

## Age-size structure and growth rate of *Barbus strumicae* (Cyprinidae) in the Mesta River, Southwest Bulgaria

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### Abstract

The primary objective of this study was to determine the growth parameters of Thracian barbel in the middle zone of the Mesta River within the Aegean basin in Bulgaria. For this purpose, a total of 106 fish were caught and examined. The sample was collected by electrofishing along the Mesta River. Fish age was determined using scalimetry, while length and mass were calculated using scale length-radius and mass-length relationships, respectively. The study identified six age groups, with the majority of the sample comprising two and three-year-old fish. The lengths ranged from 46 mm to 242 mm. Growth analysis was performed by back-calculating the length using the equation  $L = 3.0858 \cdot S + 20.759$  ( $r^2 = 0.955$ ). Furthermore, a relationship between gutted weight ( $W$ ) and standard length ( $L$ ) was established using the equation  $W = 0.00001 \cdot L^{2.9799}$  ( $r^2 = 0.967$ ).

**Key words:** linear growth, size and age composition, Thracian barbel,  $W$ - $L$  relation.

### Introduction

Thracian barbel (*Barbus strumicae* Karman, 1955) is an endemic species of the Balkan Peninsula and of the Aegean watershed (Kottelat and Freyhof 2007). It was separated relatively recently as a different species from *B. cyclolepis* Heckel. The species has been recorded in the basins of the rivers Struma and Mesta, in Bulgaria, Greece and North Macedonia, and also in some rivers of the Chalkidiki Peninsula.

Its presence has also been reported in the basins of Lakes Volvi and Koronia, and the Kerkini Lake in Greece (Kottelat and Freyhof 2007, Barbieri et al. 2015, Sapounidis et al. 2015). The Thracian barbel prefers rivers with gravel and sandy bottoms, but it is also found in the littoral zone of lakes and reservoirs (Barbieri et al. 2015). According to Sapounidis (2015), its breeding period in the Mesta River is mainly in May-June. Males reach sexual maturity in their second year, while females in their

third and fourth year. In the Mesta River, the Thracian barbel reaches a maximum fecundity of 14,280 eggs (Kottelat and Freihof 2007, Sapounidis et al. 2015). The authors established that the main food objects are the larvae of Chironomidae and Ephemeroptera and the adults of Trichoptera and Amphipoda. They have also published data on the growth rate of the species in the Mesta River. Information on the growth parameters of the Thracian barbel in the Dzherman River and the Dospat Dam is given by Dikov and Zivkov (1985). Data on linear growth of this species in the rivers Mesta and Struma were also published by Marinov (1989).

Mesta River is formed by merging of two rivers: Bela Mesta River and Cherna Mesta River. However, Bela Mesta River is considered the main source of the Mesta River. Bela Mesta River originates from an elevation of 2690 m a.s.l., from the Granchar Lake in the west part of the Rhodopes Mountains. Near the village of Statmos (Greece), opposite the island of Thassos, the Mesta River flows into the Aegean Sea. There are 39 fish species in the Mesta River, 13 of which inhabit brackish and salt waters (Economidis et al. 2009). Two large reservoirs were built in the bed of the Mesta River on the territory of Greece – Thisavros and Platanovrysi (Economidis et al. 2009) and one small dam near the village of Toxotes (Sapounidis et al. 2015). These dams divide the Mesta River bed into four distinct parts (Sapounidis et al. 2015). The Dospat Dam was built along the Mesta River, in the bed of the Dospatska River on Bulgarian territory. Dospatska River flows into the Mesta River in Greece outside the Bulgarian part of the Mesta River. Therefore, this dam has an impact on the outflow of the Mesta River in Bulgaria, but not on the river connectivity there.

The purpose of this article is to clarify the current status of the Thracian barbel population in the Mesta River. For this purpose, some of its population parameters were studied and the differences with other populations of the species were analysed.

## Materials and Methods

The material consists of 106 specimens of the Thracian barbel. Fieldwork took place in the autumn of 2021 and 2022. Sampling was via electrofishing by the use of a SAMUS 725G device with a 12V accumulator and 5–65 Amps with an output of 640 W. Studied area extends from the confluence of the rivers Cherna Mesta and Bela Mesta and reaches the vicinity of the village of Mesta. Study sites were located along the length of the area immediately following the trout area (Fig. 1, Table 1).

