Research Article

Length-weight relationships and sex ratio in populations of topmouth gudgeon (*Pseudorasbora parva*) in Ukraine and Slovakia

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Abstract

Pseudorasbora parva was first documented in Europe in 1961 and spread across Eurasia in less than 40 years. Its rapid expansion can be attributed to its opportunistic life history traits. Current data on *P. parva* life history in Ukrainian populations are incomplete. However, some information is available from Slovak populations. Samples of *P. parva* for the current study were collected from canals, rivers, and fish farms in Ukraine and Slovakia to analyze population age structure and growth. A total of 1244 specimens (563 from Slovakia, 681 from Ukraine) were analyzed. Standard lengths ranged from 13 to 71 mm, while weights varied between 0.01 and 7.4 g. The populations comprised age groups from 0+ to 6+. *P. parva* reached reproductive maturity at age 1+ and lengths of 35–40 mm in Slovakia, and at age 1+ with lengths 30–40 mm in Ukraine. In both Ukrainian and Slovak fish farms, older age groups were more common. In habitats with natural food supply (rivers, irrigation canals) younger age groups (0+ and 1+) predominated.

Key words: Cyprinidae, invasive alien species, age, growth, scale

Introduction

Pseudorasbora parva is a cyprinid of the subfamily Gobioninae. Its native distribution encompasses eastern Asia, including Japan, Korea, northern and central China, and the Amur River basin (Berg 1949). The species was first documented in Europe by Bănărescu (1964), though its initial introduction occurred in 1961 at a fish farm in Nucet, within the basin of a Dâmbovița River tributary (Danube system, Romania). *Pseudorasbora parva* was inadvertently mixed with grass carp from the Yangtze River in Wuchang, China (Bănărescu 1999). It was first documented in Ukraine in the 1970s (Kozlov 1974) and in Slovakia (Žitňan and Holčík 1976). *Pseudorasbora parva* is included in the European Union's list of invasive alien species of concern, as defined by the Regulation (EU) 1143/2014 by European Parliament (2014).

Pseudorasbora parva is a small fish that inhabits shallow lakes, pools, irrigation canals, and rivers with aquatic vegetation cover (Witkowski 2011). The species spread across Eurasia in less than 40 years (Gozlan et al. 2002, 2010). Its rapid expansion can be attributed to its opportunistic life history traits (rapid maturation and short lifespan, multiple spawning per season, high fecundity, parental care, and non-specific spawning substrate requirements; Rosecchi et al. 2001) and wide physiological tolerance to low water levels, elevated temperatures, low oxygen concentrations and algal blooms (Bănărescu 1999; Pollux and Pollux 2004).

Pseudorasbora parva is omnivorous with a broad diet range, readily adjusting its diet based on food abundance and availability (Ding et al. 2019). There are evidences suggesting that *P. parva* can negatively impact native species through various mechanisms. These include predation on eggs and larvae of native species (Stein and Herl 1986), damage to fins and tissues of other fishes (Karabanov et al. 2010), interspecific competition for food resources (Declerck et al. 2002) and introduction of exotic parasites (Gozlan et al. 2005).

Juvenile *P. parva* exhibit gregarious behavior in areas with dense vegetation (Karabanov et al. 2010). The introduction of *P. parva* can affect total fish density and community composition, potentially leading to the displacement of some fish species (e.g., *L. delineatus*) over longer periods. Paradoxically, *P. parva* presence has been associated with increased species richness in some cases. However, predatory fish species can effectively limit the invasion of *P. parva* (Rechulicz 2019). Moreover, eradication of *P. parva* increases growth and productivity of native species (Britton 2009).

Numerous studies have investigated the growth characteristics of *P. parva* in various water systems, including its original habitats in eastern Asia (Fan et al. 2015; Lin et al. 2017). In invaded water bodies, studies have been conducted in Turkish reservoirs (Kirankaya et al. 2014; Benzer et al. 2016; Benzer 2019; Benzer and Benzer 2020; Erdoğan et al. 2022; Ağdamar and Gaygusuz 2021), the Timiş River in Serbia (Stavrescu-Bedivan et al. 2017) and small ponds near Southampton, Southern England (Davies and Britton 2020). In Slovakia, studies have focused on distributional patterns (Jakubčinová et al. 2018) and reproductive parameters (Záhorská and Kováč 2009) of *P. parva*. For Ukrainian populations, extensive distribution data across different river basins (Movchan 2012; Kolomytsev and Kutsokon 2012; Sondak et al. 2021; Kutsokon et al. 2021) as well as the data on the diet of this species (Didenko and Kruzhylina 2015) have been reported.

