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The first molecular confirmation of the presence of the genus *Ladislavella* (Gastropoda: Lymnaeidae) in the European part of Russia

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ABSTRACT. The article reports the finding of a population of freshwater snails morphologically and genetically identified as *Ladislavella* cf. *terebra* (Westerlund, 1885), in a reservoir situated in Penza City. This is the first reliable record of representatives of the genus *Ladislavella* on the territory of European Russia, at a considerable distance from the previously known boundaries of its range. Molecular data suggest that the examined population belongs to the previously unknown species of *Ladislavella*. The morphoanatomic and ecological characteristics of the studied population and some information about parasites and commensals of the molluscs are given.

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Первое молекулярное подтверждение обитания рода *Ladislavella* (Gastropoda: Lymnaeidae) в европейской части России

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РЕЗЮМЕ. В статье описывается обнаружение популяции пресноводных моллюсков, морфологически и генетически идентифицированных как *Ladislavella* cf. *terebra* (Westerlund, 1885), в водоеме, расположенном в г. Пенза. Это первое достоверное нахождение представителей рода *Ladislavella* на территории Европейской России, в значительном удалении от ранее известных границ его распространения. Молекулярные данные позволяют предположить, что обследованная популяция относится к ранее неописанному виду *Ladislavella*. Приведены морфо-анатомическая и экологическая характеристики изученной популяции, некоторые сведения о паразитах и комменсалах моллюсков.

Introduction

Ladislavella terebra (Westerlund, 1885), a representative of the family Lymnaeidae Rafinesque, 1815 (pond snails), has long been thought to be endemic to Siberia and adjacent areas. It was described from the locality labelled as ‘Siberia, Tunguska’, which, most probably, corresponds to the Podkamennaya Tunguska River, and subsequently, it was recorded from various parts of Western and Eastern Siberia [Starobogatov, Streletzkaja, 1967; Kruglov, Starobogatov, 1986; Dolgin, 2001; Kruglov, 2005; Vinarski, Glöer, 2008; Khokhutkin *et al.*, 2009; Andreeva *et al.*, 2010; Vinarski, 2012] as well as from Northern

Mongolia [Vinarski *et al.*, 2017]. *Lymnaea palustris bolotensis* Mozley, 1934, a junior synonym of *L. terebra*, is known from Kazakhstan [Vinarski, 2012]. A closely related vicariant species, *Ladislavella occulta* (Jackiewicz, 1959), is distributed in Eastern and Central Europe; its type locality is situated in Poland [Jackiewicz, 1959, 1998; Stadnichenko, 1968; Korniushin, 1999; Glöer, 2002; Vinarski, 2012].

Based on the overall similarity between *L. terebra* and *L. occulta*, Vinarski [2003, 2005, 2012; Vinarski, Glöer, 2008] proposed to synonymize these two species, and it was accepted by some authors [Piechocki, Wawrzyniak-Wydrowska, 2016; Anistratenko *et al.*, 2018]. However, recently Pieńkowska and Lesicki [2018] provided molecular data allowing distinguishing between these morphologically cryptic species, and the Eastern European populations of this snail are again classified as *L. occulta* [Glöer, 2019]. The easternmost localities of *L. occulta* are situated in Western and Central Ukraine [Korniushin, 1999], and, thus, there is a wide gap in distribution of these species, embracing almost the whole European Russia.

Nowadays, the genetic approach to identification of lymnaeid snails is acknowledged as being the most effective, since the conchological characters of these molluscs are often extremely variable, and their parameters can overlap between closely related species. Even anatomical data, once thought to be the best character for species delineation and identification in the Lymnaeidae [Jackiewicz, 1998; Kruglov, 2005; Vinarski, 2011] are now regarded unsuitable; many 'good' lymnaeid species demonstrate virtually no differences in their reproductive anatomy [Aksenova *et al.*, 2018; Vinarski *et al.*, 2020].

