

On the *Theodoxus prevostianus* (C. Pfeiffer, 1828) population of the Tükör Spring in Kács (Hungary)

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Abstract: For the past nearly 15 years, we have been conducting freshwater malacological studies in the Kács spring area, a wetland of great importance in the South-Eastern Bükk (Hungary). The focus of our research is the species *Theodoxus prevostianus* (C. Pfeiffer, 1828). In the present study, population density records from the direct outlet of the tepidwater Tükör Spring are presented and compared. At the study site, the number of individuals of the accompanying malacofauna of the species under study was also recorded (*Microcolpia daudebartii* (Prevost, 1821), *Bythinella thermophila* Glöer, Varga et Mrkvicka, 2015, *Bythinella pannonica* (Frauenfeld, 1865)). The data were recorded in 2006 (general survey), 2010 (drastic reduction) and 2021 (relocation). On the stone slab squares used to record individual counts, we detected a high-density population in 2006, a drastically reduced population in 2010 and a high-density population again in 2021.

Keywords: freshwater snails, highly protected species, Mollusca, monitoring

Introduction

The *Theodoxus prevostianus* (C. Pfeiffer, 1828) (Gastropoda: Neritidae) is a rare, relict, endemic, highly protected freshwater snail species of the Pannonian biogeographical region (European Habitat Directive, Annex IV). Ovoid-hemispherical in shape, 6–9 mm wide by 2–6 mm high, with a shell of three convolutions, twisted to the right, bright black in colour (Fig. 1a), sometimes with dark purple hues providing a unique colouration (Fig. 1b). The last convolution becomes wider, and the aperture takes the shape of a crescent (Richnovszky & Pintér, 1979).

The few references in professional literature associate the species mainly with the direct outlet of tepid water (20–24°C) karst springs. Earlier observations (Soós, 1943; Lukács, 1959) show that at lower water temperature ranges (min. 15.5°C), the *T. prevostianus* is viable and able to reproduce.

They are typically found in the zones filled with solid bed material in the headwaters. They are present in high densities on the surface of the stones (Fig. 1c).

They are a dioecious species and they lay their eggs on the undersurface of stones or on the shells of other snails in the vicinity.

Now only four natural populations are left in the world. In recent decades, its habitat has declined mainly due to human interventions (dredging, construction). On the IUCN Red List, the species is classified as “endangered”.

The only habitat in Hungary where the *T. prevostianus* has survived in its natural state is in the Bükk, in the Kács spring group in the Bükkalja region. In 2010, Hungarian malacologists successfully translocated the species to an old and previously extinct habitat, the Sályi Spring (Fehér et al., 2011, 2017). Outside Hungary, Neritidae are recorded in the malacological literature in the hypothermal springs of Bad Vöslau and Bad Fischau in Austria and Bušeča Vas in Slovenia.

List of current and previously known and extinct Pannonian basin habitats (Fig. 2): Hungary: [1] Kács springs (Kács), [2] Sályi Spring (Sály Lator-Vízfő), [3] Hejő Stream (Miskolc–Dudujka), [4] Springs of