This section of the Mesta River has a slope ranging from 6 % to 8 %, and its width does not exceed 50 m. Species such as Grayling (*Thymallus thymallus* Linnaeus, 1758), Barbel (*Barbus barbus* Linnaeus, 1758), and Bream (*Abramis brama* Linnaeus, 1758) are not naturally distributed in rivers of the Aegean watershed (Kottelat and Freihof 2007). These

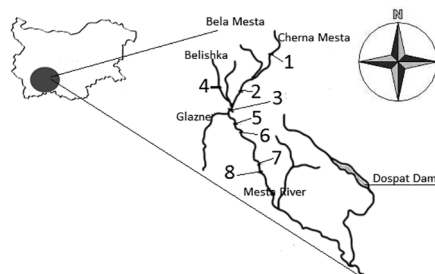


**Fig. 1. Map of Mesta River, where Thracian barbel was collected.**

**Table 1. Mesta River sampling stations in November 2021 and October 2022.**

| No | Location                                                         | Geographic coordinates |             | Altitude,<br>m a.s.l. | Month/<br>Year |
|----|------------------------------------------------------------------|------------------------|-------------|-----------------------|----------------|
|    |                                                                  | Latitude               | Longitude   |                       |                |
| 1  | In the Cherna Mesta River                                        | 42°04'18" N            | 23°43'33" E | 1073                  | XI/2021        |
| 2  | In the vicinity of the town Yakoruda                             | 41°59'51" N            | 23°37'34" E | 847                   | XI/2021        |
| 3  | In the Belitsa River, the Mesta River' tributary                 | 41°55'53" N            | 23°34'20" E | 794                   | XI/2021        |
| 4  | In the vicinity of village Kraishte                              | 41°54'34" N            | 23°34'22" E | 756                   | XI/2021        |
| 5  | Near the confluence of the Glazne River with the Mesta River (a) | 41°53'04" N            | 23°34'16" E | 748                   | XI/2021        |
| 6  | Near the confluence of the Glazne River with the Mesta River (b) | 41°55'56" N            | 23°34'23" E | 763                   | XI/2021        |
| 7  | In the vicinity of village Mesta (a)                             | 41°46'02" N            | 23°40'25" E | 650                   | X/2022         |
| 8  | In the vicinity of village Mesta (b)                             | 41°45'45" N            | 23°40'39" E | 649                   | X/2022         |

rivers are relatively short (Hristova 2012) and have a distinct fish fauna (Stefanov 2007), which does not align with Huet's ichthyological zonation (Huet 1949, Aarts and Nienhuis 2003).

Catch was performed according to the EN 14011:2003 instruction (Water quality, Sampling of fish with electricity – CEN). Upstream electrofishing was used. Species' identification was carried out according to the methodological guidance of Berg (1948, 1949), Drensky (1951), Kotelat and Freyhof (2007).

The linear growth was determined by performing a back-calculation of length data ( $L$ ) based on the diagonal oral radius of a scale ( $S$ ), following the methods described by Lea (1910), Zivkov (1980, 1981), Schneider et al. (2000). For this purpose, total length ( $L$ , mm) and full weight ( $W$ , g) were measured. The age was determined by counting the number of annuli or year marks of scales under an Olympus CX 31 light microscope. The diagonal oral radius of the scales ( $S$ ) was measured using the divisions of an eyepiece micrometer. Weight was recorded with a digital electronic balance, accurate to 0.1 g. The relation can be expressed by the following linear equation (1):

$$L = a + b \cdot S, \quad (1)$$

where:  $L$  – the length of fish, cm;  $S$  – diagonal oral radius of scale (eyepiece micrometre scales divisions);  $a$  and  $b$  – coefficients.

The absolute annual linear increment was accepted as a characteristic of the growth (Zivkov 1972), calculated by formula (2):

$$t = L_n - L_{n-1}, \quad (2)$$

where:  $t$  – absolute annual linear increment, mm;  $L_n$  –  $n$ th year body length;  $L_{n-1}$  – the average length for two consecutive years, mm.

Growth in length was compared using the method proposed by Zhivkov (1999), which ranks populations by mean length ( $L$ ) within each age group. Between two populations, the one with a larger  $L$  value at the age of the younger population is considered to have faster growth.

The determination of weight ( $W$ ) was performed with the weight-length ( $W$ - $L$ ) relationship as described in formula (3) by Le Cren (1951). This method has been discussed by Schneider et al. (2000), Froese (2006), Froese et al. (2011). It has been widely used in various studies (Zivkov 1981, 1999; Prodanov 1982; Raiko-

va-Petrova and Zivkov 1993; Kukushkin 1997; Belomacheva et al. 2005).

$$W = a \cdot L^b, \quad (3)$$

where:  $W$  – body weight, g;  $L$  – standard length, mm;  $a$  and  $b$  – coefficients.

