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MORPHOMETRICS OF *PSEUDORASBORA PARVA* (SCHLEGEL, 1842) (CYPRINIDAE: GOBIONINAE), A SPECIES INTRODUCED INTO THE POLISH WATERS

MORFOMETRIA CZEBACZKA AMURSKIEGO *PSEUDORASBORA PARVA* (SCHLEGEL, 1842) (CYPRINIDAE: GOBIONINAE), INTRODUKOWANEGO DO WÓD POLSKI

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A morphological analysis of 11 meristic and 25 plastic characters, based on 72 specimens of *Pseudorasbora parva* from carp ponds in the region of Ruda Sułowska (Barycz R. system, SW Poland). The populations occurring in European waters display a wide morphological variability, significantly differing from one another. Sexual dimorphism is manifested in larger body size of males as well as in four plastic characters. The main length increase concerns the fish medial section (positive allometry), whereas the distal parts of the body, eye diameter and the postorbital part of head grow slowlier (negative allometry).

INTRODUCTION

During the last thirty years as many as 15 fish species have been introduced (accidentally or on purpose) in Poland, most of them having rapidly spread in open waters (Witkowski 1996). In most of cases, the appearance of new species has exerted a negative influence both on the indigenous fish communities and the aquatic environment (Witkowski 1989, 1995). One of those species is *Pseudorasbora parva*, which was accidentally introduced in Poland along with fry of carp and phytophagous fish species imported for pond farms probably from Hungary at the end of the eighties (Witkowski 1991). The species must have appeared in Europe as early as the late fifties, its first records coming from Roumania, Albania (1960) and Ukraine (1962) (Bănărescu 1964; Kozlov 1974), and is currently found in most European countries (Wohlgemuth and Šebela 1987; Witkowski 1991).

In Poland *P. parva* first noted in 1990 in the Stawno and Ruda Sułowska Fish Farms near Milicz. At present it lives in all fish ponds as well as open waters of this region (Błachuta et al. 1993). The available information indicates that the species occurs practically in the whole area of Poland, both in ponds and lakes and rivers, e.g. NE Poland—environs of Knyszyn (B. Czeczuga—pers. inf.), SW Poland—environs of Jelenia Góra and Legnica (Z. Czarny, T. Domżalski—pers. inf.), S Poland—environs of Brzesk (Pławowice) (M. Tomala—pers. inf.), W Poland—environs of Środa Wielkopolska, Sieraków Wielkopolski, Miłosław, Lutom, Osieczno, Zglińce (A. Łakomy—pers. inf.), Central Poland—environs of Warsaw (Żabieniec) (K. Komosiński—pers. inf.).

The only information concerning the morphometry of *P. parva* occurring in Poland is based on one specimen from pond "Polny" in the Stawno Fish Farm (Witkowski 1991). Considering the fact that in many regions of the country the species already occurs in abundance, it is important to know its morphometry and the role it plays both in carp farms and open waters. The aim of the present paper is to fill partly this gap in the Polish ichthyological literature.

MATERIAL AND METHODS

P. parva was collected in the Ruda Sułowska Fish Farm when carp ponds were sluiced at the end of October 1991. Seventy two specimen were found among several hundred kilograms of carp and preserved in a 4%-formalin solution to serve further study. Measurements and calculations of 25 plastic and 11 meristic characters were performed according to the formula for the family Cyprinidae (Holčik 1989). The following abrevations were used in the tables and text:

A. Meristic characters: *Ab*—branched rays of anal fin, *Au*—unbranched rays of anal fin, *Db*—branched rays of dorsal fin, *Du*—unbranched rays of dorsal fin, *l.l.*—lateral line scales, $l.l._1$—scales above lateral line, $l.l._2$—scales below lateral line, *Pb*—branched rays of pectoral fin, *Pu*—unbranched rays of pectoral fin, *Vb*—branched rays of ventral fin, *Vu*—unbranched rays of ventral fin.