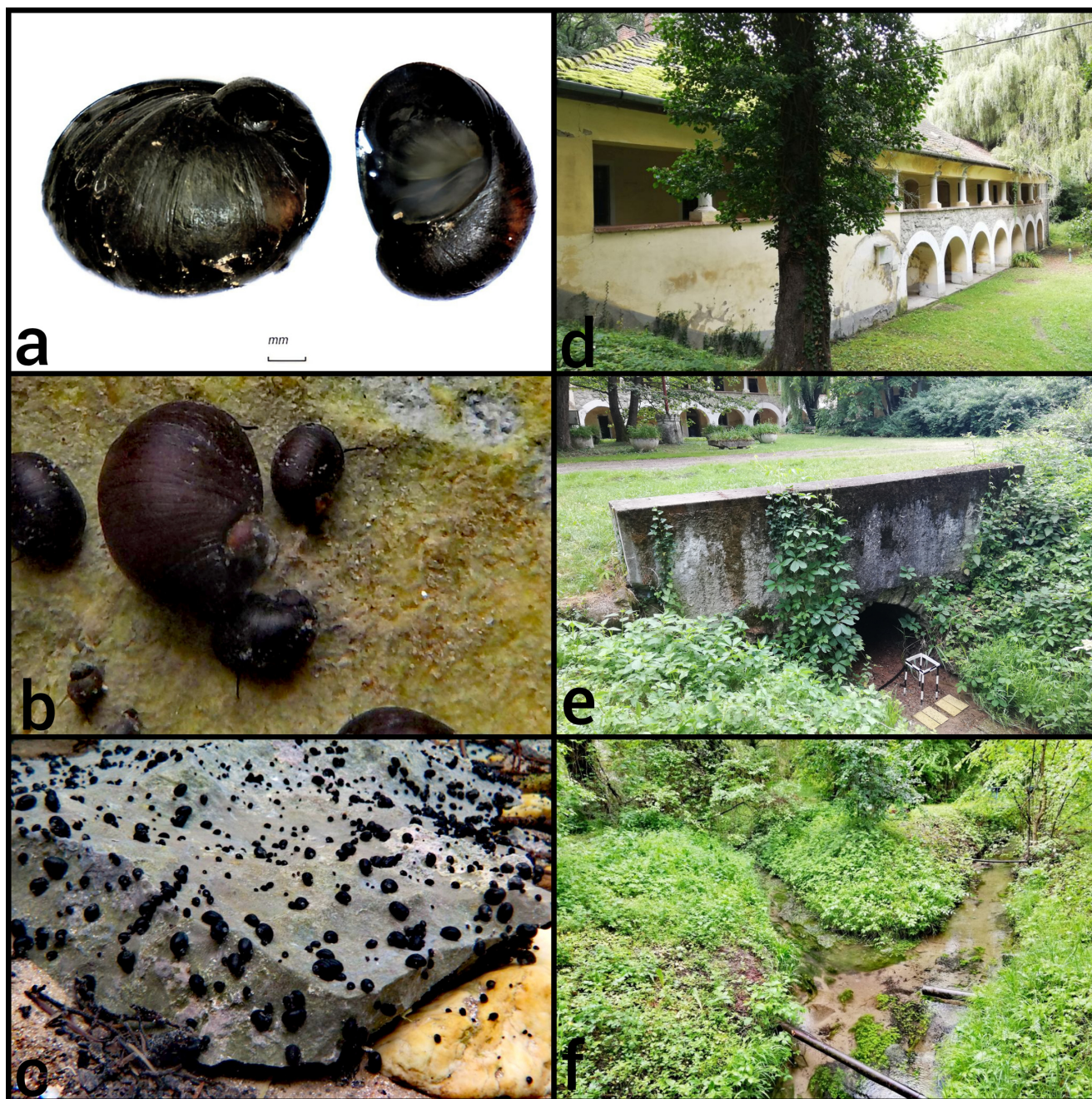


Fig. 1. (a) *Theodoxus prevostianus* (C. Pfeiffer, 1828); (b) *T. prevostianus* with dark purple hues; (c) mass occurrence of *T. prevostianus* on the surface of the stones; (d) Benedictine monastery; (e) Tükör Spring; (f) tepid spring stream (left), cold spring stream (right).

Csónakázó Lake (Miskolctapolca), [5] Tapolca Stream (Miskolc–Diósgyőr), [6] Király-kút Spring (Forrás-völgy, Bükk), [7] Tapolca Stream (Miskolc–Diósgyőr), [8] Roman Baths (Budapest), [9] English Garden (Tata), [10] Tóváros (Tata), [11] Fényes springs (Tata); Austria: [12] Bad Vöslau, [13] Bad Fischau; Slovenia: [14] Bušeča Vas; Croatia: [15]

Ivanec Bistranski, [16] Podsused, [17] Velika; Romania: [18] Răbăgani, [19] Püspökfürdő (Fehér et al., 2007; Kormos, 1905b; Soós, 1927; Sümegi, 1999; Varga, 1980, 2009; Wagner, 1937).