This study aim is to describe the length-weight relationships, age and sex structure of population of *Pseudorasbora parva* in its expanded range within Ukrainian and Slovak waterbodies.

Materials and methods

Study area

Sampling was conducted at eight locations across Ukraine and Slovakia (Figure 1, Supplementary material Table S1) and provided from July to September. Sampling methods differed between countries. In Ukrainian

Figure 1. Sample locations. Location codes shown in Table S1.

localities, a beach seine (8 m long, 0.5 cm mesh size) was used, while electrofishing was deployed in Slovakia. All samples were captured at a depth of 1.5 m. A total of 1244 specimens were analyzed (563 from Slovakia, 681 from Ukraine).

In Ukraine, three sites were sampled. UA1 was sampled on the Uday River (Dnipro Basin) near Kaplyntsy village, Poltava region. UA2 was sampled at a pond on the fish farm on the Sukil river (Dniester basin) in Lany-Sokolivsky village, Lviv region. UA3 is located on the Dnipro Reservoir near the Stary Kodaky village, Dnipro region. UA1 and UA3 sample sites had natural food supply.

In Slovakia, five sites were sampled. SK1 was sampled from the irrigation canal in the Nitra region. SK2 was sampled on the Mala Nitra River in the Nitra region. SK3 was sampled on a canal in the Košice region. SK4 and SK5 both were sampled in the fish farms in the Košice region.

The sampling sites represented diverse aquatic environments: two rivers (UA1, SK2), one large reservoir (UA3), two canals (SK1, SK3), and three fish farms (UA2, SK4, SK5).

Material processing

Age determination was conducted using scales prepared according to the classical method (Chugunova 1959). All samples were preserved in 4% formaldehyde. For each specimen, ten scales were extracted from above the lateral line, beneath the dorsal fin. Standard length (SL) was measured to the nearest 0.1 mm using a slide caliper. Fish weight was recorded to the nearest 0.01 g with electronic scales. For examining gonads every specimen was cut. Sex was determined by examining gonads visually.

Scale preparation for microscopy followed laboratory protocols. Scales were immersed in a 3% ammonia solution and individually separated using needles. After cleaning off epithelial residues, each scale was placed between two tightly pressed slides. Labels indicating specimen ID, weight, and length were affixed to each slide. The prepared slides were then left to dry (Chugunova 1959).

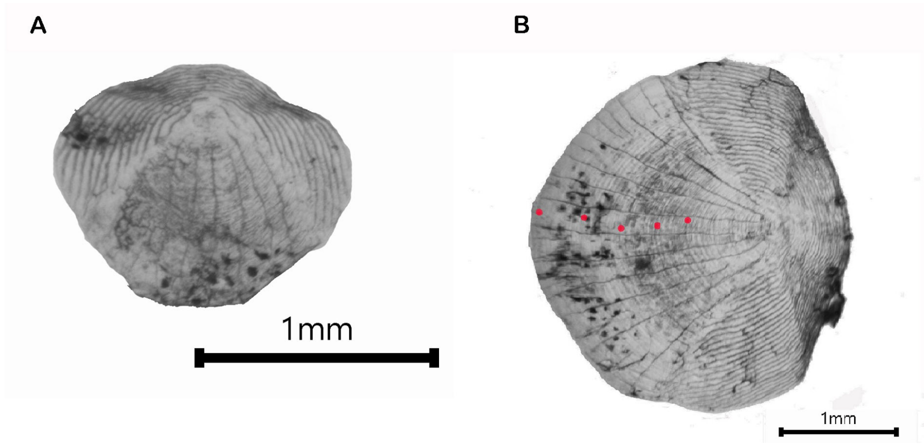

Figure 2. Scales of *Pseudorasbora parva* in the age 0+ (A) and 5+ (B)

Examination of dried scales was conducted using a Konus Crystal 7x-45x stereo microscope. Digital images were captured using a digital camera SIGETA M3CMOS 15.0MP camera with a FMA050 lens (Figure 2). Total scale radius and annuli radii were measured using ToupTek ToupView 3.7.2270 software. Measurements were taken from the scale center to the outer edge of each annulus along the largest diameter.