B. Plastic characters: *h*—minimum body depth, *H*—maximum body depth, *hA*—depth of anal fin, *hc*—head depth, *hD*—depth of dorsal fin, *io*—interorbital distance, *lA*—length of anal fin base, lC_1—length of upper caudal fin lobe, lC_2—length of lower caudal fin lobe, *lD*—length of dorsal fin, *lP*—length of pectoral fin, *lpc*—length of caudal peduncle, *lV*—length of ventral fin, *Oh*—horizontal diameter of eye, *pA*—preanal distance, *pD*—predorsal distance, *poD*—postdorsal distance, *poO*—postorbital distance, *prO*—preorbital distance, *pV*— preventral distance, *P–V*—distance between pectoral fin base and ventral fin base, *Sl*—standard length, *Tl*—total length, *V–A*—distance between ventral fin base and anal fin base.

The specimens were measured with an accuracy of 0.1 mm. The results were statistically analysed, the mean values ($\bar{x}$), standard deviation (SD) and variability coefficient (CV) calculated in the case of plastic characters expressed as percentage of body or head length (*Sl* and *lc* respectively). To determine sexual dimorphism in plastic characters two types of t-test (assuming equal and different variants on the significance level of $\alpha = 0.05$) were used. In order to perform a multidimensional analysis of the mode of growth of particular plastic features, two principal components (based on correlation matrix, using rotation—varimax normalized), i.e. PC I and PC II, were calculated from log-transformed data; than within-group allometry coefficient was calculated for each distance. The methodology of this analysis was adopted after Strauss and Bookstein (1982) and Bookstein et al. (1985). Apart from the multidimensional analysis, the correlation between the increase in distances and the body size was investigated using analysis of the linear regression equation
($y = a + bx$) coefficients for particular characters up to *Sl* or *lc*, the statistical significance of coefficients ($\alpha = 0.05$) assessed.

RESULTS

For meristic characters the following formula has been obtained:
Du (II) III, *Db* (6) 7; *Au* (II) III, *Ab* 6 (7); *Vu* II, *Vb* 7–8; *Pu* I, *Pb* 10–13 (14); *l.l.* (34) 35–38 (39); $l.l._1$ 5–6, $l.l._2$ 3–4.

The variability of most meristic characters in the specimens studied is low, which is precisely defined by the formula above. A complete picture of the variability of meristic characters and the latter's frequency are shown in Table 1.

For 23 plastic characters, expressed as percentage of *Sl* or *lc*, variability range, average value ($\bar{x}$), standard deviation (SD) and variability coefficient (CV) have been calculated (Tab. 2). Since further analysis has proved that some of them display statistically significant differences between males ($n = 61$) and females ($n = 11$), the joint list of all characters has been supplemented with average and deviation values for both sexes separately.

Within the analysed fish length range (*Sl* = 57.40–76.90 mm) males are characterised by a larger size (*Sl* and *Tl*), higher tail trunk (*h*), and higher values of distances pertaining to the structure of fin, i.e. *hD*, *lA*, *hA*, *lP* (t-test). Statistically significant differences in average body lengths in both samples do not allow, however, to acknowledge the features concerned as direct manifestations of sexual dimorphism since they may result from the allometric growth of some body sections. It should also be kept in mind that their existence is additionally dependent on the variance in *Sl* being unequal which is a result of varied numbers of males and females ($p > 0.05$, F-test) in samples.

Table 1

Meristic characters in the studied population of *P. parva* (n = 72)

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	34	35	36	37	38	39	$\bar{x}$	SD	CV
l.l.															1	3	28	26	13	1	36.69	0.91	2.48
$l.l._1$					37	35															5.49	0.50	9.11
$l.l._2$			5	67																	3.93	0.26	6.62
Du		1	71																		2.97	0.17	5.72
Db						1	71														6.99	0.12	1.72
Au		4	68																		2.94	0.23	7.82
Ab						71	1														6.01	0.12	2.00
Vu		72																			2.00	0.00	—
Vb							67	5													7.07	0.26	5.22
Pu	72																				1.00	0.00	—
Pb											6	44	20	2							12.25	0.64	3.68

Table 2

Plastic characters in the studied population of *P. parva* (n = 72) for whole sample and for males and females

