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Assessing the age structure, growth rate and condition of *Squalius cephalus* (Cyprinidae) in the middle and upper streams of the Ogosta River

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Abstract

The aim of this research is to analyse the growth and condition factor of Chub (*Squalius cephalus* L.) from the Ogosta River in north-western Bulgaria. The river belongs to the Danube basin. The study focuses on the Chub population in the middle zone of the Ogosta River, situated above the Ogosta Reservoir. The data was collected in November 2021, with a total of 76 specimens captured using electrofishing techniques. The sample consisted predominantly of three-year-old fish, with the most common size group falling within the size range 11–13 cm. The standard length of the fish ranged from 5.6 cm to 42.6 cm, while the gutted weight varied from 2.2 to 1270.2 g. The estimated length-size (L-S) relationship was determined as $L = 0.1913 \cdot S + 2.701$ ($r^2 = 0.97$), and the weight-length (W-L) relationship was derived as $W = 0.0105 \cdot L^{3.15}$ ($r^2 = 0.99$). The results were evaluated in comparison to 14 local populations of Chub in rivers across Bulgaria. The data indicate a relatively slow growth rate of the species in the Ogosta River. This study is the first of its kind to focus on the Chub population in the middle zone of the Ogosta River following the construction of the Ogosta Dam. It provides valuable insights into the impact of hydropower construction on the Chub population in the area.

Key words: age and size composition, Chub, linear growth, weight growth.

Introduction

The Chub (*Squalius cephalus* Linnaeus, 1758) is widespread in Europe, the Black Sea, the Azov Sea, the Caspian Sea and most of the inland waters in Anatolia (Kottelat and Freyhof 2007, Çiçek et al. 2015, Becer and Sari 2017, Özpiçak et al. 2018). In the West the distribution of the Chub extends to rivers in England (Warren et al. 2022) and France, north of the Pyrenees Mountains (Kottelat and Freyhof 2007). In Northern Europe, it is found in the rivers of southern Sweden, Ireland (Caffrey et al. 2008) and Finland (Kottelat and Freyhof 2007), as well as in the Northern Dvina River (Boznak 2020). To the East, the Chub's range reaches the Ural River. On the Balkan Peninsula, the species inhabits the rivers of the Black Sea and Danube basins (Zhukov 1989, Karapetkova and Zuivkov 1995, Kottelat and Freyhof 2007, Becer et Sari 2017, Tanović et al. 2022) and some rivers of the Adriatic basin (Pavlovski et al. 2020). In Asia Minor, the species reaches the Euphrates River basin (Aydin et al. 2015). The Chub is primarily found in the middle and lower zones of fast-flowing rivers, but it can also inhabit colder lakes and reservoirs. As an omnivorous species, the fish's diet consists of a variety of plants and animal organisms, which can vary depending on the age and season (Zhukov 1989). The breeding period for this species in Bulgaria typically lasts from April to July. During the summer, it tends to linger in rapids and pools, while in colder periods it retreats to deeper parts of the river bed (Michaylova 1970).

The Chub is a highly abundant fish species in water courses throughout Bulgaria (Dikov et al. 1994) and is popular among anglers in the country (Raikova-Petrova et al. 2017). Numerous studies conducted in various locations in Bulgaria have examined the age, growth and length-weight ratio of *Sq. cephalus* (Dikov 1988, Marinov 1989, Dikov et al. 1994, Dikov and Zhivkov 2004, Hamui et al. 2007, Raykova-Petrova et al. 2017). Additionally, foreign authors have also studied the species in different parts of its range (Aydin et al. 2015, Becer and Sari 2017, Benzer and Gül 2017, Özpiçak et al. 2018, Özcan and Serdar 2019, Tanović et al. 2022, Warren et al. 2022). This study aims to investigate the growth biology of *Sq. cephalus* in the upper and middle courses of the Ogosta River, which are important habitats for this species. The study specifically focuses on analysing the age and length composition, as well as the length-weight relationship of the Chub population.