An extensive study of malacological collections of Russia and some West European countries has allowed Vinarski [2020] to hypothesize that the species *L. terebra* occurs in the European part of Russia though it has never been included into faunal lists of this territory [Zhadin, 1952; Starobogatov, 1977; Leshko, 1998; Starobogatov *et al.*, 2004; Kruglov, 2005; Palatov, Vinarski, 2014; Kijashko *et al.*, 2016]. The few published finds of this species from European Russia were made in its marginal parts, namely, from the Pechora River basin, Kolguev Island, Perm, and Orenburg [Smith, 1896; Vinarski, Glöer, 2008; Vinarski, 2020; Bespalaya *et al.*, 2022]. All these recordings were based on historical museum samples, represented by empty shells. However, a molecular survey of the malacofauna of Kolguev Island and the Pechora River basin has revealed the occurrence of a conchologically similar species, *Stagnicola palustris* (O.F. Müller, 1774), there, whereas the presence of *L. terebra* in these areas has not been confirmed [Bolotov *et al.*, 2014; Bespalaya *et al.*, 2017; our unpublished data]. Thus, the western border of *L. terebra* range remains unknown, and its finding in the European part of Russia wait for approval.

In November 2021, in the process of soil sampling, two authors of this work (T.G.S. and E.V.K.) found snail individuals morphologically similar to *Ladislavella terebra* in the middle Volga basin, in Penza Region of Russia. The further observations have shown that there is a living population of this snail.

This fact can be considered the first reliable finding of the genus *Ladislavella* in the Russian part of the Eastern European plain, which greatly extends its known range. This article aims at description of this finding and illustrating the morphology of the newly discovered population and the clarification of its taxonomic position by means of molecular genetic analysis. In addition, we provide some information about parasites and epibiotic commensals of these snails registered during the field and laboratory studies.

Material and methods

Empty shells and aestivating individuals of pond snails, provisionally identified as *Ladislavella* cf. *terebra*, were for the first time found by us in November 2021, in the process of soil sampling from the bottom of a dried pond in Penza City (coordinates: 53.156851 N, 45.105405 E). On the left bank of the river there is a system of oxbow lakes, in which rich vegetation develops and various species of mollusks live, including lymnaeid snails. The studied pond is situated on the right bank of the Staraya Sura River, and, until 1945, it was a part of the riverbed. Since 1945, the habitat has been fragmented, and today only a series of isolated temporary ponds occupies the place of the former riverbed. Fig. 1 shows the studied locality in different seasons.

In the summer of 2022, when the pond filled up again, we continued our observations and were able to collect a significant number of live individuals of *L.* cf. *terebra*. This part of the study continued until the habitat dried up in early autumn. Molluscs were fixed in the field with 96% ethanol. Some of sampled individuals were taken to the laboratory, where they were placed in 200 ml micro aquariums and fed *ad libitum* with leaves of *Taraxacum officinalis* (L.). To determine the infestation of snails by trematode larvae, some individuals were dissected, and the method of *in vivo* diagnostics was also used. For this end, at the end of August, snails were kept individually in vessels with a volume of 100 ml of water, illuminating with a table lamp. Vessels were checked every day to detect trematode cercariae emerging from the molluscs. The duration of these observations was one week.

Morphological study of collected specimens, including shell measurements and dissection of snails,

FIG. 1. View of the studied biotope in different seasons of the year. Photos taken on 15.04.2022 (**A**), 05.06.2022 (**B**), 20.07.2022 (**C**).

РИС. 1. Вид исследованного биотопа в разные сезоны года. Фотографии сделаны 15.04.2022 (**A**), 05.06.2022 (**B**), 20.07.2022 (**C**).

was carried out following the standard protocols described in Kruglov [2005], Andreeva *et al.* [2010], and Kijashko *et al.* [2016]. Both conchological and anatomical characters (shape, size and coloration of the copulatory apparatus) were used for species identification. Morphological characters of studied individuals were compared with descriptions and illustrations of *L. terebra* in taxonomic works and identification keys [Jackiewicz, 1998; Kruglov, 2005; Vinarski, Glöer, 2008; Khokhutkin *et al.*, 2009; Andreeva *et al.*, 2010; Vinarski, 2012, 2020]. The identification of ciliate protozoans found on the shell surfaces of collected snails was made following Kutikova [1984].

Photographs of shells, soft body parts, and trematode cercariae were made using eyepiece WF16X of the microscope "Biomed-6" equipped with x10 objectives.

The linear dimensions of 72 shells were measured with an eyepiece ruler under a binocular with an accuracy of 0.1 mm, as well as with an electronic caliper with an accuracy of 0.01 mm. Only specimens with the same whorl number were used for measurements and subsequent comparisons. The studied material is kept at Department of Zoology and Ecology, Faculty of Physical-Mathematical and Natural Sciences of the Penza State University, Russia.