In the Hungarian malacological bibliography from 1727 (Varga et al., 2005) onwards there have been several references to the population of *T. pre-*

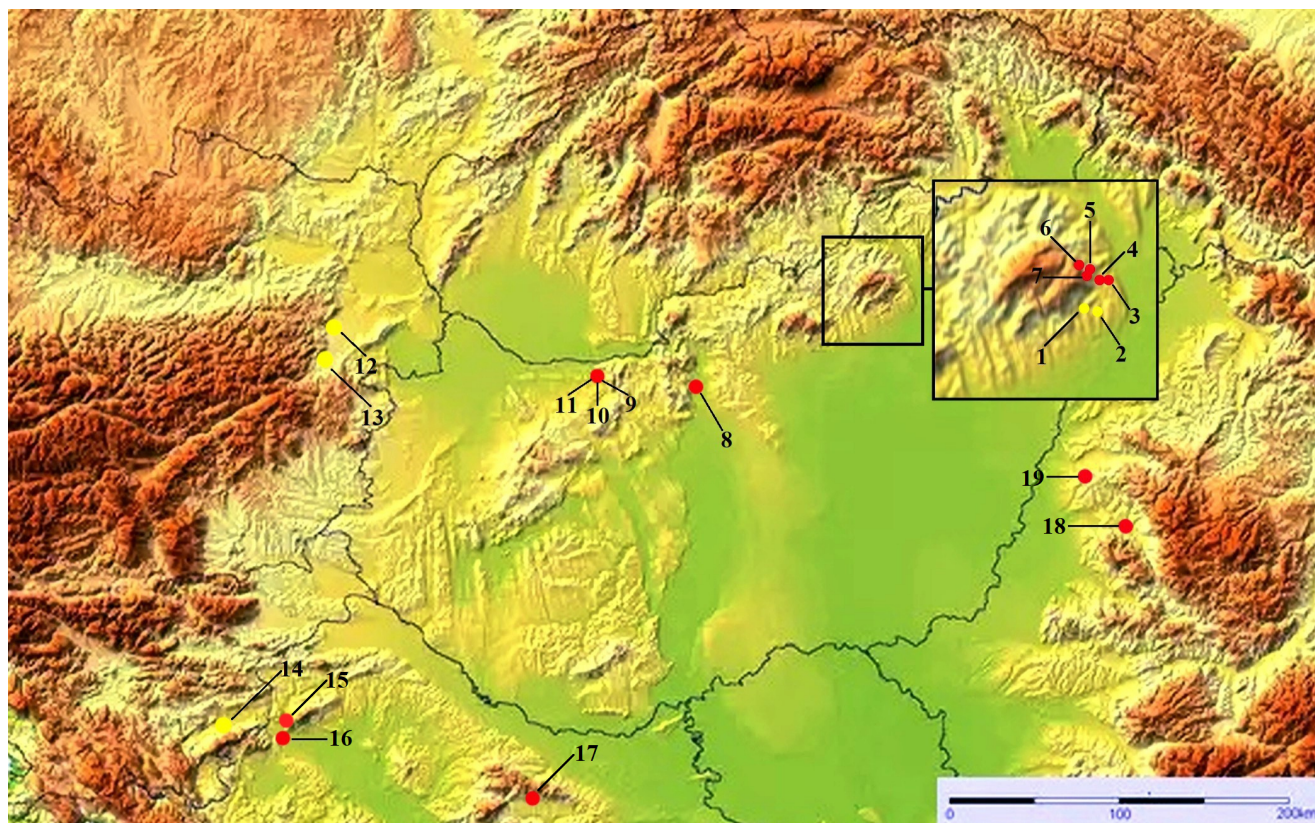


Fig. 2. Habitats of *Theodoxus prevostianus* (C. Pfeiffer, 1828) (yellow – current habitat; red – extinct habitat; base map: pinterest.com).