Growth parameters were calculated using the Bertalanffy's method (Ricker 1975):

$$L_t = L_\infty \, [1 - \exp(-K(t - t_0))]$$

Where:

L_t = Fish length at age t (years)

L_∞, K, t_0 are coefficients.

For SK1 sample growth parameters weren't calculated because of lack of mature specimens, there was only 1 mature specimen. Also because of this SK1 sample wasn't included to the comparisons of mean length by sex.

The length-weight relationship (LWR) was calculated using the function (Ricker 1975):

$$W = a * SL^b$$

Where:

W = Weight (g)

SL = Standard length (mm)

a = Scaling coefficient

b = Shape parameter (allometric growth coefficient)

A value of b = 3 indicates isometric growth, while values deviating from 3 suggest allometric growth (Tesch 1971), when b < 3 the fish grows faster in length than in weight, and when b > 3 the fish grows faster in weight than in length (Karachle and Stergiou 2012).

Table 1. Estimated parameters of length-weight relationship*.

Sample	N	Standard length (SL) range (mm)	Weight range (g)	Mean SL ± SD (mm)	log a	b	r^2
UA1	125	13.45–58.14	0.01–3.59	25.20 ± 8.79	−10.78	2.99	0.94
UA2	240	30.28–70.86	0.52–7.39	54.47 ± 6.61	−10.55	2.94	0.91
UA3	316	21.53–65.41	0.07–4.82	32.96 ± 7.82	−10.81	3.00	0.93
SK1	208	15.1–55.81	0.03–2.74	27.64 ± 3.45	−10.36	2.89	0.97
SK2	69	28.6–67.6	0.08–6.1	41.33 ± 6.31	−12.02	3.3	0.76
SK3	36	37.0–68.4	1.23–7.26	50.94 ± 8.74	−10.36	2.89	0.97
SK4	50	28.6–65.3	0.44–5.03	41.96 ± 7.23	−10.78	2.99	0.94
SK5	200	24.0–64.6	0.33–5.94	37.92 ± 9.49	−10.86	3.01	0.99

*for all samples $p << 0.05$; SD – standard deviation, a – scaling coefficient; b – growth coefficient; r^2 – coefficient of determination.

Statistical analyses were performed as follows:

1. The Shapiro-Wilk test was used to assess the normality of data distribution.
2. Analysis of Variance (ANOVA) and Mann-Whitney test were used to compare standard length among groups.
3. The chi-square (χ^2) test was used to evaluate the sex ratio for deviation from the expected 1:1 ratio (Sheskin 2000).

While performing comparisons of mean standard length between males and females in different ages some groups weren't included in analysis. Some groups were too small for analysis, so we compared groups only if two of them had 3 specimens or more and for very small groups (less than 10 specimens) we used almost equal in number.

All statistical tests were conducted with a significance level of $\alpha = 0.05$. Statistical processing was performed using PAST and R software.

Results

In the presented study 8 populations were studied, 3 from Ukraine and 5 from Slovakia. A total of 1244 specimens (563 from Slovakia, 681 from Ukraine) were analyzed. Standard length (SL) of *P. parva* specimens ranged from 13 to 71 mm, with weights varying between 0.01 and 7.4 g. Mean standard length varied across sampling sites, from 25.2 ± 8.79 mm (UA1) to 54.47 ± 6.61 mm (UA2) (Table 1, Figure S1).

ANOVA revealed significant differences in standard length among most sampling sites ($F = 486$, $df = 267$, $p << 0.05$ for all samples), with the following exceptions:

1. UA1 and SK1 ($p = 0.07$), both primarily composed of juveniles, so thereis no significant difference between standard length
2. SK3 and UA2 ($p = 0.13$), both lacking small juveniles
3. SK4 and SK2 ($p = 0.99$)

The growth coefficient (b) ranged from 2.89 (SK1 and SK3 samples) to 3.3 (SK2). All samples except UA3 shown allometric growth and UA3 sample has isometric growth. Only in SK5 sample growth is slightly faster

Table 2. Von Bertalanffy equation.