Molecular study of collected specimens (DNA extraction, PCR, and sequencing) were performed as described in our previous work [Bolotov *et al.*, 2017]. This study includes new unpublished DNA sequence molecular data for 5 *Ladislavella* specimens (Table 1). New sequences of the mitochondrial cytochrome c oxidase subunit I (COI) were amplified from these *Ladislavella* samples.

The alignment of the COI sequences was performed directly using the ClustalW algorithm [Thompson *et al.*, 1994]. For the phylogenetic analyses, each COI sequence of aligned datasets was trimmed, leaving a 657-bp fragment. Then, identical COI sequences were removed from the dataset using an online FASTA sequence toolbox [FaBox1.41: Villesen, 2007], leaving a total of 8 haplotype sequences (including the two outgroup taxa). The maximum likelihood phylogenetic analyses were carried out with an online version of IQ-TREE v1.6.11 [Trifinopoulos *et al.*, 2016] using an ultrafast bootstrap algorithm [Hoang *et al.*, 2017] and an automatic identification of the most appropriate substitution models [Kalyaanamoorthy *et al.*, 2017]. Sequences of the lymnaeid species *Pseudosuccinea columella* (Say, 1817) and *Galba truncatula* (O.F. Müller, 1774) were used as the outgroups.

Sequenced samples of snails are kept at in the Russian Museum of Biodiversity Hotspots (RMBH), N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences, Arkhangelsk, Russia.

Results and discussion

Shell characters of the studied snails fit well with

Table 1. List of *COI* sequences of *Ladislavella* species used in this study.

Таблица 1. Список последовательностей гена COI для видов рода *Ladislavella*, использованных в исследовании.

Species	GenBank acc. no	Specimen voucher no.	Locality	Reference
Ladislavella cf. *terebra*	OQ134384	MLym1118/1	Russia: Penza Oblast	Present study
*L.*cf. *terebra*	OQ134385	MLym1118/2	Russia: Penza Oblast	Present study
L. cf. *terebra*	OQ134386	MLym1118/3	Russia: Penza Oblast	Present study
L. terebra	ON603568	MLym849	Russia: Khanty-Mansi Autonomous Okrug	Present study
L. terebra	LT623591	SNSD Moll: 52850	Russia: Tyumen Oblast	Schniebs *et al*. [2018]
L. liogyra	MH190007	MLym495/6	Russia: Primorsky Krai	Aksenova *et al*. [2018]
L. liogyra	OP084702	MLym495	Russia: Primorsky Krai	Present study
L. occulta	KP070796	So13	Poland	Pieńkowska *et al*. [2015]
Ladislavella sp.	ON603577	MLym950	Russia: Altai Republic	Present study
Ladislavella sp.	LT623592	SNSD Moll: S1169	Russia: Altai Republic	Schniebs *et al*. [2018]
L. catascopium	KP830102	MLym3	Russia: Kamchatka Krai	Vinarski *et al*. [2016]
*Pseudosuccinea columella**	ON603558	MLym775	Canada: Ontario	Present study
*Galba truncatula**	MH189885	MLym49	Russia: Nenets Autonomous Okrug	Aksenova *et al*. [2018]

* - These species were used as outgroup for Maximum likelihood analyses.