prevostianus in Kács (Kormos, 1905a, 1905b; Schréter, 1915; Wagner, 1927; Wagner, 1937; Vásárhelyi, 1956; Lukács, 1959; Varga, 1976). Apart from the data on presence, specific test results are reported in only a very limited number of publications. Such is the work of Lajos Soós, who introduced the species in the drainage ditch of the Roman Baths in Budapest in 1909, but unfortunately his initial success did not lead to lasting results (Soós, 1927). In 1955, Dezső Lukács and Imre Vajon moved some *T. prevostianus* individuals from Miskolcápolca to a “hot-water spring” in Eger. Unfortunately, the population did not survive (Lukács & Vajon, 1955). Zoltán Fehér et al. have enriched the understanding of the species with important phylogenetic research results (Fehér et al., 2007). A 2009 paper by Ioan Sîrbu and Anna Maria Benedek provided valuable information about the disappearance of the Răbăgani habitat (Sîrbu & Benedek, 2009).

Detailed information on the hydrogeological characteristics of the Kács spring group is available in Hungarian scientific literature (Schulhoff, 1957;

Almássy & Scheuer, 1967; Savanyú et al., 1986; Lénárt, 2000).

The 10–12 springs of the spring group represent a range of water temperatures between 14 and 24°C, with significantly different water yields. Of these, the tepid water Tükör Spring (44 l/s) and the cold water spring of the Northern Regional Waterworks (80 l/s) have a more significant volume of water.

The Tükör Spring has its source in the side wall of a long tunnel under a Benedictine monastery built here hundreds of years ago (Fig. 1d, e). No longer in operation, the Benedictine monks established a significant spa culture in Kács.

In 1972, the cold spring was tapped. Unused water emerging from the spring house forms the cold water tributary. After a distance of 100 m from their source, the two tributaries converge and continue their course under the name of Kács Stream (Fig. 1f).

The habitat of the *T. prevostianus* covers the tepid water tributary of the Tükör Spring and the first 800 m of the Kács Stream. Here, the spreading of the snails is physically hindered by a 3 m high waterfall. Note:

recently the species has also been found in cold water springs, but the causal relationship is not addressed in this paper.

It is important to note that the tepid water spring is also home to the protected *Microcolpia daudebartii* (Prevost, 1821), and the recently described, new-to-science snail species *Bythinella thermophila* Glöer, Varga & Mrkvicka, 2015 (Glöer et al., 2015). The Kács Spring waters are also inhabited by the protected *Bythinella pannonica* (Frauenfeld, 1865).

For the last 15 years we have been studying the distribution of the *T. prevostianus* population in the Kács springs. In 2010, we tried to establish a stable population of the species through habitat reconstruction.

In the study presented in this paper, we sought to answer the question of how many individuals of the *T. prevostianus* can populate (colonise) an area of a quadrat. This study is specifically designed to analyse the spring outlet of the Tükör Spring only. From the available results, it is not appropriate to draw general conclusions for the other sections of the tepid water tributary. Due to lack of space, it was not possible to set up more quadrats in the sample area, so no statistical analysis was performed. Our aim is to obtain informative data for habitat reconstruction studies of the tepid water spring.

