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On the sexual dimorphism in *Parafossarulus manchouricus* (Gerstfeldt in Bourguignat, 1860) (Bithyniidae, Gastropoda, Mollusca)

S.I. ANDREEVA [1, 2, 3], N.I. ANDREEV[2], E.A. LAZUTKINA[1], E.S. KRYAZHEVA[4]

[1]*Omsk State Medical University. 12, Lenin street, 644099, Omsk, RUSSIA. E-mail: siandreeva@yandex.ru;*
[2]*Omsk State Transport University. 35, Marks avenue, 644046, Omsk, RUSSIA. E-mail: nik_andreyev@mail.ru;*
[3]*Omsk State Pedagogical University. 14, Naberezhnaya Tukhachevskogo, 644043, Omsk, RUSSIA;*
[4]*Tyumen Region Infection Pathology Research Institute. 147, Respubliki street, 625026, Tyumen, RUSSIA. E-mail: kryazhevaes@Tniikip.rospotrebnadzor.ru*

ABSTRACT. On the basis of dissections and shell measurements we studied sexual dimorphism in shell shape in *Parafossarulus manchouricus* taken from the bay of the Bira River (Russian Far East). It is shown that there are no statistically significant differences in shells of males and females in *P. manchouricus*.

The presence or absence of the sexual dimorphism in shell shape is often used as a diagnostic trait in malacological publications dealing with mollusks of the family Bithyniidae, including the genus *Parafossarulus* Annandale, 1924. In due time, Itakagi [1965: 177] noted that "The shell of *Parafossarulus manchouricus* scarcely shows sexual dimorphism, but the male shells appear to be somewhat more slender than those of the female", whereas in the Russian literature the presence of the sexual dimorphism in shell shape has became an indubitable diagnostic character for the genus *Parafossarulus* [Starobogatov, Zatravkin, 1987], including a case when the sex of the holotype was determined judging from its shell outline [Zatravkin *et al*., 1989]. The authors of the most recent determination key for Russian snails of the subfamily Mysorellinae Annandale, 1920, which includes the genera *Boreoelona* Starobogatov et Streletzkaja, 1967 and *Parafossarulus* [Starobogatov *et al.*, 2004], assert that in these genera males have more slender shells comparing to females. In so doing, Starobogatov *et al.* [2004] do not corroborate their statement by measurements or other quantitative data.

We could not find in available literature any sound statistical analysis of this suggestion. Therefore the aim of this study was to verify if specimens of *P. manchouricus* with relatively slender shells are actually males, and whether it is possible to determine the snails' sex using shell characteristics alone.

Materials and methods

We studied samples of molluscs of the genus *Parafossarulus* collected in August of 2011 and June of 2015 in waterbodies of the Amur Region and the Jewish Autonomous Region, both situated in the south of the Russian Far East. The snails were collected during parasitological survey of waterbodies. In total, 248 specimens of *Parafossarulus* were found in these samples.

The taxonomic identification of the molluscs was carried out with using photos of types and reference specimens of different species of *Parafossarulus* from the malacological collection of the Zoological Institute of the Russian Academy of Sciences (Saint-Petersburg) kindly provided by Dr. T.Ya. Sitnikova. Drawings and photos of the shells presented in papers by Itagaki [1965] and Prozorova *et al.* [2014] were also taken into account during identification.

The largest sample, taken in a bay of the Bira River in Birobidzhan City, was used as primary material for estimation of the shell sexual dimorphism in *Parafossarulus manchouricus*. 60 specimens of this species, randomly selected, were classified by us as "females" and "males" visually, on the basis of their shell slenderness. It was the only available method of sex identification, since Starobogatov *et al.* [2004] did not give any exact quantitative criteria for sex determination using shell mea-