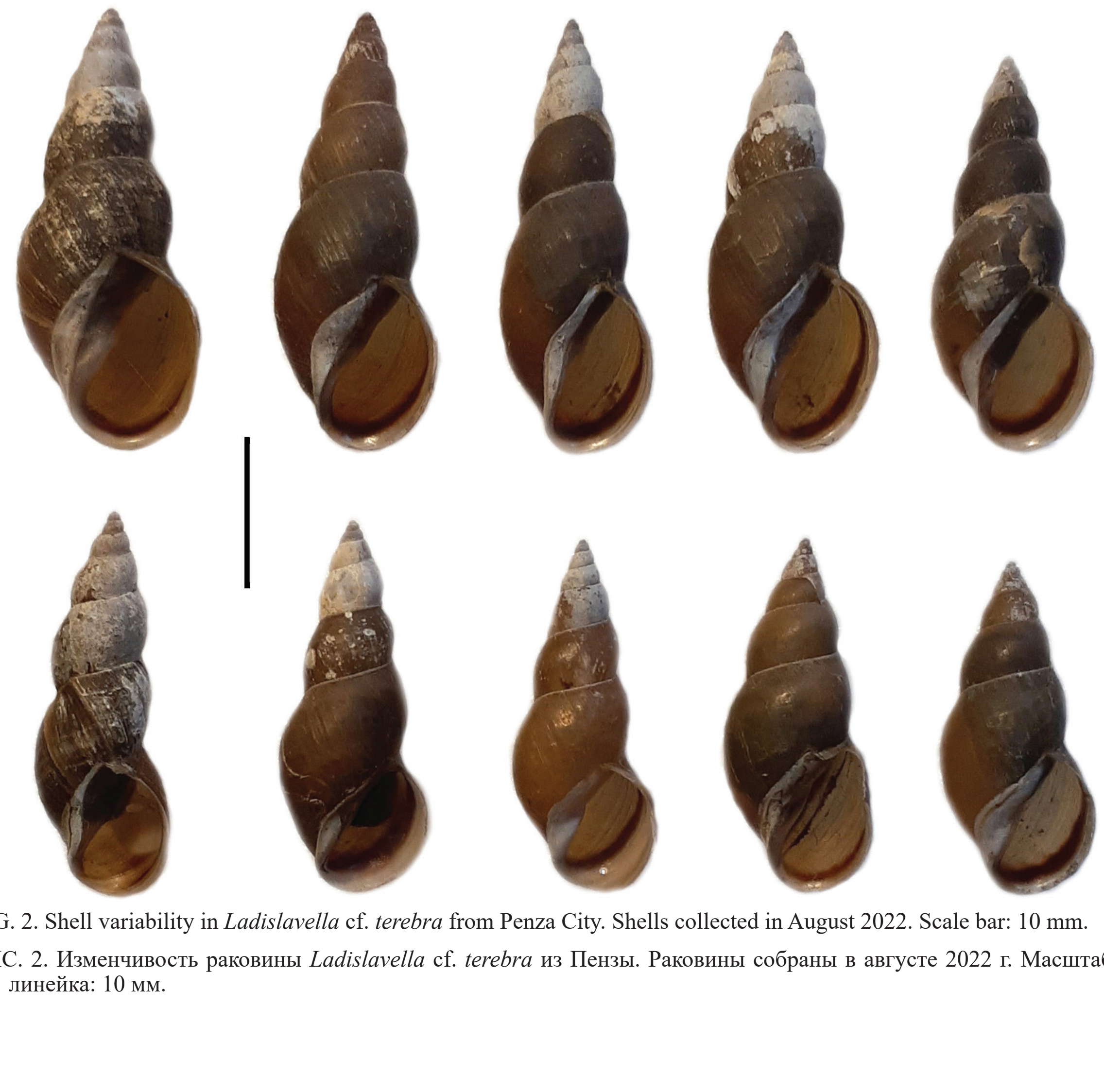

FIG. 2. Shell variability in *Ladislavella* cf. *terebra* from Penza City. Shells collected in August 2022. Scale bar: 10 mm.

РИС. 2. Изменчивость раковины *Ladislavella* cf. *terebra* из Пензы. Раковины собраны в августе 2022 г. Масштабная линейка: 10 мм.

diagnostic characters of *Ladislavella terebra* as they are described in the literature (see Introduction). Most of the collected shells were turriculate or almost cylindrical in their shape, with 6–7 whorls and wide white columellar lip (Fig. 2). The praeputium is dark-pigmented, the penis sheath oblong, relatively wide (its width is only slightly less than that of the praeputium) (Fig. 3, A; 4, B). The morphology of examined individuals did not differ from that of *L. terebra* from Siberia [Starobogatov, Streletzkaja, 1967; Vinarski, Glöer, 2008; Khokhutkin *et al.*, 2009; Andreeva *et al.*, 2010; Vinarski, 2012]. Therefore, we provisionally identified our material as belonging to *L. terebra*. However, a molecular study based on COI sequences has revealed that the snails collected in Penza can belong to a separate, still undescribed species of *Ladislavella* (Fig. 5). The genetic distance between them and snails identified as *L. terebra* from Western Siberia is high enough to ensure the separate species status of the Penza snails. However, we still do not have sequences of the topotypic specimens of *L. terebra* from the Podkamennaya Tunguska River basin, which makes the identification of the "true" *L. terebra* somewhat problematic and, consequently, affects the application of this taxonomic name. In addition, we still do not possess the sequences of genes other than COI. In this situation, it is most appropriate to designate here the discussed snails as *L.* cf. *terebra* and to leave the question of their exact

FIG. 3. The copulatory apparatus of *Ladislavella* cf. *terebra* from Penza City (**A**) and from Siberia, Tyumen Region, Labytnangi Town (**B**). Scale bar: 5 mm. A – original photo; B – photo by Dmitry Palatov.