Material and methods

At the exit of the tunnel, stone slab quadrats were placed perpendicular to the riverbed. For data collection, 2 observation sites were placed at the Tükör Spring on each test date (2006, 2010, 2021). Density counts were recorded by census from the surface of the 25×25 cm quadrats. The unevenness of the water surface and the sunlight that is refracted on it result in significant distortions and difficult calculability. To eliminate this problem, an empty aquarium was lowered 2 cm below the surface of the water above the snails to create a transparent mirror surface. In 2006, in the absence of suitable digital technology, the density counts were recorded on the spot. In 2010 and 2021, we were able to take underwater digital photos. The photos were overlaid with a spatial grid during computer processing to facilitate counting by individual censusing. Although the focus of our studies is on the *T. prevostianus*, we also recorded the density of the accompanying

species at the sampling sites. Data were collected on a weekly to fortnightly basis for 3 months.

Results and discussion

By week 4 of our 2006 survey, approximately 300 *T. prevostianus* had colonised both quadrats (Table 1). In the 5–6th week of the tests, the snow started to melt in the mountains. Due to local orographic conditions, the meltwater is drained in a dry basin, which feeds into the bed of the Tükör Spring. The temperature of the 22°C spring water dropped by 6°C and the volume of water grew eightfold. The meltwater did not bring sediment with it. The snails partly drifted off the surface of the quadrats and partly sought shelter on the back walls of the quadrats, which were more protected from the current. From week 7, the bed was again filled only with tepid water from the Tükör Spring. From week 10 onwards, apart from fluctuations in density, no further increase was recorded. The surface of the quadrats provided a favourable habitat for 400–600 *T. prevostianus*.

In 2010, we were able to directly experience the habitat-destroying effects of the surplus water mentioned earlier, bringing with it a large mass of sediment. In this case, it was not meltwater, but a significant amount of precipitation that fell on the surrounding mountains and the spring area. The original volume of water in the Tükör Spring bed was increased by 15–20 times by the sudden downpour of rainwater. At the Tükör Spring and in the tepid water tributary draining its waters, 30–50 cm thick fine sediment was deposited. The deposition of sediment had an extremely negative impact on the entire habitat of the *T. prevostianus*. At the outlet of the Tükör Spring and its tepid water tributary, the solid, rocky substrate essential for the habitat needs of the *T. prevostianus* had completely disappeared. Even by our most conservative estimates, 95–99% of the snails had died.

At the Tükör Spring, the quadrat stones were placed in the muddy bed in early April, but no Neritidae appeared on the surface. On 25 April, the observation sites were moved closer to the shore of the riverbed, where we found *T. prevostianus* clinging to the overhanging riparian foliage and an artificial structure (a drinking water pipe in the riverbed) (Fig. 3a).

On average, only 15–30 individuals settled on the quadrats in 2010. From the second week onwards,

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Table 1. The malacofauna of the Tükör Spring in Kács (2006).

Test dates	Number of individuals					
	Test point 1			Test point 2		
	<i>Theodoxus prevostianus</i>	<i>Microcolpia daudebartii</i>	<i>Bythinella</i> sp.	<i>Theodoxus prevostianus</i>	<i>Microcolpia daudebartii</i>	<i>Bythinella</i> sp.
05/2/2006	—	—	—	—	—	—
12/2/2006	1	1	—	3	—	—
19/2/2006	19	1	—	28	2	—
26/2/2006	64	16	—	166	2	—
05/3/2006	346	12	—	297	8	—
12/3/2006	—	—	—	—	—	—
19/3/2006	—	—	—	—	—	—
26/3/2006	141	—	—	110	—	—
02/4/2006	362	2	—	224	3	—
09/4/2006	556	2	—	430	—	—
16/4/2006	593	1	—	462	3	—
23/4/2006	603	1	—	472	—	—
30/4/2006	502	—	—	444	—	—
07/5/2006	453	1	—	547	2	—
14/5/2006	591	—	—	491	2	—

Table 2. The malacofauna of the Tükör Spring in Kács (2010).