Study Area

The Ogosta River, depicted in Figure 1, is the largest watercourse in the Northwestern region of Bulgaria, as shown in Figure 2. With a length of 144.1km, it ranks 7th among the Bulgarian 'largest' rivers (Hristova 2012). Originating below the Vrazha Glava peak (1935 m a.s.l.) in the Balkan Range, the Ogosta River collects

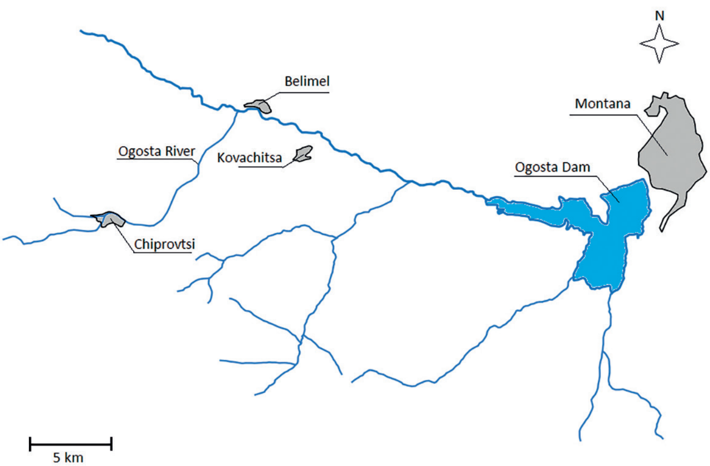

Fig. 1. Schematic map of Ogosta River's middle zone.

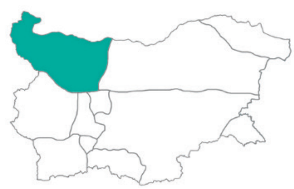

Fig. 2. Location of the studied region of Bulgaria.

waters from numerous tributaries before merging with the Danube River near the town of Oryahovo. The construction of the Ogosta Dam in 1986, near the town of Montana, divided the river into two parts. For the purpose of this study, the middle zone of the river, situated above the dam, was selected (see Table 1).

The ecological characteristics of the studied river section were determined as follows: the river meandered through a hilly area, resulting in noticeable fluctuations in the depth of its flow, which were carefully observed and documented. The riverbed consisted of a mix of larger and smaller stones, along with gravel. The terrain was sloping, facilitating a swift water current. The banks were densely covered with black alder and white willow, their branches extending over the riverbed. The tree roots provided hiding spots for fish seeking refuge from the strong current, with hidden holes between the roots serving as shelters. The studied segment of the riverbed was situated at an elevation ranging from 190 to 380 m a.s.l. The research was conducted in the autumn season, during which the measured daily water temperature ranged from 8 to 12 °C, while the recorded levels of dissolved oxygen varied between 4.8 and 7.6 mg·m^{-3}.

Materials and Methods

The study utilized a sample of 76 Chub individuals. Sampling was conducted at five designated areas within the middle zone of the Ogosta River (refer to Table 1). The collection of sampling material occurred during the autumn of 2021, employing the technique of electrofishing. For this purpose, a SAMUS 725G converter was employed, capable of delivering up to 640 V direct current (DC), with a frequency of 50 Hz and an output power of up to 200 W. The capture procedure adhered to the guidelines outlined in the EN 14011:2004 instruction for sampling fish using electricity to ensure water quality. The majority of the data was collected in the vicinity of Gorna Kovachitsa and Belimel villages. The largest female specimens were captured in the lower part of the studied section, near the confluence of the Ogosta River with the dam of the same name.

Measurements were taken of the standard length (*SL*) and total length (*TL*) with an accuracy of 1 mm, as well as the gutted weight (*W*) with an accuracy of 1 g. Fish age was determined through the examination of fish scales, utilizing an Olympus CX 31 microscope set at a magnification of 40×.

Table 1. Sampling sites at the Ogosta River: distribution and location.