РИС. 3. Копулятивный аппарат *Ladislavella* cf. *terebra* из Пензы (**A**) и Сибири, Тюменская обл., г. Лабытнанги (**B**). Масштабная линейка: 5 mm. A – ориг.; B – фото Дмитрия Палатова.

FIG. 4. Abnormally large individual of *Ladislavella* cf. *terebra* with trematode parthenitae in the hepatopancreas and mantle cavity. **A**. Shell. **B**. The copulatory apparatus. **C**. Soft body. Scale bars: 2 mm (B, C), 5 mm (A).

РИС. 4. Аномально крупная особь *Ladislavella* cf. *terebra* с партенитами трематод в гепатопанкреасе и мантийной полости. **A**. Раковина. **B**. Копулятивный аппарат. **C**. Мягкое тело. Масштабная линейка: 2 мм (B, C), 5 мм (A).

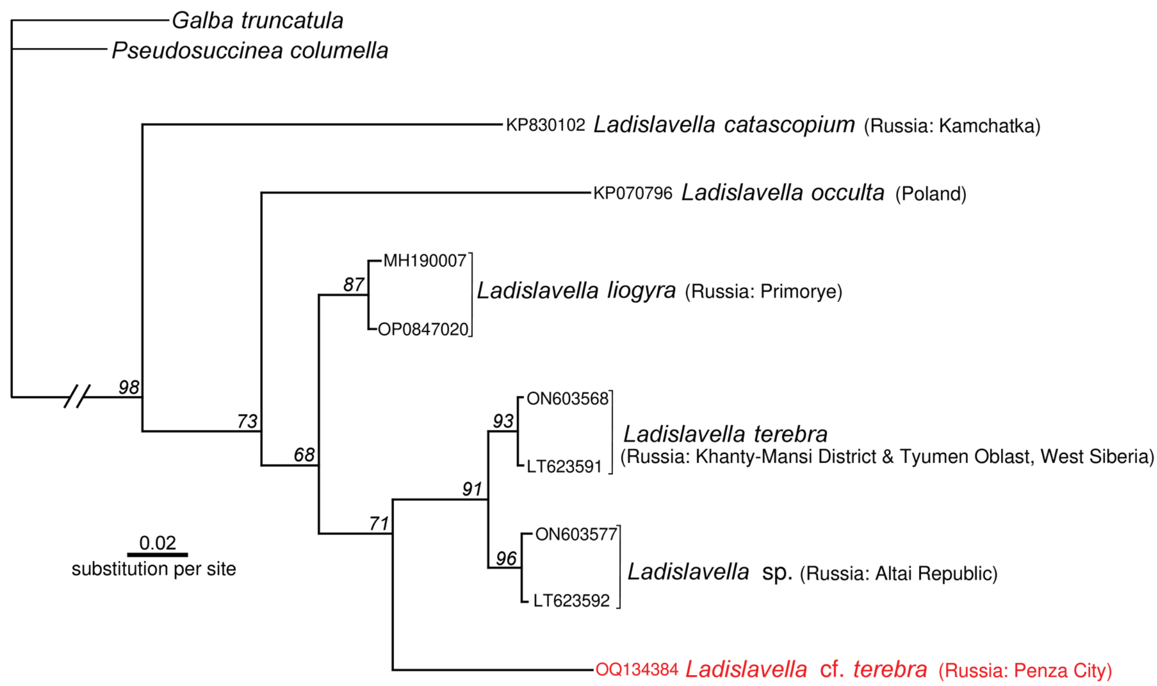

FIG. 5. Maximum likelihood phylogeny of *Ladislavella* species based on the COI barcode sequence dataset. The red color indicates our sequence from Penza City. Black numbers near nodes are bootstrap support values. Scale bar indicates the branch length.