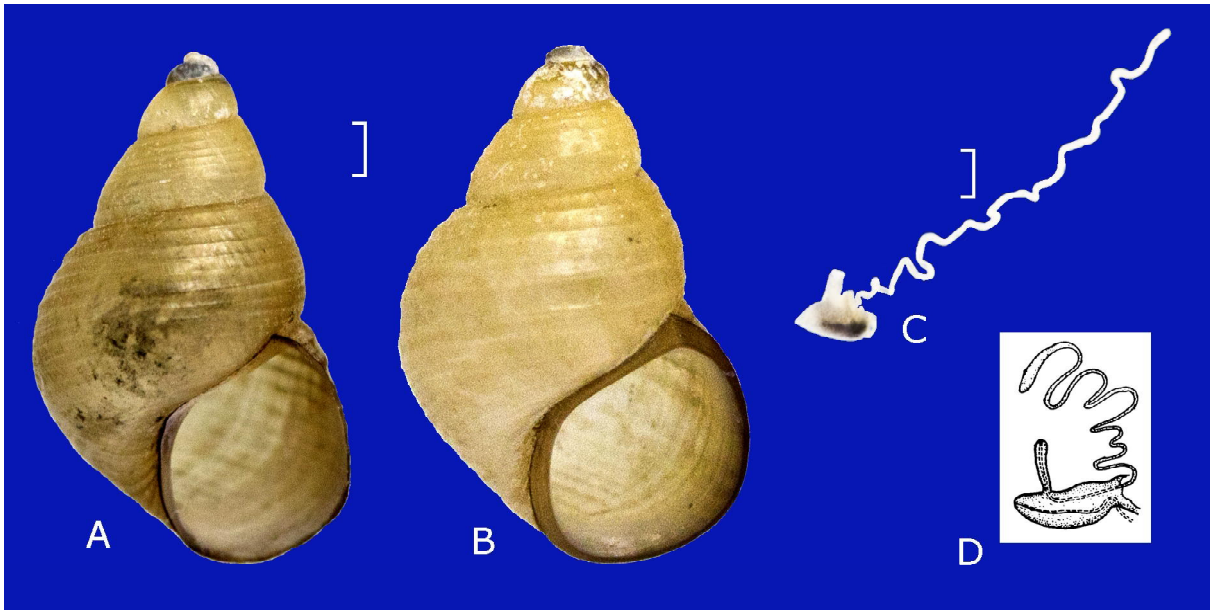

FIG. 1. *Parafossarulus manchouricus* from the bay of the Bira River: **A**. Shell of female. **B**. Shell of male. **C**. Penis. Scale bars (A-C): 1 mm. **D**. Penis of *P. manchouricus* after Itagaki [1965], the scale bar is absent in the original publication. A-C – photos by N.I. Andreev.

РИС.1. *Parafossarulus manchouricus* из залива р. Бира: **A.** Раковина самки. **B**. Раковина самца. **C**. Пенис. Масштаб (A-C): 1 мм. **D**. Рисунок пениса *P. manchouricus* из Itagaki [1965], масштаб в оригинале не приведен. A-C – фото Н.И. Андреева.

surements and/or their ratios. We treated as "males" all specimens with "narrow" slender shells (31 individuals), whereas snails with "wide" shell with inflated body whorls were classified as "females" (29 individuals).

Then, the snails were dissected, and their actual sex was determined unambiguously after examination of the genitals. For measuring shells the measurement scheme proposed by Starobogatov *et al.* [2004] and Andreeva *et al.* [2010] was used. In addition to six standard measures outlined in the two abovementioned works, we also measured the body whorl height above the aperture as the seventh measurement. Measurements were taken with the ocular-micrometer of the stereoscopic microscope MBS-9. "STATISTICA 6.0 for WINDOWS" software package was used for subsequent statistical analysis.

Results and discussion

After anatomical examination, we found that in the groups of "males" (snails with more slender shell) females dominate (17 females and 14 males), whereas in the group of mollusks with wider shells ("females") only 20 animals were the true females, whereas the rest 9 specimens were males. It means that even an experienced malacologist makes numerous mistakes when trying to determine the sex of *Parafossarulus* on the basis of conchological traits (Fig. 1).

The subsequent statistical analysis of shells of snails after their anatomical re-classification did not reveal any statistically significant differences between shells of "true" males and "true" females (Table 1), and conchologically both sexes belong to the same general totality.

The principal component analysis has shown that there are no two more or less distinct "clouds" of points in the two first PCs that would correspond to two sexes with expressed conchological dimorphism. Quite contrary, all measured shells fell into a single 'cloud' that means that there is no sexual dimorphism in conchological traits of the studied snail (Fig. 2).

Earlier [Lazutkina *et al.*, 2009, 2010; Vinarski *et al.*, 2012], we published some data on the absence of sexual dimorphism in shell characters in the Western Siberian populations of the snail *Boreoelona sibirica* (Westerlund, 1886) also classified within the subfamily Mysorellinae. Starobogatov and Streletzkaja [1967] as well as Starobogatov *et al.* [2004] reported that shells of *Boreoelona* does exhibit sexual dimorphism.

As a conclusion, we think that all statements confirming the presence of shell sexual dimorphism in bithyniid snails should be taken critically unless based on anatomical investigations.

Table 1. The comparative characteristics of shell quantitative traits of females and males of *Parafossarulus manchouricus* (above lines – limits of variation; below lines – mean values ± mean error).

Таблица 1. Сравнительная характеристика раковин самцов и самок *Parafossarulus manchouricus* (в числителе – пределы изменчивости, в знаменателе – средние значения ± ошибка среднего).