No	Location	Geographic coordinates		Altitude, m a.s.l.	Date of sampling
		N	E		
1	Near the confluence of the Ogosta River and the Ogosta Dam	43°23'49"	23°03'58"	195	17.11.2021
2	Near the strawberry farm	43°24'20"	23°03'16"	221	17.11.2021
3	Near the village of Gorna Kovachitsa	43°25'20"	23°00'40"	250	17.11.2020
4	Near the village of Belimel	43°25'33"	22°57'30"	305	18.11.2020
5	Near the town of Chiprovtsi	43°23'42"	22°55'26"	380	18.11.2020

The linear growth of a fish was determined by performing a back-calculation of its length (L) based on the diagonal oral radius of a scale (S), as described by Ricker (1979). This relation can be expressed by the following linear equation (1):

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

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

Absolute annual linear incensement was accepted as a characteristic of the growth (Zhivkov 1972), calculated by formula (2):

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

where: t – absolute annual linear incensement, mm; L_n; L_{n-1} – the average standard length of fish for two consecutive years, cm.

The estimation of weight (W) values, excluding entrails, was conducted using the W-L relation. The formula (3), proposed by Ricker (1979), has been extensively employed by various authors (Zhivkov 1981, 1999; Prodanov 1982; Raikova-Petrova and Zhivkov 1993; Kukushkin 1997; Belomacheva et al. 2005).

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

where: W – gutted body weight, g; L – standard length of fish, cm; a and b – equation coefficients.

To compare the length growth of different Chub populations, a method employed by Zhivkov (1972) involves ranking them based on their average length at the same age.

Condition of a population is studied in three ways:

1) By calculating a classical coefficient (K_f) of the Fulton equation (4).

$$K_f = (W \cdot L^{-3}) \cdot 10^2, \quad (4)$$

where: L – weighted average standard body length, cm; W – weighted average gutted body weight, g.

2) By calculating a coefficient K_b, using the Fulton equation, but instead of exponent 3, exponent b from the population weight-length relationship from equation (3) is used.

3) By comparison of weight growth (W) of fish from different populations, a method proposed by many authors (Goldspink 1979; Zhivkov 1981, 1999; Basami and Grove 1985; De Silva 1985; Raikova-Petrova 1992). A relation is expressed by the equation (5).

$$W_L = a \cdot L^b, \text{ g}, \quad (5)$$

where: L – standard length of fish, cm; W – gutted weight of fish, g; a and b – equation coefficients.

In order to obtain comparable values of W in equation (3), pre-selected rounded values of L (10, 20, 30 and 40 cm) are substituted in place of L (L = 10, L = 20, L = 30, L = 40). Using equation (5) with the listed values of L (cm), allows obtaining the corresponding values of mass W: $W_{L=10}$, $W_{L=20}$, $W_{L=30}$, $W_{L=40}$. The so-obtained mass values for each of the studied populations are then compared (Zhivkov 1981, 1999; Raikova-Petrova and Zhivkov 1993). The association degree between L and S, as well as between W and L variables, was determined by a correlation coefficient (r^2). All data were calculated by using MS-Excel 2010.

Results and Discussion

Age and size composition

In the Ogosta River, the Chub population encompasses individuals ranging from one to five years of age, as depicted in Figure 3. As zero and one-year-old fish are less susceptible to electrofishing, they

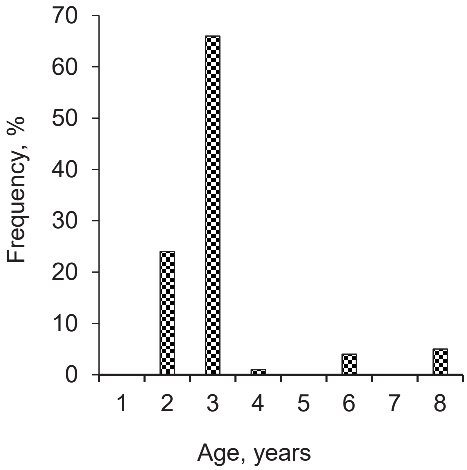

Fig. 3. Age structure of Chub from the Ogosta River.

were not included in the sample. The most abundant individuals among those captured were the three-year-old Chubs, accounting for over half of the catch at 63 %. The second most numerous age group comprised two-year-old fish (24 %). Notably, no five and seven-year-old fish were recorded during the sampling. Six and eight-year-old fish were captured in the winter quarters near the confluence of the Ogosta River and the reservoir bearing the same name. During the warm period of the year, it is likely that older fish take advantage of the abundant food resources in the dam. However, in spring and autumn, when they are searching for more suitable breeding and wintering locations, these fish migrate into the river.