Test dates	Number of individuals					
	Test point 1			Test point 2		
	<i>Theodoxus prevostianus</i>	<i>Microcolpia daudebartii</i>	<i>Bythinella</i> sp.	<i>Theodoxus prevostianus</i>	<i>Microcolpia daudebartii</i>	<i>Bythinella</i> sp.
25/4/2010	—	—	—	—	—	—
01/5/2010	8	3	—	41	4	—
08/5/2010	32	64	—	38	10	—
15/5/2010	27	109	—	44	26	—
22/5/2010	24	87	—	28	44	—
29/5/2010	26	53	—	21	41	—
12/6/2010	29	17	—	14	18	—
26/6/2010	16	9	—	17	3	—
03/7/2010	14	2	—	18	7	—
17/7/2010	18	—	—	20	1	—
31/7/2010	19	—	—	25	—	—
14/8/2010	19	4	—	24	5	—
21/8/2010	22	1	—	25	—	—
04/9/2010	32	—	—	21	2	—
17/9/2010	40	1	—	32	1	—

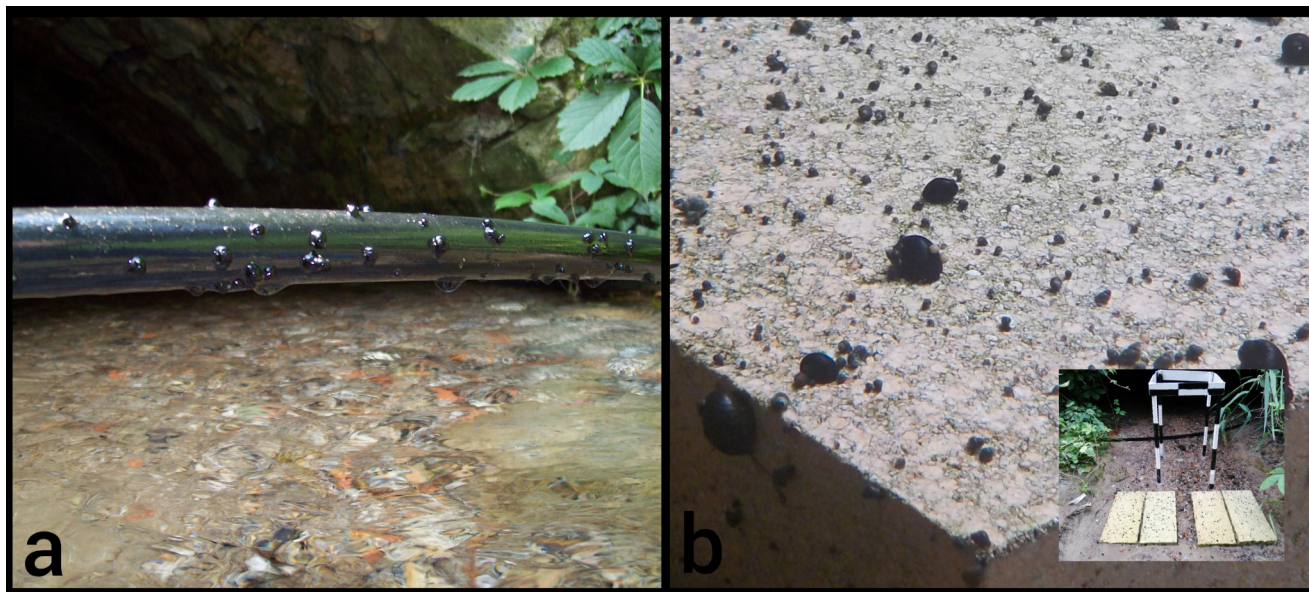


Fig. 3. (a) *Theodoxus prevostianus* clinging to an artificial surface; (b) *Theodoxus prevostianus* and *Bythinella* sp. at the Tükör Spring.

Table 3. The malacofauna of the Tükör Spring in Kács (2021).

