

LENGTH–WEIGHT RELATIONSHIP OF SIX CYPRINID FISH IN THE RIVER VARDAR (REPUBLIC OF MACEDONIA)

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Summary

This paper considers the length–weight relationship of six out of eight most commonly found fish species inhabiting the Vardar River biotope, the largest riverine system in the central part of the Balkan Peninsula: *Alburnoides bipunctatus* (Bloch, 1782); *Alburnus alburnus* (Linnaeus, 1758), *Barbus macedonicus* Karaman, 1928; *Barbus peloponnesius* Valenciennes, 1842; *Chondrostoma vardarense* Karaman, 1928 and *Leuciscus cephalus* (Linnaeus, 1758), two of which are endemic. Satisfactory results for all the length groups have been determined only for *B. peloponnesius* whereas for the other fish species exceptions were noted for some of the length classes. The rationale behind this can be sought in two reasons: insufficient number of individuals in a concrete length class or sexual maturation causing the prespawning or postspawning influence on the change of the weight of the fish.

Key words: *Length–weight relationship, River Vardar, Alburnoides, Alburnus, Barbus, Chondrostoma, Leuciscus.*

INTRODUCTION

The River Vardar is the largest flowing biotope in the central part of the Balkan Peninsula. This is a fast water potamon with relative big inclination and correspondingly fast water cross. The geographical and ichthyofaunal features of the Vardar River ecosystem are given by Grupče and Dimovski (1973) and Georgiev (2000 a).

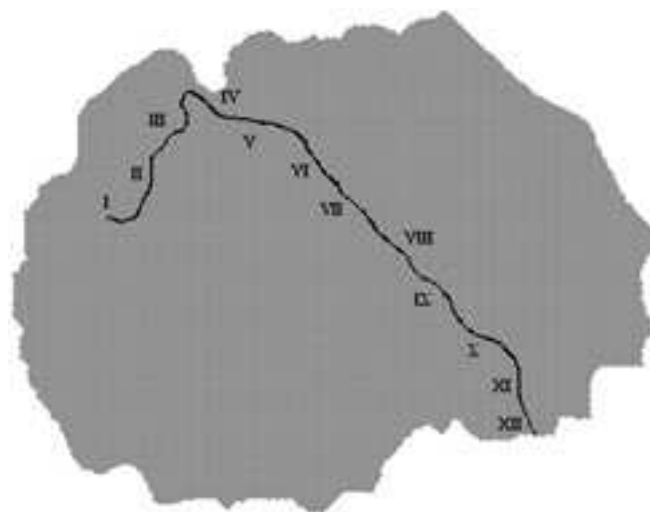
The six species studied in this paper are among the eight most common in the ecosystem along the cross down the state territory, or a total of 300 km. The length–weight relationship of the fish in the flow of the River Vardar has already been subject of study of several published papers: Georgiev

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(1978, 2000); Georgiev and Naumovski (1982); Georgiev *et al.* (1998); Petrovski and Sidorovski (1981); Šorić (2000). The following papers have been published for the other drainages where the waters of the Republic of Macedonia belong: Petrovski and Sidorovski (1971); Sidorovski (1971); Sidorovski and Petrovski (1974); Točko (1975, 1985). All the above-cited authors study this relationship as an issue which is part of complex investigations of the taxonomy or the biology of an investigated species. However, there are no papers which consider only this part of the features of the fish for the Vardar River flow or for the Republic of Macedonia; for the wider territory of the Balkan Peninsula such works are those of: Živkov (1974); Popović and Habeković (1980); Cakić (1982); Doulas and Kattulas (1984); Janković (1984); Popović *et al.* (1984); Dikov and Živkov (1985); Šorić and Ilić (1985); Šorić and Janković (1989); Janković *et al.* (1994); Mikavica *et al.* (1997); Simonović and Simonović (1997); Treer *et al.* (1999, 2000).