Sample	Sex ratio	χ2	p	Growth parameters		
				L_∞	K(year^{-1})	t_0
UA1	1:2	1.02	0.31	68.66	0.208	−1.74
UA2	1:1.09	0.02	0.97	73.15	0.256	−1.27
UA3	1:1.29	0.02	0.9	86.41	0.128	−2.86
SK2	1:1.47	0.04	0.84	73.15	0.183	−2.0
SK3	1:1.62	0.06	0.8	111.9	0.112	−3.53
SK4	1:1.08	0.002	0.97	75.06	0.133	−3.53
SK5	1:2.03	0.15	0.7	82.88	0.138	−2.89

* χ^2 – result of the chi-squared test; L_∞ – theoretical maximum (asymptotic) length (mm); K(year^{-1}) – growth coefficient; t_0 – theoretical age at zero length.

for weight than length (b = 3.01), for others length growths faster than weight. All LWR were highly significant (p << 0.01 for all samples), with coefficient of determination (r2) values exceeding 0.75, indicating a strong positive correlation between length and weight across all samples.

The sex ratio in the samples ranged from 1:1.08 (SK4) to 1:2.03 (SK5) (Table 2). Chi-square tests revealed no significant deviations from the expected 1:1 ratio in any of the sampled groups (p > 0.05 for all comparisons).

Age-specific linear growth was modeled using the von Bertalanffy growth function based on the observed age-length relationship. Parameter estimates for each sample site are presented in Table 2.

Sexual maturity in *P. parva* varied among sites. In Ukrainian samples maturity reached at age 1+ and length over 30–40 mm depending on sample cite. For waterbodies with natural food supply (UA1, UA3) smaller individuals were matured than for fish farm (UA2). For Slovak samples populations maturity reached at age 1+ or 2+, with a standard length of 35–40 mm, but two samples (SK2 and SK3) lacked small specimens, potentially affecting the estimation of size at maturity, also in SK1 there was only 1 mature specimen.

Table S2 shows mean standard length by sex and age group for all samples except SK1, where only one mature specimen was found. Mann-Whitney U tests were conducted to compare mean standard lengths between sexes for each sample. No significant differences were observed in most samples (p-values ranging from 0.09 in UA2 to 0.67 in UA1). However, the SK5 sample showed a significant difference (U = 6006.5, z = 1.99, p = 0.046), with females being larger than males).

Figure 3 shows mean standard length (mm) of *P. parva* depending on age group and sex. Additionally, Mann-Whitney U tests were conducted to compare mean standard lengths among fish of the same age group across different samples. Due to variations in sample sizes and age groups (Table S3), comparisons were limited to groups of similar size. In all sample there were no significant differences in standard length between males and females (Table S4). Because of small size of some groups, we couldn't compare all samples. The age group 2+ was analyzed in the UA2, SK2, SK3, SK5 samples. The age group 3+ was analyzed in the UA2, SK2, SK4, SK5 samples.