Test dates	Number of individuals					
	Test point 1			Test point 2		
	<i>Theodoxus prevostianus</i>	<i>Microcolpia daudebartii</i>	<i>Bythinella</i> sp.	<i>Theodoxus prevostianus</i>	<i>Microcolpia daudebartii</i>	<i>Bythinella</i> sp.
21/3/2021	—	—	—	—	—	—
28/3/2021	3	—	12	9	—	21
04/4/2021	23	8	50	9	13	31
11/4/2021	49	53	177	60	16	68
18/4/2021	104	20	621	156	49	570
25/4/2021	170	11	389	197	25	280
02/5/2021	206	29	151	177	22	215
09/5/2021	141	17	127	179	12	185
16/5/2021	284	—	256	237	1	287
23/5/2021	318	2	253	308	2	281
30/5/2021	306	2	246	335	2	261
06/6/2021	254	—	243	179	—	209
13/6/2021	454	—	388	435	—	406
20/6/2021	445	—	283	411	2	286
27/6/2021	447	1	279	409	—	268

the number of individuals did not change, apart from minor fluctuations, and the steady upward trend of the previous period was not observed (Table 2).

By 2021, the fine sediment in the bed of the Tükör Spring had been completely washed away, and the bed is now covered by a stony substrate. Note: only