MATERIAL AND METHODS

The fish specimens for this work have been collected in the course of three years, from 1996–1999, for 11 profiles every month, at equal distance one from the other (Fig. 1). The fish were caught with nets or hooks. Some of the samples were delivered by the anglers. After being caught the fish were



I Vrutok II Volkovija III Siričino IV Raduša V Skopje VI Taor 1
VII Taor 2 VIII Nogaevci IX Pepelište X Klisura XI Miravci XII Gevgelija

Figure 1. Flow of the River Vardar and sampling sites

Slika 1. Slijev rijeke Vardara i postaje uzorkovanja

conserved in 4 % solution of phormaldehyde and weighted in the laboratory as follows: the specimen bellow 10 g were weighted with ± 0.01 g precision, the specimens from 10 to 100 g were weighted with ± 0.05 g precision, the specimen from 100 to 1000 g were weighted with ± 0.5 g precision and the specimen above 1000 g were weighted with a precision of ± 1 g. The length–weight relationship was studied according the logarithmic equation $W=a*L^b$, (Weatherly, 1972): $\log W=a+b*\log L$. A total of 1068 samples were used, among which two species were endemic: 204 of *B. macedonicus*; 222 of *Ch. vardarensis*; 156 of *B. peloponnesius*; 106 of *A. alburnus*; 229 of *L. cephalus* and 151 of *A. bipunctatus*. Due to the disproportionate participation of the different length classes and profiles in the course of the year, the results are not presented according the seasons of the year. By using the received equations for the l–w relationship the »Bank's start« was calculated (which is the length when the fish reaches the weight of 1 g), cited Bank (1940) in Dikov and Živkov (1985).

NOMENCLATURAL PRINCIPLES USED

The taxonomy of the fish inhabiting the central part of Balkan Peninsula has not been completely resolved yet; some scientists find the situation chaotic (Kottelat, 1997). The determination of the fish mentioned in the paper was according the key Vuković and Ivanović (1971). New names have been used for some fish species which are mentioned in the paper, according Kottelat (1997): *B. macedonicus* for the former *Barbus barbatus* (Linnaeus, 1758), *Ch. vardarensis* for the former *Chondrostoma nasus* (Linnaeus, 1758), *Chalcalburnus belvica* (Karaman, 1924) for the former *Alburnus alburnus* (Linnaeus, 1758) cited in the references.

RESULTS AND DISCUSSION

B. macedonicus

The results for the l–w relationship for this endemic species are shown on Table 1 A and Figure 2 A. As it can be seen, there are three cases when the difference between the real and calculated data exceeds 10 % which indicates the presence of a certain condition of the population for the length classes 12.1–14.0; 26.1–28.0 and 30.1–32.0. The rational behind this situation might be the physiological state caused by the prespawning (for the length classes 12.1–14.0 and 26.1–28.0) or postspawning period (for the length class 30.1–32.0). For the last two cases, the reason might also be sought in the small number of variants (3 and 2). Since these are the first results for this endemic fish species, there is no data available for comparison. Nevertheless, this fish was primarily described as *Barbus barbatus* (Linnaeus, 1758) by Karaman (1924); there is no doubt that *B. macedonicus* has evolved from *B. barbatus*, and there is data for the later, initial species, for both the Black Sea watershed and the main stream of Danube River, Janković *et al.* (1994); Šorić (1999),

and its second rank confluent Drina, Mikavica *et al.* (1997). Janković *et al.* (1994); Mikavica *et al.* (1997), do not verify the equations but only quote them, as well as their graphical representations. The Bank's start for *B. macedonicus* was stated to be 36 mm and consequently when compared to the fish that belong to the same genus which have been previously studied, it can be deducted that this species reaches the weight of 1 g sooner.