Among the Chub specimens collected from the Ogosta River, the largest individual was an eight-year-old fish measuring 42.6 cm in standard length (*TL* 49.6 cm) and weighing 1270.2 g (with a total weight of 1433.4 g). The mean length of the sample was 13.6 ±7.9 cm, and the mean weight was 104.9 ±263.1 g. The size group ranging from 11.1 to 13.0 cm was the most abundant. Notably, there were relatively few specimens longer than 18 cm (refer to Fig. 4). Since the specimen were collected in late autumn, electrofishing was conducted at the wintering sites. The largest specimens were females that wintered in the pits near the river's confluence with Ogosta Reservoir. Males, as well as young fish, winter in the deeper places further upstream.

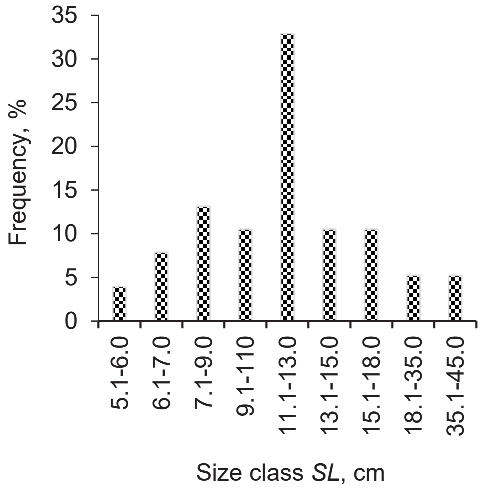

Fig. 4. Size classes of Chub of the Ogosta River.

The stable conditions in the Ogosta Reservoir, along with the abundant food resources and protection from predators like otters and cormorants, create favourable conditions for the Chub to attain older ages and larger sizes. Notably, the age and size of the *Sq. cephalus* specimens from the Ogosta River surpass all previously reported data in the country (Table 2).

Growth rate

The relation between the fish length and the scale radius is represented with the equation (6).

$$SL = 0.19137 \cdot S + 2.701,\ r^2 = 0.97,\ n = 76, \tag{6}$$

The growth rate in length is comparatively sluggish during the early stages of development and picks up pace in four, five, and six-year-old Chubs (see Table 3). As the fish age, the yearly growth gradually diminishes and reaches its lowest point in eight-year-old individuals.

By comparing the length (*SL*) of Chub fish of the same age from various rivers that are experiencing a decline (see Table 4), it is evident that the Iskar River, originating from the Danube watershed, and the Veleka River, originating from the Black Sea watershed, exhibit the fastest growth rates. Conversely, the linear growth of Chub in the Ogosta River is among the slowest in Bulgaria. This can be attributed to the highly disturbed outflow of the Ogosta River, primarily caused by the Ogosta Dam near the city of Montana. The dam divides the river into two distinct sections with contrasting beds and water flow. Upstream of the dam, the river is characterized by shallow depths, swift currents, and a bottom covered with stones, gravel, and sand. Downstream of the dam, the river has a higher water volume, a more even and calm current, and greater depth. The bottom is sandy and adorned with aquatic vegetation. Unfortunately, the dam lacks a fish passage, rendering bottom-up fish migration impossible.

As a result, fish move upstream from the dam to spawn, while younger age

Table 2. Age and maximum size of the Chub from the rivers of Bulgaria.

River	Author	Age, years	Length (*L*), cm	Weight (*W*), g
Sredetska	Dikov et al. 1994	3	16.2	77
Fakiyska	Dikov et al. 1994	4	18.0	111
Palakaria	Dikov et al. 1994	6	18.6	114
Vit	Dikov et al. 1994	6	20.4	153
Vit	Dikov 1988	7	29.0	425
Lesnovska	Raikova-Petrova et al. 2017	5	29.5	476
Veleka	Zhivkov et al. 2003	5+	39.0	800
Iskar	Hamui et al. 2007	7+	38.8	1150
Ogosta	Our data 2021	8	42.6	1272

Table 3. Back-calculated standard body length (*SL*) of Chub from the Ogosta River.