To compare the growth in length between populations, a method employed by Zivkov (1972) was followed in which population are ranged based on length at the same age.

The condition of a population was studied in three ways:

1) by calculating a classical Fulton coefficient ( $K_f$ ) using the equation (4) (Froese 2006).

$$K_f = 100 \cdot W \cdot L^{-3}, \quad (4)$$

where:  $L$  – length, mm;  $W$  – body weight, g.

2) By calculating the factor  $K_b$  using Fulton's equation. In the case, the coefficient  $b$  from equation (3) is used as an exponent.

All data were calculated by using MS-Excel 2010. The Past program is also used for statistical processing.

## Results

### Species composition

In the sampling sites, we found five fish species – Macedonian trout (*Salmo macedonicus* Karaman 1924), Minnow (*Phoxinus phoxinus* Linnaeus 1758), Aegean dace (*Squalius orpheus* Kottelat & Economidis 2006), Thracian barbel (*B. strumicae* Karaman 1955), and Bleak (*Alburnus alburnus* Linnaeus 1758). However, only three specimens of Thracian barbel were caught in the vicinity of the town Yakoruda and the village Kraishte. In the rivers Cherna Mesta and Belishka, we did not detect the presence of fish at all. There was visible sewage and litters water pol-

lution in both tributaries. Ultimately, most of the research material was obtained in the section of the Mesta River, located between the confluence of Glazne River with the Mesta River and the section of the Mesta River near the village of Mesta.

### Age and size composition

The age of specimens ranged from one to six years. In the sample, two and three-year-old fish were the most abundant, comprising 68 % of the overall capture (Fig. 2). One-year-old fish were less numerous than those in the following three age groups. From the second to the sixth year, the number of fish decreased. Five and six-year-old fish were relatively few.

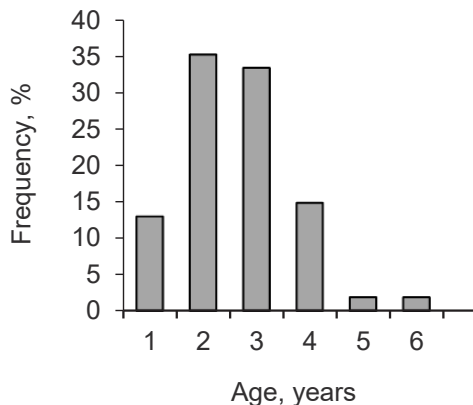


Fig. 2. Age structure of the population.

The largest specimen was a female of 242 mm length and 168.7 g weight. Mean weight was 24.2 g, and the mean length was 122.8 mm. The distribution of fish by size classes closely mirrored that of age groups. One-year-old fish, ranging from 40.1 mm to 80.0 mm in size, were scarce. More fish were found in the 80 mm to 170 mm range, which includes two-, three-, and four-year-olds. The size classes of 170.1–180.0 mm and 180.1–250.0 mm,

which include five- and six-year-old fish, were also less common (Fig. 3).

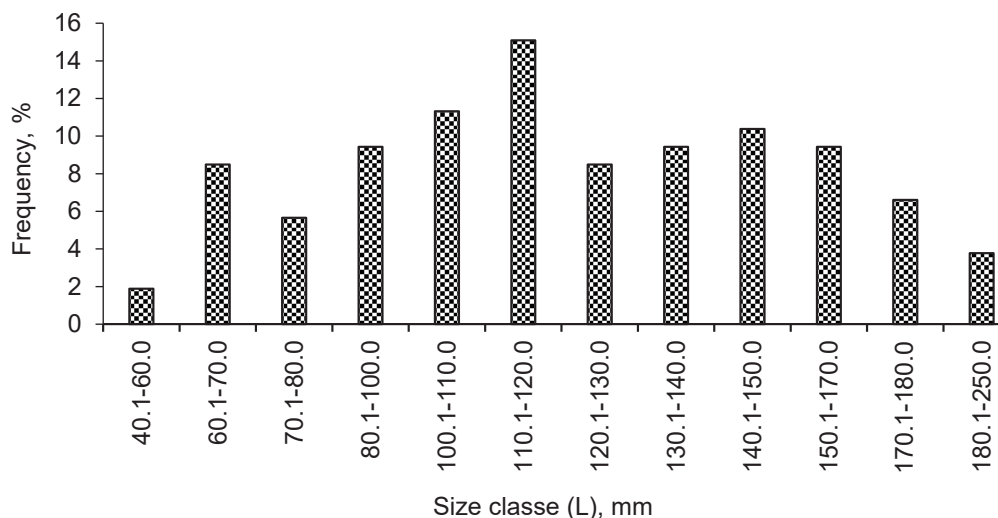


Fig. 3. Size classes of the Thracian barbel.