Table 1. Data on the measured and computed values for the *l-w* relation of *B. macedonicus* and *B. peloponnesius*

Tablica 1. Podaci o izvaganim i izračunanim vrijednostima alometrijskog suodnosa kod *B. macedonicus* i *B. peloponnesius*

Length Class Dužina		\underline{L} x	\underline{W} x	Counted w Izračunata w	Difference among the real and counted w Razlika između stvarne i izračunane w	
cm	n	cm	g	g	g	%
A	<i>B. macedonicus</i>			log w=2.904715*log l -10.3966		
4.1–6.0	2	4.45	1.74	1.87	-0.13	-6.90
6.1–8.0	4	7.12	7.89	7.36	+0.53	+7.23
8.1–10.0	12	9.45	16.00	16.71	-0.71	-4.23
10.1–12.0	29	11.28	27.07	27.94	-0.87	-3.11
12.1–14.0	33	12.33	41.61	36.18	+5.43	+15.00
14.1–16.0	24	15.20	71.58	66.44	+5.14	+7.74
16.1–18.0	29	17.06	91.93	92.91	-0.98	-1.06
18.1–20.0	28	18.90	119.61	125.11	-5.50	-4.40
20.1–22.0	16	21.08	172.19	171.79	+0.40	+0.23
22.1–24.0	7	23.16	205.00	225.79	-20.79	-9.21
24.1–26.0	9	24.74	292.44	273.50	+18.94	+6.93
26.1–28.0	3	27.33	314.00	365.22	-51.22	-14.02
28.1–30.0	6	29.27	430.33	445.73	-15.40	-3.45
30.1–32.0	2	31.25	614.50	539.07	+75.43	+13.99
B	<i>B. peloponnesius</i>			log w=2.9082*log l -3.739		
3.1–4.0	3	3.53	0.92	0.93	+0.02	+1.90
4.1–5.0	4	4.42	1.78	1.80	+0.02	+0.97
5.1–6.0	4	5.55	3.53	3.17	-0.06	-1.75
6.1–7.0	7	6.77	6.02	6.19	+0.17	+2.91
7.1–8.0	13	7.73	9.44	9.10	-0.33	-3.54
8.1–9.0	24	8.69	13.44	12.78	-0.65	-4.87
9.1–10.0	41	9.66	15.59	17.38	-0.20	-1.16
10.1–11.0	25	10.43	21.63	21.77	+0.13	+0.63
11.1–12.0	32	11.52	28.61	29.04	+0.43	+1.49
12.1–13.0	3	12.10	32.15	33.51	+1.36	+4.23

B. peloponnesius

The results of l–w relationship investigation for the stream barbel are shown at Table 1 B and Figure 2 B. All the values for absolute and relative difference between the real and the calculated weight are less than 10 %, so the equation can be considered acceptable. The Bank's start has been calculated to be 37 mm. Šorić and Janković (1989), studying the l–w relationship for the populations from Beli Drim (Adriatic Sea watershed) and Gruža River (Black Sea watershed), have stated the following values for the Bank's start: 4.1 cm for Beli Drim and 4.3 cm for Gruža River. This data is different from the value received for the population inhabiting the Vardar River. In fact, these authors do not check the accurateness of the equation between the measured and calculated values for the length classes; they just use it in order to calculate the theoretical weight of the fish at the end of the every age class. In other words, they use the equation to determine the weight increase in any successive year of life.

Ch. vardarensis

The data on the l–w relationship for the second endemic fish species which was subject to research from the biotope of the River Vardar is presented on Table 2 A and Figure 2 C. By checking the accuracy of the equation, it can be seen that for three length classes (12.1–13.0; 24.1–25.0 and 29.1–30.0) the differences between the real and calculated weights almost never exceed 10 percent. Having in mind that the material that was on disposition was quite satisfactory for each length group, it is considered that the differences are due to the sexual maturation. The Bank's start is stated to be 39 mm. Since there is no literature containing data on this endemic fish species, we have compared our results with the ones of the other species from the genus *Chondrostoma*, *Chondrostoma nasus* (Linnaeus, 1758) from the Black Sea watershed, Mikavica *et al.* (1997), which is without suspect the mother-species, because the population of *Ch. vardarensis* has been first described as *Ch. nasus*, Karaman (1924), and another endemic species from the Adriatic Sea watershed *Ch. prespense*, from the Prespa Lake limnetic biotope (Sidorovski and Petrovski, 1974), which is a sister-species. These authors have determined almost the same value of 38 mm for Bank's start and almost the same equation. Regrettably, they did not check the accuracy of the equation; they only provided the diagram created on the basis of the equation and use it to calculate the theoretical weight at a certain age, as well as the absolute and relative increase. Mikavica *et al.* (1997) do not check the accuracy of the attained equation; they only show the diagram of the created theoretical l–w relationship and discover that the tendencies of the weight growth curve is more expressed for the older species.