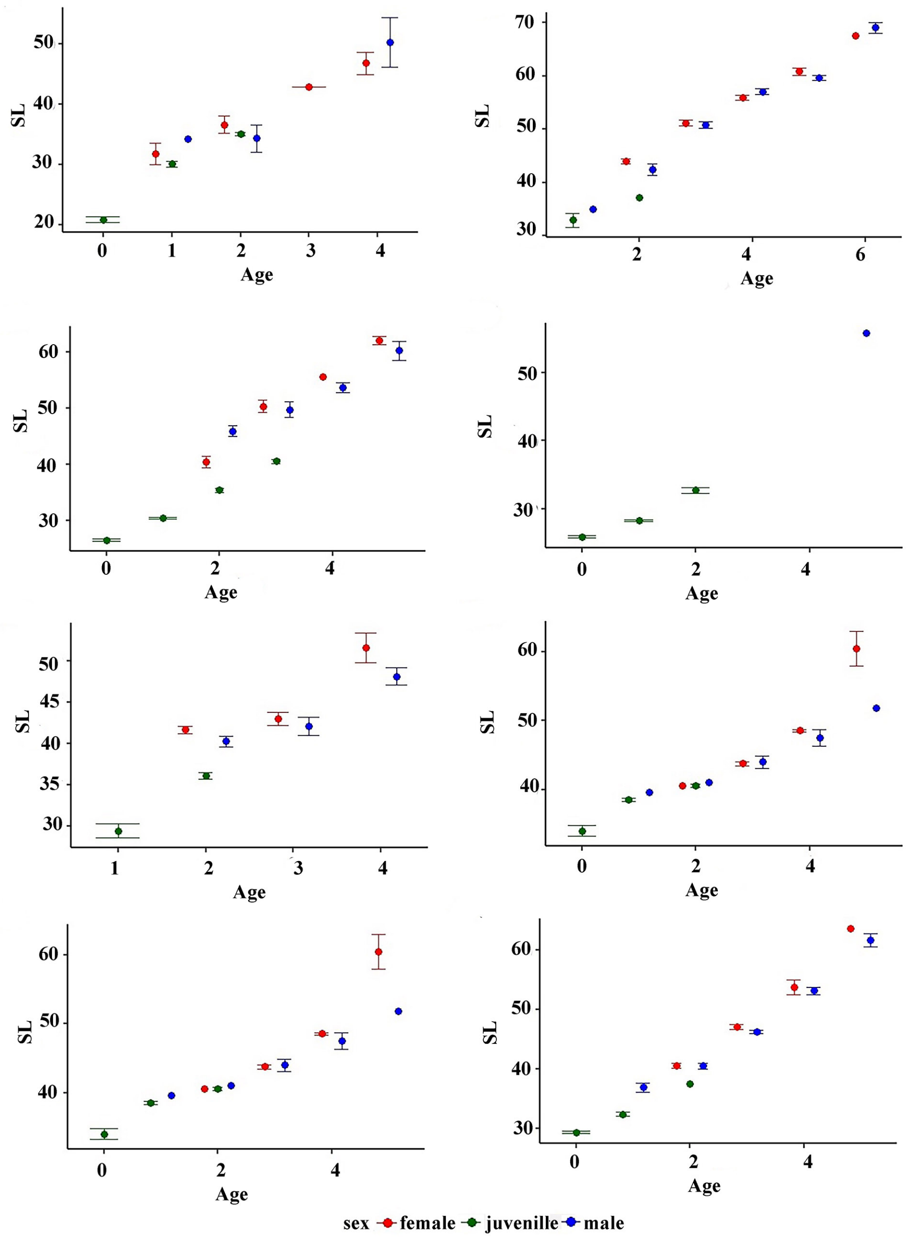

Figure 3. Mean standard length ± SE (mm) of *P. parva* in different ages.

The age group 4+ was analyzed in the samples UA2, UA3, SK2, SK4, SK5 samples. The age group 5+ was analyzed only in the UA2 sample. For presented groups there was no significant difference between males and females sizes. We can assume that for groups which weren't compared this tendency isn't different.

Discussion

While extensive data exist on *P. parva* distribution and biology across various environments, information on its life history traits in Ukrainian rivers remains incomplete (Movchan and Smirnov 1981; Kozlov 1974; Novitskiy et al. 2015). The widespread establishment and proliferation of *P. parva* can be attributed to several factors: wide ecological amplitude (Sunardi et al. 2005, 2007); highly plastic life history traits (Rosecchi et al. 2001; Pinder et al. 2005; Britton et al. 2007; Onikura and Nakajima 2013); generalized feeding habits (Rosecchi et al. 1993; Zhang et al. 1998; Xie et al. 2000).

Pseudorasbora parva is a small fish species, typically reaching up to 50 mm of total length (TL), with maximum reported lengths between 60 and 120 mm TL. Sexual maturity is usually attained in the first year of life (Gozlan et al. 2010).

Among Ukrainian samples, the maximum observed length was 71 mm, with variations across sampling sites. *Pseudorasbora parva* from UA1 were the smallest, while those from UA2 were the largest. The larger size of fish from UA2, a fish farm site, may be attributed to better food availability and reduced predation pressure, allowing specimens to attain greater sizes. The maximum observed standard length across all Slovak samples was 68 mm, with minimal variation among sites (64–68 mm). SK1 sample was not representative due to absence of mature specimens for this observation.

Previous studies have reported a maximum age of 5+ for *P. parva* (Ding et al. 2019; Benzer and Benzer 2020). In our study, we observed a maximum age of 6+ in two samples (UA2 (fish farm): 4 specimens, SK3 (canal): 1 specimen).

However, given the rarity of 6+ individuals (only 5 out of the entire sample set), this may be an exception rather than the norm. The majority of our samples had a maximum observed age of 5+, with two exceptions (maximum observed age for UA1 (river) and SK2 (river) was 4+).

Notably, specimens from UA1 and SK2 were also the smallest in terms of maximum observed length. The size difference could be attributed to habitat conditions, particularly the presence of predatory fish species (Northern pike (*Esox lucius*) for UA1, European chub (*Squalius cephalus*) for SK2), which were caught during our investigations. The presence of these predators may influence the survival rates of larger, older *P. parva* individuals in these riverine environments.

