17.5 | | | | | |
| Arda River, DIKOV, JOCEV (1994) | 6.4 | 10.6 | 14 | 18.2 | | | | | |
| Struma River, BORISOV (1991) | 6.4 | 11.6 | 15.4 | 19.2 | 20.1 | 21.2 | 22.3 | | |
| Strumeshnitsa River, MARINOV (1989) | 6.3 | 9.6 | 15.6 | | | | | | |
| Almi River, MOVCHAN, SMIRNOV (1981) | 6.8 | 12.8 | 15.7 | 18.1 | 21 | | | | |
| Mesta River, MARINOV (1989) | 8.5 | 13.2 | 16.3 | | | | | | |
| Dospat Reservoir, DIKOV, ZIVKOV (1985) | 9.2 | 12.5 | 18.7 | 24.1 | 25.7 | 26.1 | | | |

Table 5. Linear growth of *B. cyclolepis* presented with the parameters: L_{∞} , k , t_0 from Von Bertalanffy's equation and the parameters ω and ϕ'

| Water body and author | L_{∞} , cm | $2\log L_{\infty}$ | k | $\log k$ | t_0 | ω | ϕ' | r | Sd, % | a | b |
|--|----------------------|--------------------|--------|----------|--------|----------|---------|------|-------|--------|-------|
| Maritsa River – our data | 73.55 | 3.73 | 0.0394 | -1.40 | -0.178 | 2.90 | 2.33 | 1 | 5.25 | 2.8382 | 0.961 |
| Doirani River, VASILIOU, ECONOMIDIS (2005) | 35.4 | 3.10 | 0.112 | -0.95 | -0.813 | 3.96 | 2.15 | | | | |
| Dospat Reservoir, ZIVKOV (1999) | 32.7 | 3.03 | 0.2621 | -0.58 | -0.462 | 8.57 | 2.45 | 0.97 | 12.25 | 75.4 | 0.77 |
| Dzherman River, ZIVKOV (1999) | 21.2 | 2.65 | 0.3053 | -0.52 | -0.055 | 6.47 | 2.14 | 1 | 5.17 | 55.7 | 0.74 |

Table 6. Weight growth of *B. cyclolepis* presented with the parameters W_{∞} , k , t_0 from Von Bertalanffy's equation and the parameters ω and ϕ'

| Water body and author | W_{∞} , g | $2\log W_{\infty}$ | k | $\log k$ | t_0 | ω | ϕ' | r | Sd, % | a | b |
|---------------------------------|------------------|--------------------|---------------|--------------|----------------|---------------|-------------|--------------|-------------|------------|-------------|
| Maritsa River – our data | 9118 | 7.92 | 0.0362 | -1.44 | -0.2326 | 330.07 | 6.48 | 0.995 | 4.56 | 0.7 | 0.96 |
| Dospat Reservoir, ZIVKOV (1999) | 392 | 5.19 | 0.307 | -0.51 | -0.182 | 120.34 | 4.67 | 0.993 | 12.44 | 2.35 | 0.74 |
| Dzherman River, ZIVKOV (1999) | 176 | 4.49 | 0.2994 | -0.52 | -0.012 | 52.69 | 3.97 | 0.999 | 5.01 | 1.5 | 0.47 |

The parameters ω and ϕ show contradictory results (Table 5 and 6) and are not appropriate to be used for comparison of the growth rate of *B. cyclolepis*.

Compensation growth

In analyzing the changes in the annual linear and weight increments of generations 2000 and 2001 (Fig. 2-5), it was found that the increments are getting closer in the third year. For the six-year old fish from generation 2000 and five-year old fish from generation 2001 the linear increments are intercross-

ing. That proves that the compensation growth appears in the third year and strengthens with the increase in the fish age. The presence of compensation growth in the population is confirmed by the uneven change of the annual length increments (Table 2).

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