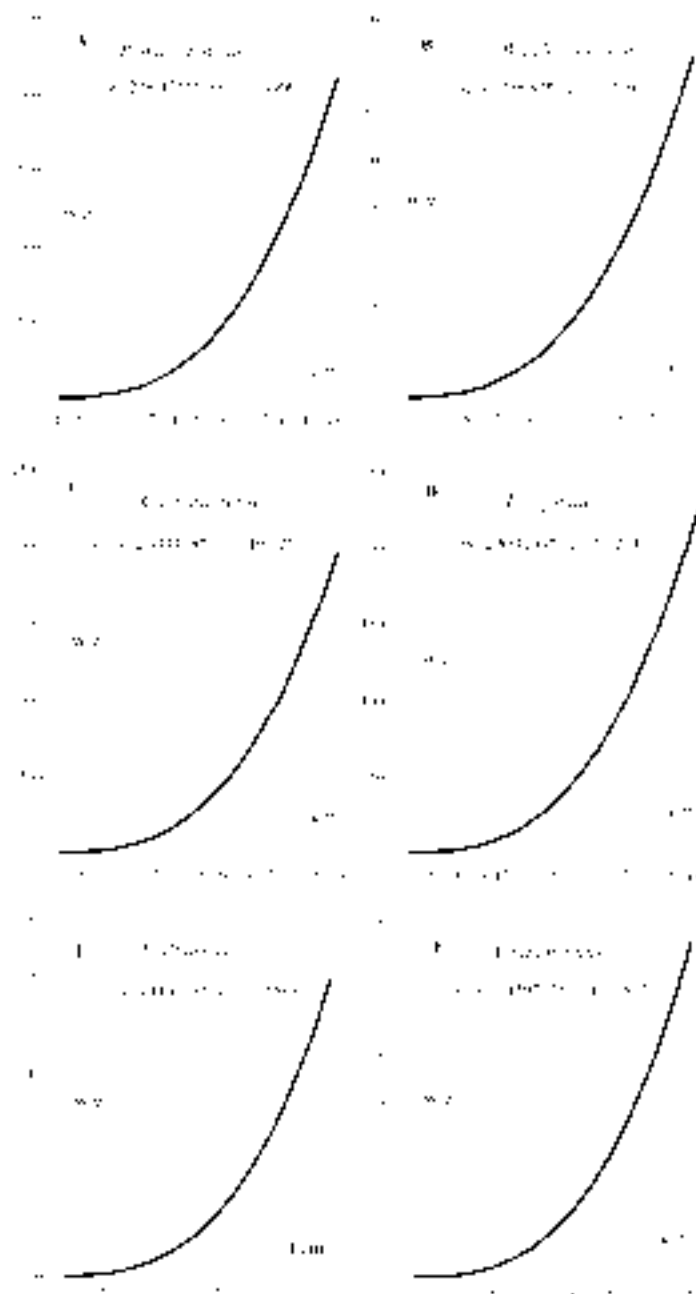


Figure 2. Graphical presentation of l - w relationship for six cyprinid fishes from the Vardar River

Slika 2. Grafički prikaz alometrijskog suodnosa kod šest ciprinidnih riba iz rijeke Vardara

Table 2. Data on the measured and computed values for the *l*–*w* relation of *Ch. vardarensis* and *L. cephalus*Tablica 2. Podaci o izvaganim i izračunanim vrijednostima alometrijskog suodnosa kod *Ch. vardarensis* i *L. cephalus*