Character	Range	$\bar{x}$	SD	CV	$\bar{x}$ males (n = 61)	SD	$\bar{x}$ females (n = 11)	SD
Tl (mm)*	70.80–93.70	80.82	5.42	6.71	81.57	5.53	76.64	1.69
Sl (mm)*	57.40–76.90	66.50	4.55	6.84	67.10	4.65	63.13	1.71
				in % *Sl*				
lc	23.32–27.49	25.38	1.00	3.94	25.39	1.02	25.35	0.92
pD	48.35–54.92	51.71	1.22	2.36	51.69	1.15	51.85	1.60
poD	36.66–44.73	39.94	1.36	3.41	39.91	1.33	40.11	1.59
pV	46.55–53.91	49.84	1.44	2.89	49.72	1.34	50.50	1.82
pA	67.52–73.51	70.13	1.32	1.88	70.03	1.25	70.66	1.60
H	22.11–26.47	23.96	0.93	3.88	23.97	0.94	23.90	0.94
*h**	11.15–13.32	12.25	0.49	4.00	12.32	0.45	11.87	0.55
lpc	20.63–27.39	24.18	1.43	5.91	24.30	1.41	23.54	1.49
lD	8.81–13.86	11.36	1.01	8.89	11.44	0.99	10.96	1.06
*hD**	19.41–25.61	22.30	1.33	5.96	22.51	1.27	21.13	1.09
*lA**	5.62–10.66	7.89	0.88	11.20	7.99	0.85	7.35	0.89
*hA**	12.25–17.84	15.34	1.10	7.17	15.56	0.95	14.09	1.09
*lP**	14.99–19.76	17.16	1.14	6.64	17.29	1.13	16.47	0.99
lV	14.27–18.74	16.90	0.94	5.56	16.95	0.94	16.63	0.93
P–V	20.42–28.21	24.54	1.42	5.79	24.42	1.44	25.19	1.15
V–A	18.15–23.83	20.85	1.35	6.47	20.86	1.38	20.78	1.25
C1	20.03–27.74	22.74	1.56	6.86	22.76	1.62	22.64	1.21
C2	19.28–25.46	22.35	1.40	6.26	22.39	1.45	22.15	1.12
				in % *lc*				
prO	30.00–40.00	35.81	1.99	5.56	35.74	2.09	36.21	1.28
Oh	20.92–32.00	24.62	2.10	8.53	24.49	2.20	25.31	1.23
poO	39.26–52.27	45.45	2.80	6.16	45.61	2.63	44.52	3.60
hc	58.67–72.41	65.46	2.91	4.45	65.53	2.99	65.07	2.49
io	33.99–46.86	41.89	2.39	5.71	41.99	2.49	41.38	1.67

*—statistically significant differences between males and females at α =0.05 (t-test)

An analysis of the growth pattern of particular distances, based on within-group allometry coefficients (Strauss and Bookstein 1982; Bookstein et al. 1985), has been presented in diagrammatic form in Fig. 1. Value “1” indicates perfectly isometric growth, higher and lower values meaning respectively allometric growth of a given character of increasing (positive allometry) or decreasing (negative allometry) proportion in the composite size measure—PC I. The length of head (*lc*) and distances strongly correlated with body length, located in the anterior part (*pD*, *pV*, *P–V*), are characterized by negative allometry. The main increase within the fish length falls on the medial body section (*lD*, *lA*, *V–A*), whereas the tail trunk (*lpc*) grows somewhat slower. In the analysed size range the small specimens have a considerably larger relative value of *Oh* than the big ones, which is manifest in a very distinct negative allometry of this character. Another head measurement which shows a slightly slower increase is *poO*, whereas *io* has been found to grow more rapidly. *lA* was the only one of the characters displaying significant differences in the mean values for males and females that demonstrated clear allometry. The growth of *h*, *hD*, *hA*, *lP* is close to isometric and thus it can be assumed that the characters reflect sexual dimorphism. It cannot be excluded either that the larger size of males is also a manifestation of sexual dimorphism.

Similar conclusions can be drawn from an analysis of correlation between the increase of distances and the body size, based on interpretation of regression equations for particular distances (dependent variable—y) in relation to *Sl* or *lc* (independent variable—x). The coefficients of those equations are given in Table 3. Acceptance of the significance level of 0.05% allows to establish that only four characters (*pD*, *lD*, *lA*, *V–A*) do not grow proportionally to *Sl* and one (*Oh*) to *lc* ($a \neq 0$). Two of them, i.e. *pD* and *Oh*, increase slower ($a > 0$) while the remaining ones quicker ($a < 0$) than the independent variable.