### Growth in length

The relationship between length ( $L$ ) and scale radius ( $S$ ) was well expressed based on linear function (Fig. 4). This al-

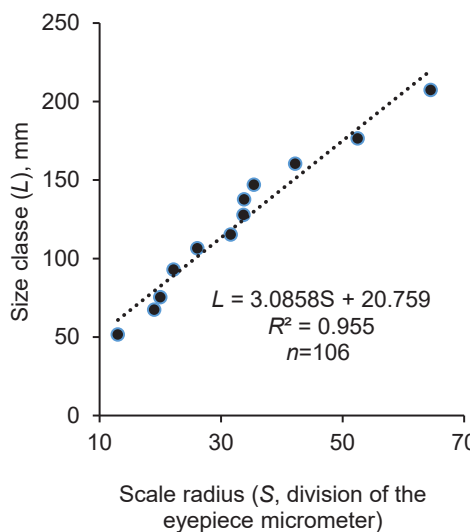


Fig. 4. Growth in length.

lowed a reliable back-calculation of the length along the scale radii.

The average lengths calculated this way at age are presented in Table 2. The study of the individual growth in length shows that in the first year the growth was the most intense. Fish from the other age groups grew by about 22 mm per year (with one exception, four-year-old fish). The measured real sizes of the fish were close to, but smaller than, the theoretically calculated ones (Table 2).

The  $W$ - $L$  relation was very well expressed by power function (Fig. 5). As with other species of the genera *Barbus* (Rozdina 2009, Kolev and Raikova 2015, Kolev 2022), the Thracian barbel shows a regular increase in mass with increasing length.

We compared our data on the growth of the Thracian barbel with those of Marinov (1989) for the rivers Strumeshnitsa, Struma and Mesta (Table 3).

**Table 2. Back-calculated  $L$  of the Thracian barbel in the Mesta River.**

| Age group                | $n$ | Mean calculated $L$ , mm at age 1 to 6 |       |       |       |       |       |
|--------------------------|-----|----------------------------------------|-------|-------|-------|-------|-------|
|                          |     | $L_1$                                  | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ |
| I                        | 2   | 60.9                                   |       |       |       |       |       |
| II                       | 37  | 67.7                                   | 88.0  |       |       |       |       |
| III                      | 46  | 70.1                                   | 99.1  | 124.4 |       |       |       |
| IV                       | 10  | 66.7                                   | 94.5  | 125.7 | 151.0 |       |       |
| V                        | 7   | 63.0                                   | 91.1  | 120.4 | 162.7 | 182.8 |       |
| VI                       | 4   | 63.3                                   | 91.1  | 120.4 | 162.7 | 192.0 | 219.8 |
| Mean calculated $L$ , mm | 106 | 65.3                                   | 92.8  | 122.7 | 158.8 | 187.4 | 219.8 |
| Mean observed $L$ , mm   |     | 51.5                                   | 85.5  | 131.9 | 160.3 | 176.4 | 207.3 |
| Annual increment, mm     |     | 65.3                                   | 26.6  | 28.8  | 36.6  | 24.7  | 27.8  |

**Table 3. Observed mean total length ( $TL$ ) of the same age from some Bulgarian rivers.**

| River        | $n$ | Total body length ( $TL$ ), mm |        |        |        |        |        | Source          |
|--------------|-----|--------------------------------|--------|--------|--------|--------|--------|-----------------|
|              |     | $TL_1$                         | $TL_2$ | $TL_3$ | $TL_4$ | $TL_5$ | $TL_6$ |                 |
| Strumeshnica | 15  | 63                             | 96     | 156    | -      | -      | -      | Marinov (1989)  |
| Struma       | 15  | 65                             | 119    | 154    | 175    | -      | -      | Marinov (1989)  |
| Mesta        | 106 | 52                             | 86     | 132    | 161    | 176    | 207    | Our data (2024) |
| Mesta        | 32  | 71                             | 120    | 127    | -      | -      | -      | Marinov (1989)  |

We also used more recent data. Since these are the calculated standard lengths ( $SL$ ) for comparison we have transformed our data. For the Thracian barbel popula-

tion in the Mesta River  $SL$  was calculated as average 82 % of  $TL$ . Thus,  $TL$  data were recalculated as  $SL$  (Table 4).