РИС. 5. Молекулярная филогения с использованием метода максимального правдоподобия на основе нуклеотидных последовательностей фрагмента митохондриального гена COI. Красным цветом обозначен наш сиквенс для образца из Пензы. Черные числа в узлах – значения индексов бутстреп-поддержки. Масштабная линейка указывает длину ветвей.

taxonomic position to a further research. The genetic data, however, allow us to reject the hypothesis that snails collected in Penza belong to *L. occulta*. Vinarski [2020] inclines to identify all *Ladislavella* from Ukraine and the middle part of European Russia as *L. occulta*, but his conclusion, based on an examination of the shell material only, lacks a molecular support.

Morphologically, many of the collected specimens can be considered relatively large, as compared with the typical values of shell size reported for *L. terebra*. Khokhutkin *et al.* [2009] and Kijashko *et al.* [2016] gave the maximal shell height of this species as equal to 25 mm. However, around the half of the measured shells exceeded this size (Table 2). The origin of unusually large individuals of *L.* cf. *terebra* in the studied pond can tentatively be related to the effect of parasitic castration, not rare among aquatic gastropods [Wilke, Falniowski, 2001; Lafferty, Kuris, 2009], including the lymnaeids [Wilson, Davison, 1980; Chapuis, 2009]. The dissection of two particularly large individuals collected in August 2022, whose shell height exceeded 30 mm, has shown that they were heavily infected by trematode larvae; their hepatopancreas was enlarged, and numerous trematode parthenitae were seen in the mantle cavity (Fig. 4). Among nine dissected specimens with shell height 25–30 mm, six were parasitized by trematodes.

After aestivation, the first living specimens of *L.* cf. *terebra* were found in the studied pond on April 15, 2022, at a water temperature of 5–8° C. The shells of most of these individuals were covered by peritrich ciliates (*Epistylis* sp.) (Fig. 6). These protozoans are known as epibionts of freshwater snails belonging to different families [Dias *et al.*, 2006; Sartini *et al.*, 2018] as well as of other groups of freshwater mac-

Table 2. Morphometric characteristics of the measured shells of *Ladislavella* cf. *terebra*.

Таблица 2. Морфометрическая характеристика промеренных раковин *Ladislavella* cf. *terebra*

Shell parameter	At 7 whorls (n = 37)			At 6 whorls (n =35)		
	Min–max	M±m, mm	Cv, %	Min–max	M±m, mm	Cv, %
Shell height	20.7–31.8	25.0±0.4	10.5	16.6–23.3	20.6±0.3	9.0
Shell width	7.1–11.0	9.5±0.2	10.6	7.1–8.8	8.3±0.1	9.1
Aperture height	7.7–11.8	10.3±0.2	9.9	8.1–7.1	9.3±0.1	8.4
Body whorl height	12.6–18.5	15.7±0.3	9.7	12–15.3	13.8±0.2	7.8