Measurement / index	Males (n = 23)	Females (n =37)	Significance of differences between means (Student's t-test)
Shell height, mm (SH)	8.9–11.0 9.9±0.1	8.8–11.0 10.0±0.1	0.86 (p = 0.39)
Shell width, mm (SW)	5.8–7.0 6.4±0.1	5.9–7.2 6.6±0.1	1.32 (p = 0.19)
Spire height, mm (SpH)	4.6–6.0 5.3±0.1	4.8–6.3 5.4±0.1	1.10 (p = 0.27)
Body whorl height, mm (BWH)	6.5–7.8 7.2±0.1	6.4–8.1 7.3±0.1	1.18 (p = 0.24)
Body whorl height above the aperture, mm (BWHap)	2.2–2.9 2.6±<0.1	2.2–3.1 2.7±<0.1	1.30 (p = 0.20)
Aperture height, mm (AH)	4.2–5.2 4.7±0.1	4.3–5.3 4.8±<0.1	1.71 (p = 0.09)
Aperture width, mm (AW)	3.1–4.3 3.8±0.1	3.3–4.2 3.8±<0.1	1.23 (p = 0.22)
SW/SH	0.61–0.69 0.65±<0.01	0.62–0.72 0.66±<0.01	0.81 (p = 0.42)
SpH/SH	0.52–0.57 0.54±<0.01	0.52–0.57 0.54±<0.01	1.01 (p = 0.32)
BWH/SH	0.70–0.76 0.73±<0.01	0.70–0.78 0.73±<0.01	0.76 (p = 0.45)
AH/SH	0.42–0.51 0.47±<0.01	0.44–0.52 0.48±<0.01	1.07 (p = 0.29)
AW/AH	0.74–0.88 0.81±0.01	0.73–0.89 0.80±0.01	–0.35 (p = 0.73)
BWHap /SH	0.25–0.28 0.26±<0.01	0.25–0.29 0.27±<0.01	1.03 (p = 0.31)
BWHap /BWH	0.33–0.38 0.36±<0.01	0.33–0.38 0.36±<0.01	0.59 (p = 0.56)

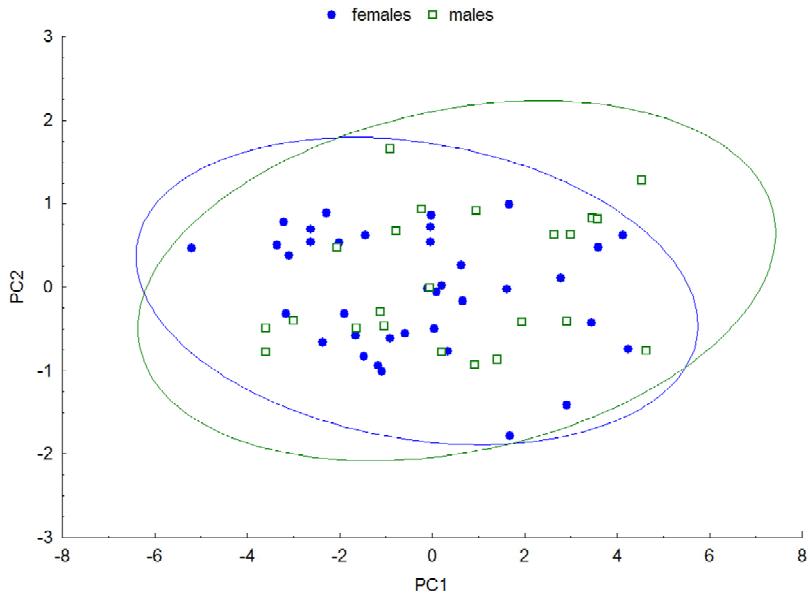

FIG. 2. Distribution of specimens of different sex of *Parafossarulus manchouricus* in the plain of the first and second principal components. The first PC explains 82.6% of variance, the second PC explain 7.6 % of variance.

РИС. 2. Распределение разнополых особей *Parafossarulus manchouricus* в плоскости первой и второй главных компонент. Первая ГК объясняет 82.6% изменчивости, вторая ГК – 7.6% изменчивости.

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К вопросу о половом диморфизме у *Parafossarulus manchouricus* (Gerstfeldt in Bourquignat, 1860) (Bithyniidae, Gastropoda, Mollusca)

С. И. АНДРЕЕВА[1,2,3], Н. И. АНДРЕЕВ[2],
Е. А. ЛАЗУТКИНА[1], Е. С. КРЯЖЕВА[4]

[1]Омский государственный медицинский университет, 644043 , Омск, ул. Ленина, 12;
e-mail: siandreeva@yandex.ru
[2]Омский государственный университет путей сообщения 644046, Омск, пр. Маркса, 35;
e-mail: nik_andreyev@mail.ru
[3]Омский государственный педагогический университет 644043, Омск, наб. им. Тухачевского, 14
[4]Тюменский научно-исследовательский институт краевой инфекционной патологии 625026, Тюмень, ул. Республики, 147;
e-mail: kryazhevaes@Tniikip.rospotrebnadzor.ru

РЕЗЮМЕ. На основании анатомирования моллюсков и морфометрии раковин проверена гипотеза о наличии полового диморфизма в форме раковины *Parafossarulus manchouricus* из залива р. Бира. Показано, что статистически значимых различий по раковине у самок и самцов *P. manchouricus* не наблюдается.