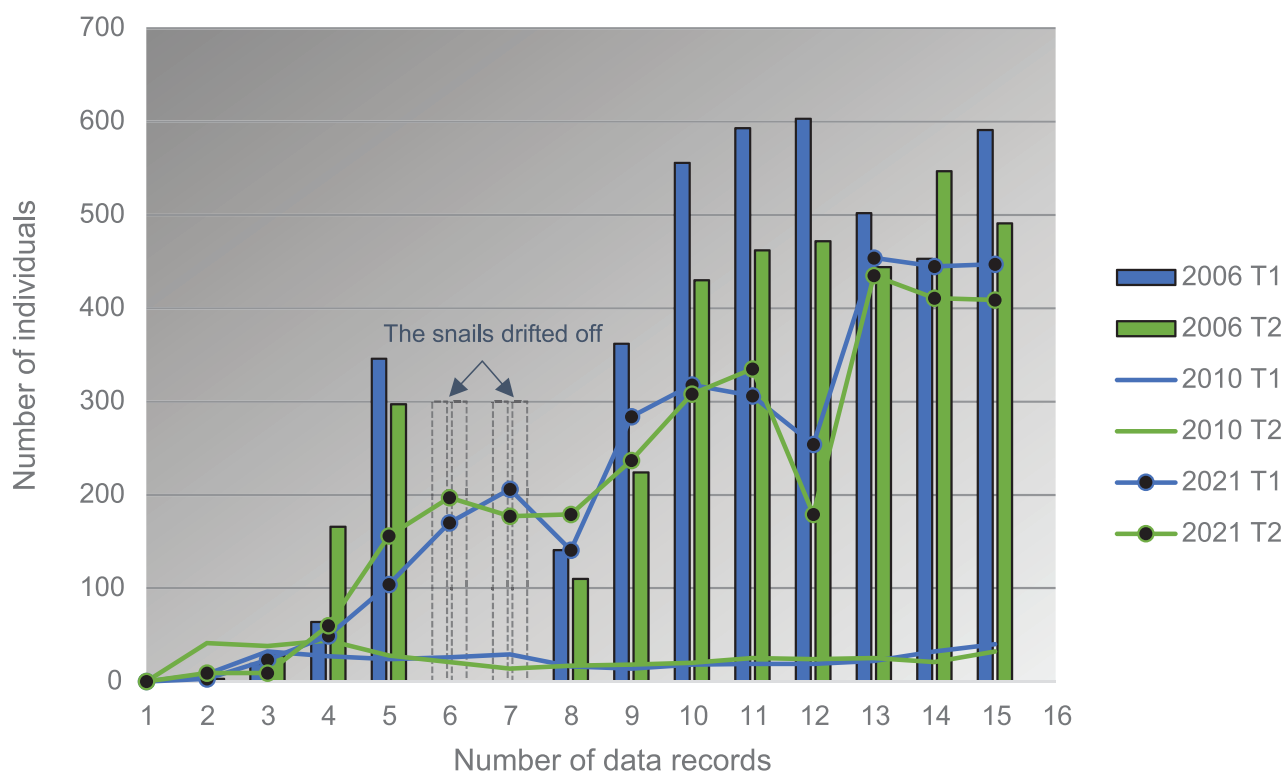


Fig. 4. Changes in the number of the individuals of *Theodoxus prevostianus* (C. Pfeiffer, 1828) at the Tükör Spring (2006, 2010, 2021). T1 – test point 1, T2 – test point 2.

partial washout was observed in the tepid water tributary. The colonisation of the quadrates was continuous and uninterrupted. Maximum densities were recorded at the survey sites in week 12. With minor fluctuations, 300–400 *T. prevostianus* settled on the quadrate surfaces during this test cycle (Table 3).

The changes in the number of the individuals of *T. prevostianus*, based on the tables and explanations presented above, are also represented with a summary diagram (Fig. 4).

Although the analysis of the accompanying fauna is not the subject of this article, we cannot but note some findings.

Microcolpia daudebartii is found in abundance at the Tükör Spring and in the entire Kács habitat, mainly in the fine sediment zones. However, on all three study dates, active presence was observed for the first 4–5 weeks on all quadrates set out, followed by a steady decline in numbers and then total disappearance from the test sites. Particularly high densities of this species were recorded during the 2010 study. Whether this is due to the absence of the *T. prevostianus*, requires further analysis. In any case,

we are experiencing a similar phenomenon in our current ongoing studies.

Bythinella thermophila and *Bythinella pannonica* as *Bythinella* sp. are listed in the recorded data. The differentiation between the two species is extremely difficult from a shell morphological point of view, and impossible without manual handling of the individuals.

The *B. thermophila* was described only in 2015, from this very branch of the tepid water spring of the Kács Tükör Spring (Glöer et al., 2015). No studies have been carried out so far and we have no factual data on the species. It is important to clarify whether the *Bythinella* population here is exclusively, or to a lesser or greater extent, *thermophila* or *pannonica*. One wonders, if it is a newly described species, how it could have spread in such a short time. It also makes one wonder if *B. pannonica* is also present in the snail population of the Tükör Spring, as it has only been known in the literature to occur in colder spring waters.

In 2006 and 2010, no *Bythinella* species were detected at the Tükör Spring during the data

collection. In 2021, we recorded surprisingly large numbers, sometimes exceeding those of the *T. prevostianus* (Fig. 3b). Their study is extremely important because it represents a new element in the direct outlet of the Kács Tükör Spring. Note: Until 2010, we had only observed *Bythinella* in the immediate vicinity of the mouths of a few subaqueous creek springs in the tepid water tributaries, which we then assumed to be *B. pannonica*. Dezső Lukács had already issued a publication about it in the late 1950s under the species designation “*Bythinella austriaca*” (Lukács, 1959). The snail prefers the surface of stones as its habitat, so it may have a significant impact on the population of the *T. prevostianus* here. With regard to *Bythinella*, we will carry out further investigations in cooperation with a researcher specialised in Hydrobiidae.

Conclusion

The *Theodoxus prevostianus* (C. Pfeiffer, 1828) form a stable population at the outlet of the Tükör Spring under undisturbed hydroecological conditions. Meteorological and orographic factors in the Kács spring area can adversely affect this stability. After the solid surfaces important for the *T. prevostianus* were cleared, the relocation processes were activated. Since 2010, no episodes of rainwater runoff and sedimentation have been observed, but the risk remains. The results of the study will certainly provide useful guidance for our further explorations. The study of the rare snail fauna of the Kács spring area requires very complex planning and implementation, which we are striving to achieve.

Acknowledgements

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