Length Class Dužina		\underline{L} x	\underline{W} x	Counted w Izračunata w	Difference among the real and counted w Razlika između stvarne i izračunane w	
cm	n	cm	g	g	g	%
A	<i>Ch. vardarensis</i>				log w = 2.944108 * log l - 10.7213	
7.1–8.0	1	8.00	8.2	8.84	+0.64	+7.29
9.1–10.0	5	9.78	15.69	15.99	+0.29	+1.79
10.1–11.0	8	10.71	22.55	20.89	-1.65	-7.92
11.1–12.0	2	11.43	23.60	25.31	+1.71	+6.74
12.1–13.0	19	12.71	38.25	34.57	-3.67	-10.66
13.1–14.0	15	13.59	43.02	42.06	-0.95	-2.27
14.1–15.0	11	14.56	53.54	51.66	-1.93	-3.75
15.1–16.0	20	15.60	64.44	63.18	-1.26	-1.99
16.1–17.0	25	16.83	76.29	79.03	+2.73	+3.46
17.1–18.0	16	17.61	94.48	90.22	-4.27	-4.73
18.1–19.0	11	18.64	108.81	108.81	0.00	0.00
19.1–20.0	19	19.53	125.04	122.45	-2.58	-2.12
20.1–21.0	9	20.82	147.08	147.84	+0.76	+0.52
21.1–22.0	3	21.67	167.82	166.20	-1.62	-0.97
22.1–23.0	8	22.96	180.97	197.19	+16.22	+8.22
23.1–24.0	17	23.75	215.73	217.85	+2.13	+0.98
24.1–25.0	11	24.52	214.84	239.17	+24.33	+10.17
25.1–26.0	3	25.20	254.17	259.29	+5.12	+1.97
26.1–27.0	8	26.67	293.98	306.56	+12.58	+4.10
27.1–28.0	2	27.50	346.00	335.32	-10.68	-3.18
28.1–29.0	5	28.42	371.98	369.43	-2.55	-0.69
29.1–30.0	4	29.30	445.14	404.13	-41.00	-10.15
B	<i>L. cephalus</i>				log W = 2.884293 * log l - 10.2047	
3.1–5.0	3	3.93	1.71	1.47	+0.23	+13.77
5.1–7.0	8	6.35	5.19	5.86	-0.67	-12.96
7.1–9.0	35	8.32	12.07	12.79	-0.72	-5.93
9.1–11.0	44	10.33	23.28	23.83	-0.54	-2.33
11.1–13.0	60	11.92	35.35	36.06	-0.71	-2.02
13.1–15.0	44	14.00	55.48	57.17	-1.69	-3.05
15.1–17.0	16	15.92	79.56	83.00	-3.44	-4.33
17.1–19.0	6	17.97	121.00	117.68	+3.32	+2.74
19.1–21.0	10	20.22	175.60	165.46	+10.14	+5.77
21.1–23.0	3	22.43	237.00	223.26	+13.73	+5.79

L. cephalus

The data on the l–w relationship for this fish from the biotope of the River Vardar which is quite common in Europe is shown on Table 2 B and Figure 2 D. By checking the accuracy of the equation it can be seen that difference between the measured and calculated weight of the smallest length classes (3.1–5.0 cm and 5.1–7.0 cm) rarely exceed the 10 percent which can be tolerated. Since we had on disposal satisfactory amount of samples for both length classes, and these as small fish are still too young, the rational behind the difference cannot be explained by the physiological state and maturation; therefore the rational behind the determined situation must be sought somewhere else. Starting from the biology of this species, the reason is sought in the different micro settlements, in fact the different ecological conditions where different age classes, respectively length classes, live. In general, the oldest age classes in the fast running Vardar River ecosystem prefer to live in open water, in the deep waters or near the vertical banks next to the roots of the trees, where the moderate speed of the water stream brings food. On the contrary, the youngest fish prefer the quite bays with warm and stagnant water where the limnetic water conditions are predominant. That the different ecologic conditions have influence on the l–w relationship even in the lotic biotope, at two different parts of the same brook, was also shown by the results of l–w relationship examination of *Salmo trutta* (Linnaeus, 1758), which inhabits the upper and downward part of Lipkovka River, (Georgiev, 1978).