The outcome of both analyses leads to conclusions which, to a high degree, are mutually supportive. Multidimensional analysis, however, has such an advantage that it allows to consider the mode of growth of particular body parts not only with regard to two arbitrarily chosen distances, as is the case with regression equations analysis, but also to relate them to a new variable which is derived from compilation of the growth index of all characters investigated. Thanks to this type of analysis, it is also possible to express the allometry measure in their increase in a convenient numerical way.

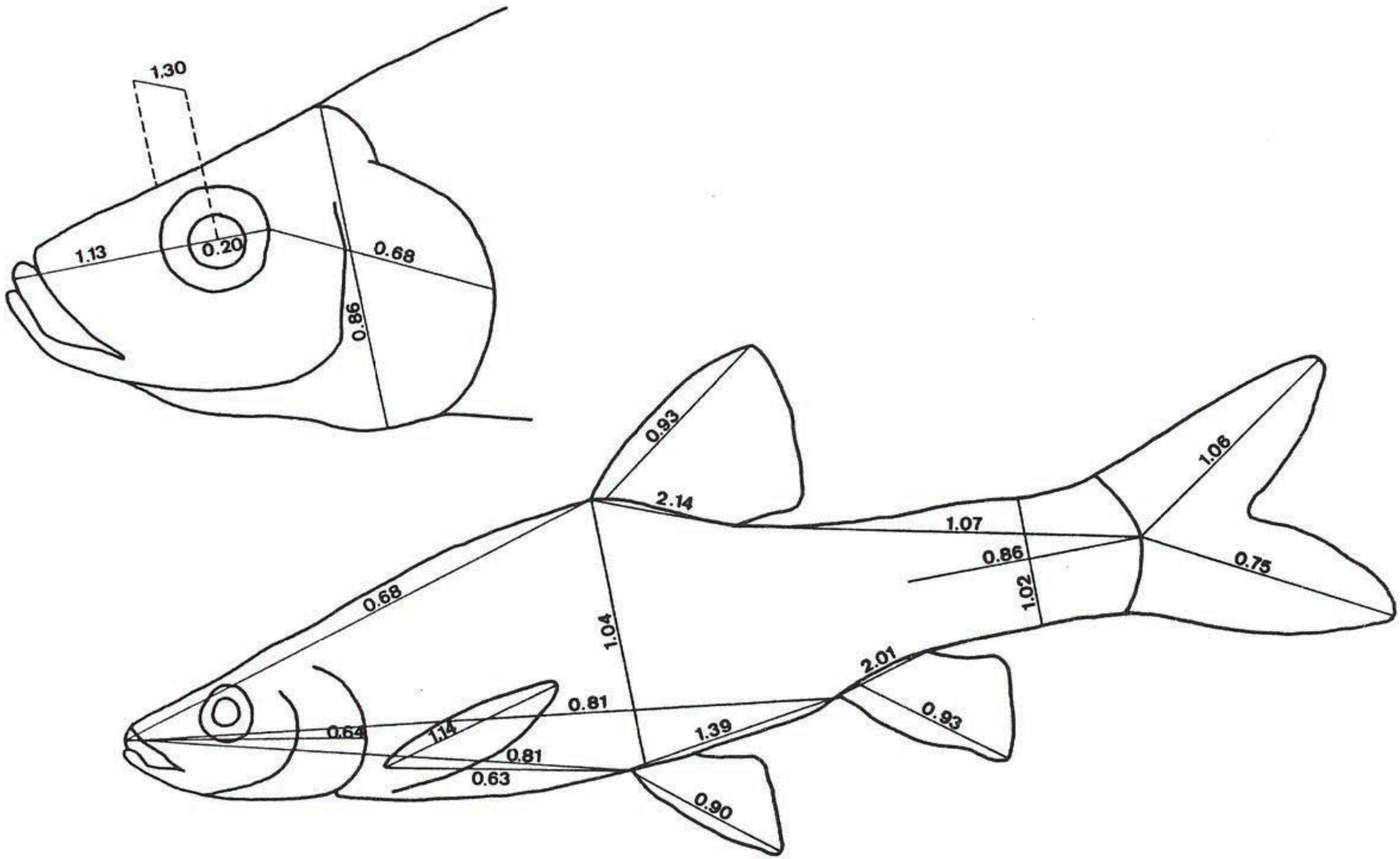

Fig. 1. Multivariate within-group allometry coefficients for each character. Symbols explained in the text