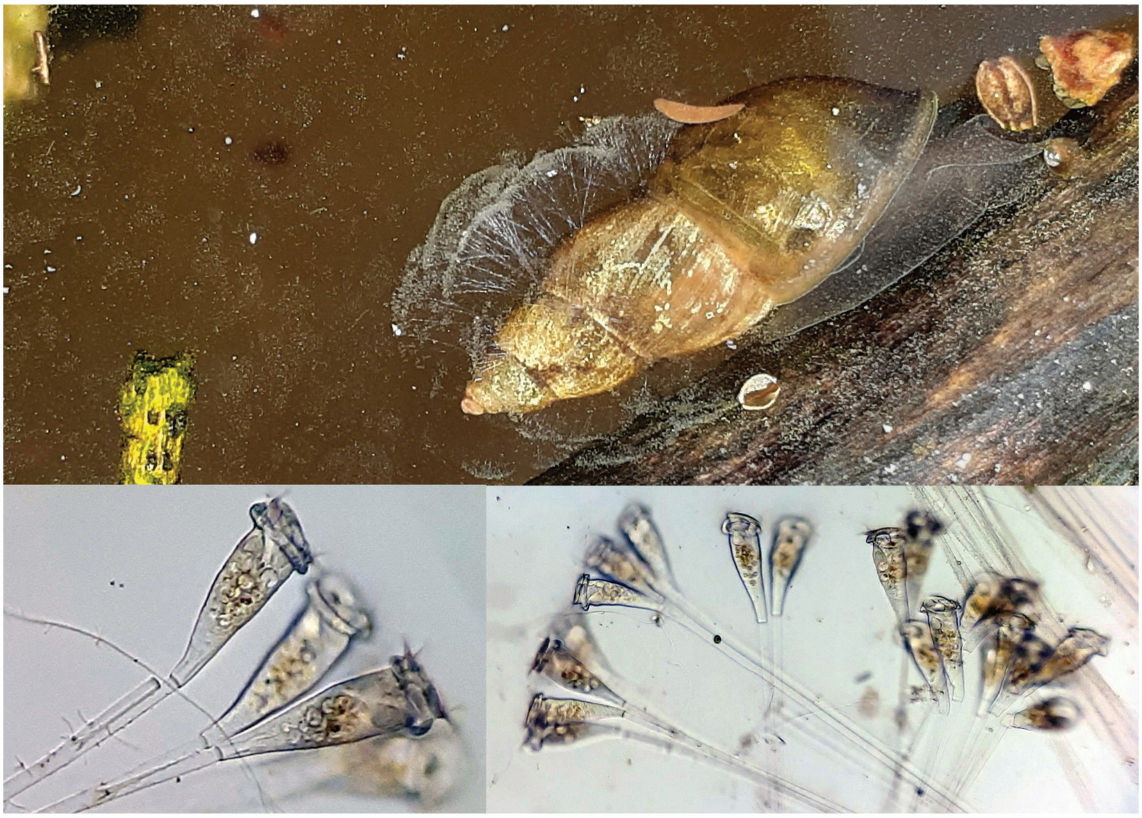

FIG. 6. The ciliate *Epistylis* sp. on surface of the shell of *Ladislavella* cf. *terebra.*

РИС. 6. Колонии инфузорий *Epistylis* sp. на поверхности раковины прудовика *Ladislavella* cf. *terebra.*

roinvertebrates [Clamp *et al.*, 2016; Ramírez-Ballestrini *et al.*, 2018]. In early May, egg-masses of *L. terebra* began to appear in the pond. The snails taken to the laboratory started to oviposit at the same time. The egg-masses are oblong, spirally twisted, which is typical for the egg-masses of *L. terebra* described from Western Siberia [Vinarski, 2005].

A week later, the shell and foot were already formed in the embryos within the egg, and the hatching was observed after two weeks since the oviposition; the hatchlings had shells with three whorls. It took more than three months for the full completion of the fifth whorl and the start of the sixth whorl formation. The final shell size of the laboratory reared *L. terebra* was approximately two times less than of those that developed under natural conditions. Moreover, their shells were much slender as compared with those collected from the natural habitat. The mean shell height in adult snails from the aquarium culture was 14.5 ± 0.8 mm (min-max 12.3–18.7 mm; n = 7).

In an experiment on *in vivo* diagnosis of infestation of molluscs by trematodes, cercariae were found in three out of seven individuals subjected to it. At the same time, two species of trematodes were found in one of them. The cercariae of the detected trematodes were identified as *Leptophallus nigrovenosus* (Bellingham, 1844) and *Cotylurus syrius* Dubois, 1934.

Further research is needed to outline the distribution pattern of *Ladislavella* snails in the Volga Basin and the peculiarities of their ecology in the European Russia. The data on parasitofauna of this species are also very scarce, and no data on this subject is available for localities situated outside Northern Asia.

The finding of *L. terebra* reported in this paper has some zoogeographic implication. Makhrov *et al.* [2022] included the discussed species into a list of freshwater molluscs having a peculiar pattern of distribution, namely they occur throughout the entire Siberia, but in Europe are found only in its northeastern part. This is interpreted as a sign of relatively late dispersal to Europe from Siberia, where these species evolved. According to Makhrov *et al.* [2022], *L. terebra* might have migrated to Europe before the Pleistocene glaciations, i.e., in the Pliocene. Our data, which confirm the presence of a closely related and, probably, derived species of *Ladislavella,* in the middle Volga basin, give some support to this assumption. The presence of shells, morphologically similar to those of *L. terebra*, in historical samples collected in various regions of European Russia [see also Vinarski, 2020] makes it highly probable that the discussed snail is distributed in the East European Plain much wider than it was thought before. The westernmost border of its distribution in Europe has to be determined in future.