The length-weight relationship (LWR) parameters are influenced by various factors, including sex, gonadal maturity, health status, season, habitat, nutrition, environmental conditions (e.g., temperature and salinity), stomach fullness, overall physiological state, length range of specimens, and collection methods (Froese 2006; Tesch 1971; Oliveira et al. 2020).

In our study, the LWR exponent b for all samples was often close to 3. The coefficient of determination (r^2) exceeded 0.9 for most populations, indicating a strong positive relationship between length and weight. Only the SK2 sample showed a lower r^2 value, suggesting a weaker length-weight correlation in this population. These results are consistent with findings from other studies on *P. parva* (Benzer and Benzer 2020; Fan et al. 2015; Kirankaya et al. 2014; Stavrescu-Bedivan et al. 2017).

Immature specimens prevailed at the SK1 sample (99.5%), the SK5 sample (51.5%), the UA1 sample (86%) and the UA3 sample (88%). At the SK4 sample there were 50% of mature specimens. In other samples mature specimens prevail (68% for the SK2 sample, 94% for the SK3 sample, 98% for the UA2 sample). The difference can be due to higher fish mortality in rivers than in fish farms.

The most common immature age group is 0+ (76% in the UA1 sample, 67% in the UA3 sample, 35% in the SK5 sample, 56% in the SK1 sample, in the SK4 sample 1+ and 0+ has both the same 22%). For older age groups there were some differences between samples. For Ukrainian samples the most abundant age group was 4+ in the UA2 and UA1 sample (30% and 6% respectively) and 3+ (5%) in the UA3 sample. Among mature specimens at the Slovak samples, the 2+ age group predominated in most samples, with the exception of SK4, where the 3+ age group was most prevalent. These differences in population structure likely reflect varying environmental conditions and management practices across sites.

Špelić and Piria (2023) found that *P. parva* prefers water bodies with low flow rates and sandy or silty substrates, and is significantly associated with high local fish diversity. However, the natural or regulated state of the water body is not a significant predictor of *P. parva* presence.

Pseudorasbora parva exhibits high life history plasticity, facilitating its spread and success in new environments. Our study of well-established populations showed both similarities and differences with other studies. In our study, most specimens larger than 30–35 mm were mature. It is common for many *P. parva* populations (more than 30 mm; Záhorská et al. 2010; Czerniejewski et al. 2019; Nocita et al. 2023). According to mean length at maturity (Záhorská et al. 2010), we can assume that *P. parva* in northern populations reaches maturity at larger sizes, but the studied populations are more southern and keep the trend going. Most studies showed that the older age classes were caught in decreasing numbers displaying normal mortality rate in populations. In our study, older age groups prevailed in the fish farm samples while immature specimens prevailed in the samples from rivers. There are large populations of *P. parva* in the fish farms that could have a negative effect on fish stocks in those ponds. Also due to the lack of predators and amount of food resources it is easy for *P. parva* to reach larger sizes and more specimens can live longer while they are smaller in natural water bodies because of predator pressure and higher competition. As a result, fewer specimens reach older age.

This habitat-dependent variation in population structure underscores the adaptability of *P. parva* to diverse environmental conditions, while maintaining some consistent life history traits across populations.

Pseudorasbora parva is a common and abundant invasive alien species in both Ukraine and Slovakia. Its growth in the studied water bodies is isometric. Maturity age is 1+ or 2+ at the length about 30–40 mm. In both Ukrainian and Slovak fish farms older age groups are more abundant. In the habitats with natural food supply (rivers, meliorative canals), smaller age groups prevail (0+ and 1+). It may indicate significant invasive potential of *P. parva* in non-native areas. Overall, our data for Ukrainian and Slovak samples fit the common patterns in the expanded areas.

Authors' contribution

Conceptualization: A.S., Y.K.; methodology: A.S., J.F., L.P., Y.K.; formal analysis and investigation: A.S., J.F., L.P., Y.K.; writing – original draft preparation: A. S., Y.K.; writing – review and editing: A.S., J.F., L.P., Y.K.

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Supplementary material

The following supplementary material is available for this article:

Figure S1. Length-weight relationships of *Pseudorasbora parva.*
Table S1. Sampling locations.
Table S2. Standard lengths (mm) for different sexes of *P. parva.*
Table S3. Values of standard length (SL, mm) by sex and age group.
Table S4. Results of the mean standard length comparisons between sexes using Mann-Whitney test.

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