**Table 4. Mean calculated  $SL$  of the same age from some rivers.**

| River/Dam  | $n$ | Length ( $L$ ), mm at age 1 to 7 |       |       |       |       |       |       | Source                   |
|------------|-----|----------------------------------|-------|-------|-------|-------|-------|-------|--------------------------|
|            |     | $L_1$                            | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $L_7$ |                          |
| Dospat Dam | 110 | 92                               | 125   | 187   | 241   | 257   | 261   | -     | Dikov and Zivkov (1985)  |
| Dzherman   | 167 | 54                               | 90    | 126   | 152   | 167   | 180   | 185   | Dikov and Zivkov (1985)  |
| Mesta      | 106 | 53.5                             | 76.1  | 100.7 | 130.2 | 153.7 | 180.2 | -     | Our data (2024)          |
| Mesta      | 185 | 55.5                             | 79.7  | 100.9 | 115.8 | -     | -     | -     | Sapounidis et al. (2015) |

### Growth in weight

The weight-length relationship  $W$ - $L$  shown in Figure 5 is clearly defined. The exponent  $b$  was slightly less than 3, but very close to this value, making the difference

negligible.

The back-calculated masses of the Thracian barbel from the  $W$ - $L$  relation are listed in Table 5. The values of the calculated and observed masses were closer in exception of one-year-old fish. In general,

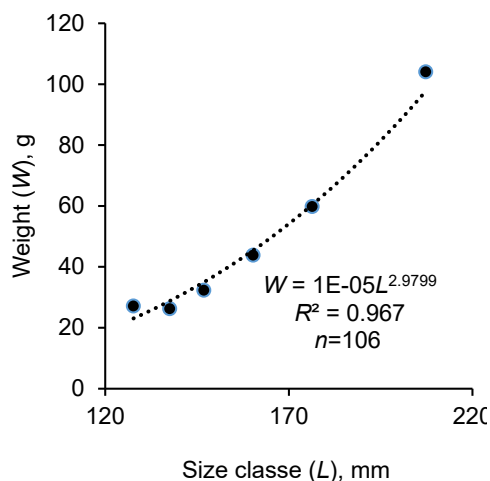


Fig. 5. Length-weight relationship of Thracian barbel in the Mesta River.

mass gain was slow. Annual growth progressively increased with age. Two- and three-year-old fish doubled their mass during the year. From the fourth year onwards, however, the annual increment began to slow down.

### Condition coefficients

The condition was evaluated using the Fulton ( $K_f$ ) and the  $K_b$ , coefficients derived by substituting the exponent  $n$  with  $b$  from equation 7 (as shown in Table 5). Data for Fulton coefficient ( $K_f$ ) was available for fish populations of the Mesta River in the territory of Bulgaria and Greece. The data in Table 6 shows the coefficients  $K_f$  calcu-

Table 5. Back-calculated gutted body  $W$ .

| Age group               | $n$ | Mean calculated $W$ , g at age 1 to 6 |       |       |       |       |       |
|-------------------------|-----|---------------------------------------|-------|-------|-------|-------|-------|
|                         |     | $W_1$                                 | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| I                       | 2   | 2.1                                   |       |       |       |       |       |
| II                      | 37  | 2.9                                   | 6.2   |       |       |       |       |
| III                     | 46  | 3.2                                   | 8.9   | 17.5  |       |       |       |
| IV                      | 10  | 2.7                                   | 7.7   | 18.0  | 31.1  |       |       |
| V                       | 7   | 2.3                                   | 6.9   | 15.9  | 38.9  | 55.0  |       |
| VI                      | 4   | 2.3                                   | 6.9   | 15.9  | 38.9  | 63.7  | 95.3  |
| Mean calculated $W$ , g | 106 | 2.6                                   | 7.3   | 16.8  | 36.3  | 59.3  | 95.3  |
| Mean observed $W$ , g   |     | 1.8                                   | 6.3   | 28.5  | 43.8  | 59.8  | 104.0 |
| Annual increment, g     |     | 2.6                                   | 4.7   | 9.2   | 19.7  | 20.5  | 31.6  |

lated from material obtained in November therefore they were comparable. In our research,  $K_b$  was much lower than  $K_f$ .