Table 3

Parameters of linear regresion equations: y = a + bx and correlation coefficient "r" describing dependence of particular characters on *Sl* or *lc* in *P. parva* (n = 72)

x	*y*	*r*	*b*	*a*	H_0: *a* = 0
Sl	*lc*	0.838	0.221	2.139	+
Sl	*pD*	0.940	0.470	3.087	–
Sl	*poD*	0.909	0.441	-2.763	+
Sl	*pV*	0.910	0.454	2.930	+
Sl	*pA*	0.962	0.710	-0.555	+
Sl	*h*	0.898	0.267	-1.826	+
Sl	*H*	0.900	0.141	-1.260	+
Sl	*lpc*	0.784	0.267	-1.651	+
Sl	*lD*	0.782	0.169	-3.632	–
Sl	*hD*	0.774	0.233	-0.699	+
Sl	*lA*	0.661	0.109	-2.014	–
Sl	*hA*	0.689	0.152	0.066	+
Sl	*lP*	0.726	0.174	-0.189	+
Sl	*lV*	0.762	0.159	0.649	+
Sl	*P-V*	0.732	0.227	1.189	+
Sl	*V-A*	0.836	0.280	-4.728	–
Sl	*C1*	0.733	0.244	-1.130	+
Sl	*C2*	0.733	0.219	0.276	+
lc	*prO*	0.812	0.377	-0.139	+
lc	*Oh*	0.292	0.072	2.919	–
lc	*poO*	0.760	0.461	-0.107	+
lc	*hc*	0.823	0.604	0.844	+
lc	*io*	0.810	0.456	-0.615	+

"+" H_0 confirmed; "–" H_0 rejected

DISCUSSION

Pseudorasbora parva, a species introduced in the Polish waters almost 10 years ago, has very rapidly spread over nearly the whole continent (Wohlgemuth and Šebela 1987). It dispersed either spontaneously or with fry material of other fish species transported from country to country. Supposedly, all European populations have spread from Roumania or Ukraine, those from the countries mentioned having originated from the region of the lower Yangtze Kiang (at Wuchung, Hupeh Province, China) from where they migrated along with first herbivorous fishes. The species discussed occurs in eastern Asia, where it inhabits Japan, Korea, Russia (the Amur River basin), Mongolia, China (the Yangtze Kiang and Hwang Ho River basins), Taiwan (Mori 1936; Berg 1949).

According to Bănărescu and Nalbant (1965) and Žitan and Holčik (1976), the European populations represent the nominate form *P. parva parva*. The species has been described as *Leuciscus parvus* by Schlegel (1842) from the environs of Nagasaki. Hence, Japan should be regarded as terra typica of the nominate subspecies. From the territory of China six subspecies of *P. parva* have been described (Nichols 1943). In the opinion of Baruš et al. (1984), the populations from the south of Slovakia (confluence of the rivers Ipel and Danube) in some characters (among others rounded fin ends, long basis *D*, moderately marked transverse stripe in *D*, presence of longitudinal dusky band along the body sides) resemble *P. parva fowleri*. Similar features are observed in the populations from the Amur River (Berg 1949). Yet, Bănărescu and Nalbant (1965) maintain that most subspecies (including *P. parva fowleri*, and even some species described by Nichols (1943)) are merely variations of this polymorphic species. Thus, "the taxonomy of the species imported to Europe is still unclear" (Bianco 1988).