Age group	*n*	Mean calculated *SL*, cm at age							
		L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8
II	19	4.6	7.5						
III	49	4.6	7.5	11.9					
IV	1	4.0	6.0	10.6	18.0				
VI	3	4.0	5.2	9.0	15.9	24.9	31.8		
VIII	4	4.2	6.2	11.7	18.8	25.5	32.2	35.6	37.5
Mean calculated *SL*, cm	76	4.3	6.4	10.8	17.6	25.2	32.0	35.6	37.5
Mean observed *SL*, cm		nd	7.1	12.7	20.1	nd	31.0	nd	39.6
Annual increment t_L, cm		4.3	2.1	4.6	7.1	7.8	6.8	3.4	1.9

Note: nd – missing data.

Table 4. Comparison of mean observed length (*SL*) of Chub at the same age.

River	Source	Total body length (*SL*), cm							
		L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8
Kamchia#	Marinov 1989	4.2	7.5	10.4	14.0	-	-	-	-
Dunav#	Marinov 1989	3.7	8.1	10.6	-	-	-	-	-
Ogosta*	Our data 2021	4.3	6.4	10.8	17.6	25.2	32.0	35.6	37.5
Palakaria*	Jocev and Dikov 1991	4.2	8.4	12.7	14.5	17.4	18.6	-	-
Vit*	Dikov 1988	4.4	8.9	12.7	15.0	17.9	20.4	-	-
Veleka*	Dikov et al. 1994	5.0	11.0	15.5	19.5	22.3	-	-	-
Lesnovska*	Raikova-Petrova et al. 2017	7.0	11.2	16.0	20.0	23.5	-	-	-
Dryanovska#	Marinov 1989	4.7	8.5	12.9	20.5	28.5	-	-	-
Rositsa#	Marinov 1989	3.8	8.9	15.7	-	25.7	-	-	-
Lom#	Marinov 1989	5.8	9.0	-	-	-	-	-	-
Fakiyska*	Dikov et al. 1994	5.1	10.4	15.4	18.0	-	-	-	-
Skutt#	Marinov 1989	6.0	10.5	14.2	18.3	-	-	-	-
Veleka*	Dikov and Zhivkov 2004	5.8	11.4	15.7	2.3	30.1	-	-	-
Osam#	Marinov 1989	6.2	12.8	-	-	-	-	-	-
Sredetska*	Dikov et al. 1994	6.4	13.0	16.2	-	-	-	-	-
Iskar*	Hamui et al. 2007	6.8	13.6	19.9	25.8	29.6	33.9	35.8	-

Note: * – calculated length; # – observed length.

groups remain and develop in this area. Additionally, the hydroelectric plant near the town of Chiprovtsi (refer to Fig. 1) significantly influences the water levels in the river stretch between Chiprovtsi and Montana. The absence of migration routes, fluctuating water flow, colder temperatures, and faster water in this region further impact the growth of Chub.

Mass was calculated using the well-defined and nearly functional relation (7) between body length and weight (*W*-*L*), which is characteristic of the Chub.

$$W = 0.0105 \cdot SL^{3.15},\ r^2 = 0.99,\ n = 76. \quad (7)$$

Chub's weight gain exhibits a distinct pattern, characterized by a significant increase until the sixth year. Although the annual increment decreases in seven- and eight-year-old fish, it remains relatively high, as shown in Table 5. However,

Table 5. Back-calculated gutted body weight (*W*) of Chub from the Ogosta River.

Age group	*n*	Mean calculated *W*, g at age							
		W1	*W2*	*W3*	*W4*	*W5*	*W6*	*W7*	*W8*
II	19	1.3	6.0						
III	49	1.3	6.0	25.8					
IV	1	0.8	3.0	17.9	95.0				
VI	3	0.9	1.9	10.7	64.3	264.2	571.1		
VIII	4	1.0	3.3	24.4	108.9	284.8	594.0	815.1	960.2
Mean calculated *W*, g	76	1.1	4.0	19.7	89.4	274.5	582.6	815.1	960.2
Mean observed *W*, g		nd	5.0	34.0	177.0	nd	533.0	nd	1113.0
Annual increment, g		1.0	3.0	17.2	71.7	187.9	308.1	221.1	145.1

Note: nd – missing data.

it is important to note that one-year-old fish have a significantly lower calculated mass. This indicates that the conditions for their development in the middle zone of the Ogosta River are not particularly favourable. Additionally, due to their small size, young fish are more susceptible to heavy losses during winter.