Georgiev (2000) studied this character for the same flow of the Vardar River for the chub inhabiting the Babuna River, its right hand confluent. No differences exceeding the 10 % were determined in that case. Dikov and Živkov (1985), have studied this ratio for the chub of larger length classes living in the Đerman River. Mikavica *et al.* (1997) for the chub population of the Drina River, Black Sea watershed, present only the equation for this relationship and diagram of the parabola from theoretically calculated values. For the chub living in Beli Drim, Adriatic Sea watershed Šorić (1984), gives only the equation without calculating the differences between the measured and calculated values; the equation differs drastically from the one obtained for the chub in the Vardar River. For the chub population living in the limnetic biotope of the reservoir Batak, the same Aegean Sea watershed Živkov (1974) gives two graphical presentations without the equation that he has determined. Treer *et al.* (1999) studying length–mass relationship of chub in five rivers in Croatia have stated this character to be »a precise reflection of the overall environmental conditions of the rivers they inhabit«. Beyond the borders of the Balkan Peninsula this characteristic of the chub was studied by Geldiay and Balik (1973); they gave both an equation and a diagram for the chub population of the Pinarbasi brook, a part of the *L.*

cephalus area in Asia Minor. For the juvenile chubs in the Rokytna River, Middle Europe part of the Danube River flow Prokeš *et al.* (1978) by using the formula determined deviations which exceeded the acceptable 10 %. Timmermans (1961) gives only the diagram for the chubs living in the L'eau Blanche, Atlantic Ocean watershed, without providing the equation; Sczerbowski *et al.* (1976), provide both the equation and the diagram for the chubs living in the River Lyn, the Baltic Sea watershed.

It was determined that the Bank's start for chub from the River Vardar occurs at the length of 35 mm. For the confluent of the Vardar River, the Babuna River, Georgiev (2000), has determined the Bank's start at the length of 40 mm; Dikov and Živkov (1985), give data of 38 mm for the Bank's start. The closest values for the Bank's start, as determined for the Vardar River chubs, has been provided by Krupka (1969), of 35 mm for the River Turiec in Middle Europe. Kirka (1962), comes up with the value of even 44 mm for chubs from the upper stream of the river Vah, Danube River flow in the Middle Europe. Kirka (1965), for the chub from the reservoir Orava, Atlantic Ocean watershed, comes up with a Bank's start of 39 mm.

A. alburnus

The data for the l–w relationship for the second species that has been subject to study from the biotope of the River Vardar, which is with large European distribution, is shown on Table 3 A and Figure 2 E. By checking the accuracy of the equation, it can be seen that for the first length classes (3.1–4.0; 4.1–5.0; 5.1–6.0 and 6.1–7.0 cm) the differences among the real and the calculated weight exceed the acceptable 10 percent far more than for the previous species. The rational behind this is the small number of samples for each length class, only one in the first three and two in the fourth. It has been determined that the Bank's start for the bleak from the River Vardar occurs at the length of 41 mm, the largest value out of all the values obtained for the six fish subject to study. It is quite clear since this species has elongated body.

Data for the bleak from the Velika Morava, Danube River flow the part on Balkan Peninsula is given by Cakić (1983); this data contains the average values of the body weight of any age class by direct measurements without investigating the relationships of interdependence. Petrovski and Sidorovski (1971); Točko (1975, 1985) do not provide the equations but only the graphic view and tabelar numerical weight obtained on the basis of diagram for every separate age. Šorić (1980), gives an allometric equation for the bleak from Beli Drim, Adriatic Sea watershed, which is different from the ones for the Vardar River. He represents the differences between the real and the calculated values which are quite insignificant. Petrovski and Sidorovski (1971), give the value of 38 mm for the Bank's start of *Ch. belvica*.