Table 6. Condition coefficients of the Thracian barbel.

| Condition coefficients |       | Source                   |
|------------------------|-------|--------------------------|
| $K_f$                  | $K_b$ |                          |
| 1.011                  | 0.730 | Our data (2024)          |
| 0.903                  | -     | Sapounidis et al. (2015) |

Note: Coefficient of Fulton  $K_f$  ( $n = 3$ ) and  $K_b$  ( $n = b$ ), measured in November.

### Discussion

The analytical discussion will now examine the growth patterns and mass accumulation of the Thracian barbel, focusing on the variations observed in the Mesta River in Bulgarian and comparing with data available from Greek territory. This discussion aims to offer a thorough understanding of the growth and mass accumulation patterns of the Thracian barbel across diverse river systems.

First of all, in order to explore the fish

population dynamics, it is important to investigate the potential factors affecting the survival rates and age structure. The low number of one-year-old fish suggests poor survival rates at a young age. Similarly, there is also low number of five- and six-year-old fish (Fig. 2). The scarcity of older fish could be due to both natural mortality and increased fishing activity (Pravdin 1965). However, given that the Thracian barbel is a popular target for sport fishing in this area of the Mesta River, the latter explanation seems more plausible.

The size distribution of the fish reflects these patterns (Fig. 4). The youngest and oldest fish classes have fewer individuals compared to other size classes, likely for the same reasons mentioned earlier. The growth in length is relatively consistent across the years (Table 2), with the highest growth expected in the first year. The rapid growth of one-year-old fish in length may be a strategy to evade predators by reaching a larger size (Nikolsky 1965).

The study utilised directly reported total fish lengths ( $TL$ ) as presented by Marinov (1989). Discrepancies were noted in the lengths measured by the author compared to our findings. It was observed that fish in the Struma River basin exhibit a faster growth in length, likely influenced by the larger size and higher flow rate of the river (more than twice as high). The wider valley of the Struma River, exposed to Mediterranean climatic influences, may also contribute to this growth pattern. However, the limited number of specimens examined by Marinov (1989) may have impacted the accuracy of the data. Variations in fish length measurements were also observed in the Mesta River. For instance, one-year-old barbels with an average length of 50 mm typically weigh around 2–2.5 g, while three-year-old barbel at 100–120 mm length reach about

52 g in weight. It is only when the fish reach a length of 200 mm and are over six years old that they approach a weight of 100 g (tables 3 and 5).

Since only the mean values of  $L$ , by age, are reported in the literature, a statistical comparison between them is not possible. The assessment of the growth of the species in the individual populations was made according to the method proposed by Zivkov (1999). Our research findings show that the growth rate of the Thracian barbel closely aligns with those observed in the Mesta River in Greece (Sapounidis et al. 2015). Noticeably faster linear growth was reported for the species in the Dospat Reservoir (Dikov and Zhivkov 1985). Growth in the dam is especially rapid in the first year, with yearlings reaching the length of two-yearlings in the rivers probably due to the more abundant food there. However, due to the decrease in the speed of the water current, the Thracian barbel decreased in the Dospat reservoir and today it is no longer found there (Stefanov 2007).

Fulton coefficient values obtained from fish in both Bulgarian and Greek territories show similarities. Nonetheless, the coefficient  $K_b$ , which some authors, such as Zivkov (1981, 1999) and Raikova-Petrova and Zivkov (1993), consider more reliable, appears to be relatively low. This observation suggests that the Thracian barbel does not experience significant fattening before the onset of winter.

## Conclusion

The comparative analysis of Thracian barbel populations in the Mesta River basin indicates a relatively slow growth rate for the species. In Dospat Reservoir, the species reaches the highest length-by-year

values reported in the literature.

This slow growth is reflected in the gradual mass accumulation observed within the population. Furthermore, the findings suggest that the condition factor for the Thracian barbel in this region is suboptimal. Notably, the population appears to have limited numbers of large and older specimens. Given that fecundity increases with age and size (Raikova-Petrova 1992, Rozdina 2009, Kolev 2021), it should be expected that the lack of larger fish has a negative impact on the reproductive potential of the species. All of these facts indicate that additional conservation efforts may be needed in the future, such as regulations in fishing for the species in order to maintain the long-term sustainability of its population in the Mesta River.

## Conflict of interest

The authors of this article declare no conflict of interest.

## Data availability statement

The data that support the findings of this study are available on request from the main author.

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