Condition factor

The condition of the fish was assessed by calculating the condition factor (K_b) (Table 6) from the rivers Ogosta, Lesnovska and Iskar, as well as comparing fish of the same length (10, 20, 30 and 40 cm) from different water bodies (refer to Table 7). The condition factor (K_b) indicate that growth conditions for Chub are significantly better in the Iskar River.

Although the mass of older fish from the Ogosta River approaches that of the Iskar River, the condition factor (K_b), which represents the entire population, is nearly four times higher in the Iskar River. This suggests that adult Chub in the Ogosta River benefit from the more abundant food resources in the Ogosta Reservoir. However, juvenile Chub in the middle zone of the river develop under less favourable conditions.

Despite using *TL* and *TW* measurements, the data reveals that Chub in water bodies located in Eastern and Black

Table 6. Condition coefficients.

River	Source	Condition coefficients	
		K_f	K_b
Ogosta	Our data 2021	1.67	1.14
Lesnovska	Raikova-Petrova et al. 2017	2.98	2.71
Iskar	Hamui et al. 2007	3.39	4.08

Note: Coefficient of Fulton K_f (n = 3) and K_b (n = b).

Table 7. Weight calculated using Length-Weight relationship at the same length.

Water body	Source	Equation of the total population	Average weights (W_L, g) calculated at the same rounded lengths (L, cm)			
			W_{10}	W_{20}	W_{30}	W_{40}
Terme River	Özpiçak et al. 2018	$TW = 0.005 \cdot TL^{3.29}$	9.9	97.7	372.0	960.6
Karasu River	Özcan and Serdar 2019	$TW = 0.006 \cdot TL^{3.27}$	11.2	107.8	405.8	1039.7
Yedikir Dam	Özpiçak et al. 2018	$\mathrm{TW} = 0.007 \cdot TL^{3.21}$	11.4	105.1	386.1	972.1
Akçai River	Özpiçak et al. 2018	$TW = 0.006 \cdot TL^{3.28}$	11.6	112.7	427.1	1098.8
Adbal River	Özpiçak et al. 2018	$TW = 0.007 \cdot TL^{3.22}$	11.7	109.6	404.9	1023.6
Ogosta River	Our data 2021	$GW = 0.0105 \cdot SL^{3.15}$	15.0	133.4	478.9	1185.8
Lesnovska River	Raikova-Petrova et al. 2017	$GW = 0.015SL^{3.03}$	16.3	133.7	457.7	1096.3
Keban Dam	Aydin et al. 2015	$TW = 0.0084 \cdot TL^{3.14}$	16.7	164.1	624.9	1613.9
Iskar River	Hamui et al. 2007	$GW = 0.024 \cdot SL^{2.94}$	20.9	160.4	528.4	1231.0

Note: W_L – weight of the fish, rounded values of length (10 to 40 cm), *TW* – weight with entrails, *GW* – gutted body weight, *TL* – total length, *SL* – standard length.

Sea Anatolia exhibit lower mass (Table 7). These observed differences can be attributed to the significant variations in climatic conditions between the compared areas. Interestingly, the data for *Sq. cephalus* from Keban Reservoir, situated on the Euphrates River in Southeastern Anatolia, align closely with our results, and in some cases, even exceed them. This finding suggests that, in addition to the warm climate and extended growing season, the dam provides a plentiful food supply. The growth in mass is particularly faster in larger Chubs, as they consume smaller fish within the dam.

Conclusions

Chub in the Ogosta River exhibits slower growth in length compared to those in the Danube River and its Bulgarian tributaries. Furthermore, the overall condition of the species in the Ogosta River is relatively poor. The development of hydro technical infrastructure in the area is likely to have a detrimental effect on the Chub population in the Ogosta River. However, it is worth noting that the Ogosta Dam offers favourable conditions for the feeding and survival of the older age groups of this species.

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Author's statement

The present study was conducted in compliance with national legislation. Electrofishing was performed under a permit issued by the Minister of the Ministry of Agriculture and Food of Bulgaria.

Conflict of interest

The author declares no conflict of interest.

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