Table 3. Data on the measured and computed values for the l–w relation of *A. alburnus* and *A. bipunctatus*Tablica 3. Podaci o izvaganim i izračunanim vrijednostima alometrijskog suodnosa kod *A. alburnus* i *A. bipunctatus*

Length Class Dužina		L x	W x	Counted w Izračunata w	Difference among the real and counted w Razlika između stvarne i izračunane w	
cm	n	cm	g	g	g	%
A	<i>A. alburnus</i>				log w=3.119703*log l-11.5563	
3.1–4.0	1	3.5	0.52	0.63	+0.11	+17.24
4.1–5.0	1	5.0	2.35	1.91	-0.44	-22.92
5.1–6.0	1	5.3	2.85	2.29	-0.56	-24.29
6.1–7.0	2	6.6	3.75	4.55	+0.80	+17.50
7.1–8.0	8	7.5	7.04	6.88	-0.16	-2.35
8.1–9.0	38	8.6	9.85	10.26	+0.41	+4.00
9.1–10.0	47	9.5	13.77	14.34	+0.57	+3.96
10.1–11.0	8	10.5	19.73	19.42	-0.31	-1.60
B	<i>A. bipunctatus</i>				log w=3.159712*log l-11.507	
4.1–5.0	3	4.93	2.00	2.25	+0.25	+12.50
5.1–6.0	6	5.73	3.59	3.62	-0.03	-0.84
6.1–7.0	31	6.65	6.00	5.79	+0.21	+3.60
7.1–8.0	54	7.50	8.56	8.45	+0.11	+1.28
8.1–9.0	51	8.54	12.78	12.77	+0.00	+0.04
9.1–10.0	6	9.38	16.77	17.16	-0.39	-2.28

A. bipunctatus

The data on the l–w relationship for this smallest, free–water living species from the biotope of the River Vardar is presented at Table 3 B and Figure 2 F. By checking the accuracy of the equation, it can be seen that for the smallest length class (4.1–5.0 cm) the difference between the real and the calculated values goes slightly over the acceptable 10 percent. Since there are only three samples in this length group, we consider this to be the cause of the situation. The Bank's start was calculated to be 39 mm. Šorić and Ilić (1985), have studied the weight growth of this fish in two localities, the first one is the River Gruža, Black Sea watershed, the other is the Beli Drim, Adriatic Sea watershed. These authors however do not offer an equation nor they check its accuracy; they only give the data on the weight of the fish at a certain age, both for the males and the females. They have determined that the weight of the fish increases progressively with the age but this intensity of growth decreases with the years of age. Treer *et al.* (2000) have stated in

Croatia, that in four out of the five examined locations, weight expressed positive allometric growth and negative in one. On those results they conclude the spirlin to be subjected to great predation.

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Proofread by Ms Mirjana Makedonska.

Sažetak

SUODNOS DULJINA–TEŽINA ŠEST CIPRINIDNIH RIBA U RIJECI VARDARU (REPUBLIKA MAKEDONIJA)

S. B. Georgiev

U radu je istraživana alometrijski suodnos kod šest od osam najčešćih ribljih vrsta koje nastavaju biotop rijeke Vardara, najvećega riječnog sustava u središnjem dijelu Balkanskoga poluotoka: *Alburnoides bipunctatus* (Bloch, 1782); *Alburnus alburnus* (Linnaeus, 1758), *Barbus macedonicus* Karaman, 1928; *Barbus peloponnesius* Valenciennes, 1842; *Chondrostoma vardarense* Karaman, 1928 te *Leuciscus cephalus* (Linnaeus, 1758), dviju među njima endemičnih. Jedino su kod *B. peloponnesius* za sve duljinske grupe dobiveni zadovoljavajući rezultati, a u ostalih je bilo utvrđeno odstupanje od nekih duljinskih klasa. Ovakvi se nalazi objašnjavaju dvama čimbenicima: nedovoljnim brojem primjeraka u određenoj duljinskoj klasi ili spolnim sazrijevanjem koje uzrokuje prijemrijestni ili poslijemrijestni utjecaj promjene mase ribe. Osim toga, na rezultate utječe život riba u različitim ekološkim uvjetima u drugim nastambama tijekom rasta.

Ključne riječi: *suodnos duljina–težina, rijeka Vardar, Alburnoides, Alburnus, Barbus, Chondrostoma, Leuciscus*

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