A comparison of our own results with data obtained by other authors on plastic characters indicates that all the hitherto studied (European) populations of the species differ considerably one from another (Tab. 4). Although the data are comparable with the use of statistical methods, we have not attempted such a comparison considering the fact that the differences in the values of particular characters are difficult or even impossible to interpret biologically. The origins of individual European "populations" of *P. parva* are not known thoroughly, whereas the differences in body proportions may have different reasons. Holčik (1972) provides examples of rapidly appearing significant differences in biometrical characters of acclimatized fishes compared with the parent populations. This may be accounted for by reaction to stress due to a drastic change in the ecological conditions in which a given species evolved, and by the following necessity to adapt to a new environment. The genetic structure of a population introduced to new habitats is also of major importance. In the case of species dispersal with the anthropogenic factor involved the founder effect and that of inbreeding, whose manifestation through morphological features is difficult to predict or reconstruct, are likely to exist. The problem of the Ukrainian population of *P. parva* being widely varied has already been recognized by Movčan and Kozlov (1978), in whose opinion under new living conditions a phenotypic change in some of the characters has taken place, which may indicate a strong plasticity of the species. The differences in meristic features are not as substantial (Tab. 5).

Sexual dimorphism manifested in larger body size of males was reported by other authors (Kozlov 1974; Movčan and Kozlov 1978; Baruš et al. 1984; Libosvárský et al. 1990), too. The last of the papers mentioned demonstrates that such differences exist in particular age categories as well. The correspondence of results obtained by various authors allows to assume with high probability that the disproportion in size between the sexes constitutes a manifestation of sexual dimorphism. Movčan and Kozlov (1978) assume that sexual dimorphism manifests itself in different body heights (both maximum and minimum) and fin lengths, which is to a great extent confirmed by our research (differences in *h*, *hD*, *hA*, *lP*). However, contrarily to Baruš et al. (1984), we have not found sex-dependent differences in the case of *lD* and *P–V*.

Table 4

Plastic characters of *P. parva* from different populations (mean values)

Character	Barycz (author's data)	Ipel-Danube (Baruš et al. 1984)	Danube (Movčan and Kozlov 1978)	Dnestr (Movčan and Kozlov 1978)	Dnestr (Movčan and Kozlov 1978)	Amur (Muchačeva 1950)
Sl (mm)	66.50	67.1	63.2	38.8	63.5	61.4
			in % *Sl*			
lc	25.38	24.1	25.44	26.63	25.62	23.03
pD	51.71	49.3	48.55	50.47	49.03	48.50
poD	39.94	40.6	—	—	—	—
pV	49.84	—	48.03	49.99	48.11	—
pA	70.13	—	68.88	69.55	68.18	—
H	23.96	23.8	25.99	22.39	24.29	22.72
h	12.25	12.6	12.26	11.36	12.22	11.27
lpc	24.18	25.3	23.59	22.99	24.14	24.39
lD	11.36	12.8	13.44	12.67	13.66	12.03
hD	22.30	21.7	22.81	22.19	22.29	21.20
lA	7.89	8.5	9.03	8.83	9.03	7.83
hA	15.34	17.4	14.9	14.91	15.41	13.91
lP	17.16	17.8	17.29	17.87	18.22	16.38
lV	16.90	18.4	17.43	17.43	17.85	17.34
P–V	24.54	22.0	23.07	23.39	23.03	23.57
V–A	20.85	22.6	22.66	20.71	21.51	—
C1	22.74	22.8	25.33	26.71	25.71	—
C2	22.35	22.1	25.28	26.79	25.92	—
			in % *lc*			
prO	35.81	29.5	30.69	27.45	32.69	—
Oh	24.62	23.0	22.71	29.57	21.69	—
poO	45.45	43.4	46.41	43.33	45.91	—
hc	65.46	—	67.12	66.41	68.45	—
io	41.89	39.4	40.19	26.93	42.33	—

An analysis of dimensions variability dependent on body size was performed by comparison of two groups of specimens, i.e. large and small ones, from the Dnestr population of *P. parva* (Movčan and Kozlov 1978; Movčan and Smirnov 1981). The study reveals that the characters which increase faster than body length are *H* and *h*, whereas *pD*, *pV*, *pA*, *lpc*, *lD*, *Oh*, *prO*, *poO*, *io* and "the mouth width from the nose top to the maxillare end", which we have not investigated, are relatively decreasing. When we compare these data with those obtained for the population from the Odra River basin (ponds in the Barycz River valley), only the mode of growth of *pD*, *pV*, *pA*, *lpc*, *Oh* and *poO* is negatively allometric.