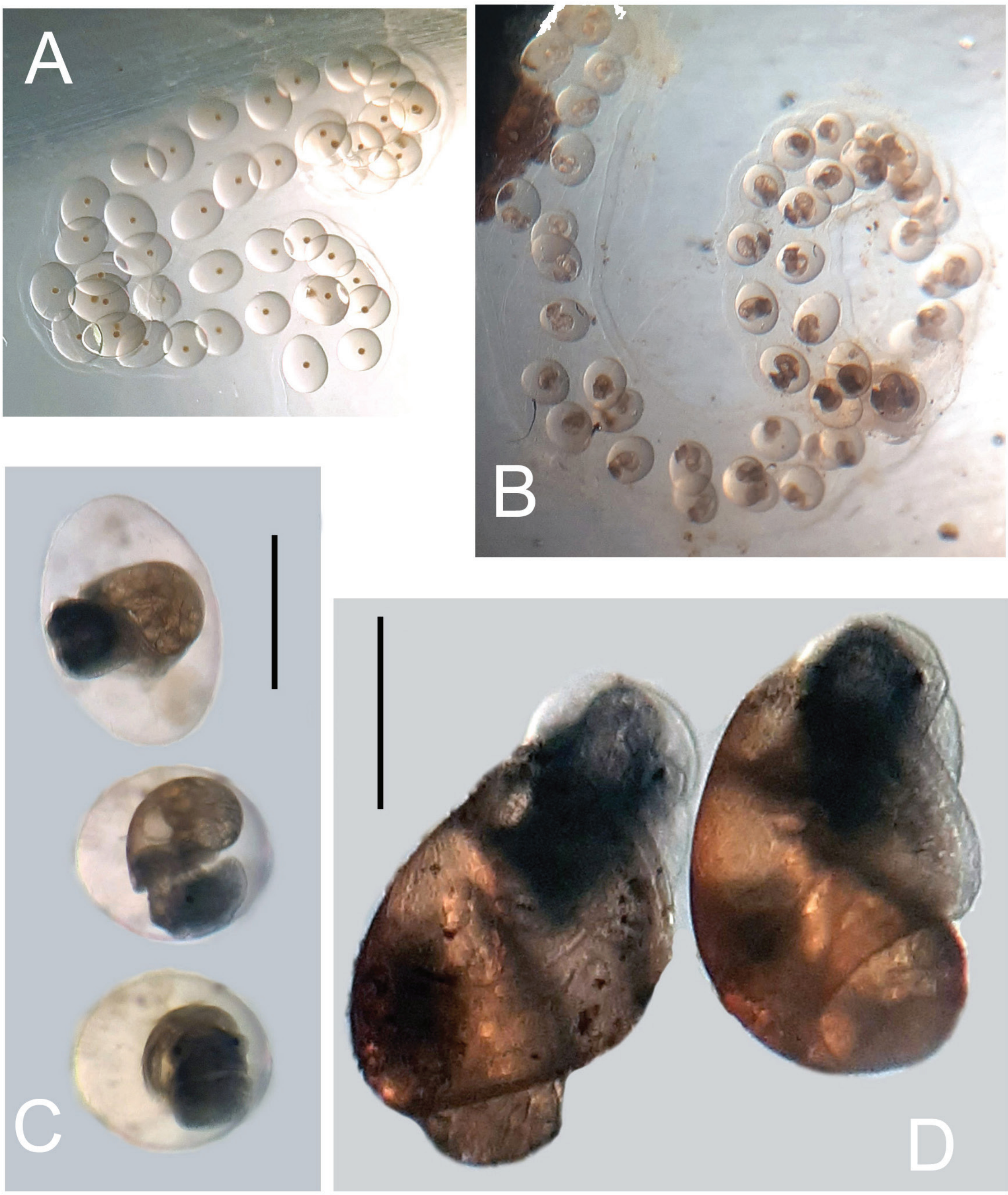

FIG. 7. Some stages of embryonic development of *Ladislavella* cf. *terebra.* in the lab culture. The successive photo images were made on: 06.05.2022 (**A**), 14.05.2022 (**B, C**), 17.05.2022 (**D**). Scale bars: 0.2 mm (C), 0.25 mm (D).

РИС. 7. Некоторые стадии эмбрионального развития *Ladislavella* cf. *terebra* в лабораторной культуре. Фото были сделаны: 06.05.2022 (**A**), 14.05.2022 (**B, C**), 17.05.2022 (**D**). Масштабная линейка: 0.2 мм (C), 0.25 мм (D).

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