Tabele 5

Meristic characters of *P. parva* from different populations (range and mean)

Locality	*Db*	*Ab*	*Vb*	*Pb*	*l.l.*	$l.l._1$	$l.l._2$
Barycz R. ponds of region Ruda Sułowska (own data)	6–7 6.99	6–7 6.01	7–8 7.07	10–14 12.25	34–39 36.69	5–6 5.49	3–4 3.93
Turunčuk R., Dnestr basin (Movčan and Kozlov 1978; Movčan and Smirnov 1981)	7 7.00	6 6.00	6–7 6.96	11–13 11.88	34–38 36.00	5–6 5.12	3–4 3.69
Danube R., region of Vilkovo (Movčan and Kozlov 1978; Movčan and Smirnov 1981)	7–8 7.04	6 6.00	7 7.00	11–13 11.64	30–37 33.61	5 5.00	3–4 3.77
Dnepr R., canals and ponds (Movčan and Kozlov 1978; Movčan and Smirnov 1981)	6–7 6.83	6 6.00	7 7.00	—	36–38 37.82	5–6 5.06	4–5 4.52
Ipel-Danube conf., region of Chlaba (Baruš et al.1984)	7 7.00	6 6.00	7 7.00	11–14 12.40	34–38 36.40	—	—
Amur R., region of Balon (Muchačeva 1950)	7 7.00	6 6.00	—	—	35–38 36.70	—	—

CONCLUSIONS

1. Morphological characteristics of *Pseudorasbora parva* from the fish ponds of the Barycz River basin:
   Du (II) III, *Db* (6) 7; *Au* (II) III, *Ab* 6 (7); *Vu* II, *Vb* 7–8; *Pu* I, *Pb* 10–13 (14), *l.l.* (34) 35–38 (39); $l.l._1$ 5–6, $l.l._2$ 3–4.
2. The populations of *P. parva* occurring in Europe display wide morphological variability.
3. Sexual dimorphism is manifested in larger body size as well as higher values of *h*, *hD*, *hA* and *lP* in males.
4. The main length increase in *P. parva* falls on medial sections (positively allometric growth of *lD*, *lA*, *V–A*, the growth of the distal body parts, eye diameter and postorbital distance being relatively slower (negative allometry of *lc*, *pD*, *pV*, *P–V*, *Oh*, *poO*).

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MORFOMETRIA CZEBACZKA AMURSKIEGO *PSEUDORASBORA PARVA* (SCHLEGEL, 1842) (CYPRINIDAE: GOBIONINAE), INTRODUKOWANEGO DO WÓD POLSKI

STRESZCZENIE

Celem pracy była analiza cech merystycznych i plastycznych, w tym również określenie dymorfizmu płciowego, introdukowanego do naszych wód gatunku – *Pseudorasbora parva* (n = 72) w populacji pochodzącej ze stawów karpiowych gospodarstwa rybackiego Ruda Sułowska (dorzecze Baryczy, SW Polska).

Badana próba charakteryzuje się następującą formułą: *Du* (II) III, *Db* (6) 7; *Au* (II) III, *Ab* 6 (7); *Vu* II, *Vb* 7–8; *Pu* I, *Pb* 10–13 (14); *l.l.* (34) 35–38 (39); $l.l._1$ 5–6, $l.l._2$ 3–4 i pod tym względem nie różni się ona istotnie od innych europejskich populacji tego gatunku. W cechach plastycznych wszystkie opisywane dotąd populacje wykazują silne zróżnicowanie fenotypowe, co prawdopodobnie jest związane z wysoką plastycznością tego gatunku – konieczną przy dostosowywaniu się do różniących się między sobą warunków klimatycznych i ekologicznych nowo zasiedlanych biotopów.

Dymorfizm płciowy zaznacza się w większych rozmiarach ciała (*Sl* i *Tl*) i wyższym trzonie ogona (*h*) u samców, a także w cechach związanych z budową płetw: *hD, hA, lP*, w których również samce wykazują wyższe średnie wartości.

Główny przyrost ciała *P. parva* przypada na jego środkowe partie (pozytywnie allometryczny wzrost *lD, lA, V–A*) i względnie wolniejszy jest wzrost przedniej i tylnej części ciała oraz średnicy oka i tylnej części głowy (negatywna allometria *lc, pD, pV, P–V, Oh, poO*).

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