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A journey on the railway to nowhere: terrestrial isopod assemblages on an abandoned railway in western Romania

(Crustacea, Isopoda)

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Increasingly more, constructions left behind by human activities are becoming part of our surrounding environment. Railways can also become such structures after the closure of some lines. In 2020 we studied the terrestrial isopod assemblages on a railway in western Romania, 20 years after it was abandoned. We identified 17 terrestrial isopod species, most of which were native, but largely distributed; some of them are associated with wet and forest habitats, and others with human settlements. The only endemic species on the railway was *Mesoniscus graniger*, a Carpatho-Dinaric cave species. Nevertheless, on the railway, it was identified in the soil, at the base of a stone rail culvert, situated on a forested hill. Non-native, synanthropic species, like *Armadillidium nasatum*, were also identified. The number of terrestrial isopod species on the railway was similar to other natural habitats from western Romania, but it was higher than in the region's towns. Thus, the abandoned railway shelters most of the native species from the region. The non-native and synanthropic species were generally present near the railway end toward the city. Along the gradient from the city to the natural areas the synanthropic species were replaced with species related to natural habitats. The fact that a railway, shortly after it was abandoned, can shelter diverse terrestrial isopod assemblages, similar with those from natural habitats, shows that the rail system does not seem to have a high negative effect on nature, and it can be quickly colonized after abandonment.

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Introduction

There are numerous railways in western Romania (e. g. Turnock 2004, C.F.R. 1987-C.F.R. 2020), many of them being built for more than 100 years ago (Popescu 2014). In the last 30 years some of them were abandoned, and even on lines still in use the traffic has decreased (Turnock 2011, Coroiu & Ciupan 2019, C.F.R. 1993-C.F.R. 2020). Numerous railway stations were closed, even in railway zones which are still active (C.F.R. 1993-C.F.R. 2020). Although the railway system seems to have a low negative impact on nature compared to other transportation types (see in: Borda-de-Água et al. 2017), railways are abandoned across Europe (e. g. Link 2003, Csemez 2010, Foster 2010, Taczanowski 2012, Stanev et al. 2017). Consequently, the railways network is getting shorter (see in: Morillas-Torné 2012). Even though railways are narrower than roads (Borda-de-Água et al. 2017), after their abandonment artificial elements remain in the landscape, even in cities (e. g. Hutter & Szilági 2014, Jucu & Voiculescu 2020, Zhang et al. 2020). In the last years, several animals were reported using abandoned railway structures as shelter (e. g. Leaney 1983, Parsons et al. 2003, Herrero & Hinckley 2014, Braschler et al. 2020, Graitson et al. 2020). For example, abandoned railroad tunnels are used by different animals, including terrestrial isopods (Covaciu-Marcov et al. 2017). A small number of terrestrial isopod species was identified recently in the buildings of some abandoned railway-stations along a railway line still in use in southeastern Romania (Pop et al. 2021). However, it is difficult to make comparisons between the isopod fauna in the tunnels and the one in natural habitats, because the tunnels are scattered across Romania (Covaciu-Marcov et al. 2017), even in regions with few data regarding terrestrial isopods. In western Romania, the knowledge regarding terrestrial isopods is more numerous, with data both from natural (e. g. Tomescu et al. 2008, Ferenți et al. 2012, 2013a,b, Ianc & Ferenți 2014) and artificial habitats, like towns (e. g. Bodin et al. 2013, Ferenți et al. 2015, Herle et al. 2016, Laza et al. 2017, Bodog et al. 2018, Pal et al. 2019). At the same time, in western Romania many railroads were abandoned in the last years (e. g. Turnock 2011, Coroiu & Ciupan 2019, C.F.R. 1993-C.F.R. 2020). If abandoned railway tunnels and abandoned constructions on active railways can shelter terrestrial isopods (Covaciu-Marcov et al. 2017, Pop et al. 2021), our hypothesis was that abandoned railways and their associated constructions will also shelter terrestrial isopods. Thus, we aimed to analyse the terrestrial isopod assemblages on an abandoned railway in western Romania. We set the following objectives: (1) to establish what isopod species are present on the railway, (2) to compare the isopod assemblages from the railway with the data from the neighbouring areas, (3) to compare the isopod fauna from different abandoned railway structures.

Material and methods

The study was realised on 14, 23 June and 7 July 2020 on the former railway 314, which connected the localities Oradea and Vașcău (C.F.R. 1987). The railway crosses the central and southern areas of Bihor County (Berindei et al. 1973). Presently it is completely abandoned between Oradea and Holod due to landslides, the last train passing on this segment in 1998 (Turnock 2011). From Holod to Vașcău there were passenger trains until the end of 2019 (C.F.R. 2019), but after that only freight trains passed occasionally. Also, in the sector that is still in use, the railway stations were abandoned (C.F.R. 1993–C.F.R. 2020). After Oradea, the line crosses the Tășad Hills (with altitude between 200 and 300 meters), and then runs along the Crișul Negru River (Berindei et al. 1973). Thus, the railway goes through a mosaic of habitats with different degrees of human impact (woods, pastures, localities). Even in the abandoned area, the line is still in place, but it is invaded by vegetation. Judging by the trains timetable from the past (C.F.R. 1990) the speed on this line was never great (at most 50 km/h). Railway 314 was a secondary branch, with a simple, non-electrified line, and low traffic even in the past (C.F.R. 1987–C.F.R. 1993).

Totally, we collected 58 samples from 48 locations. In the area where the railway is still in use, we collected isopods from abandoned railway stations or cantons, under rubble or lumber. On the abandoned sector, we collected isopods directly from the track ballast, or from railway sleepers covered with grass or fallen leaves. Also, in the hilly area, we collected isopods beneath some stone railway culverts that were made for torrents. Culverts maintain high humidity, but are partially degraded, with fallen stones. Isopods were collected under fallen stones or from wet soil and moss. We collected isopods from three habitat types: (1) abandoned buildings, (2) the line itself and (3) culverts. The shelters from where we collected isopods were of five types: (1) stones, (2) debris, (3) sleepers, (4) wet soil, (5) fallen logs and bark. All isopods were collected directly by hand. At each location, we spent approximately 20 minutes, as in other cases (e. g. Pop et al. 2019, 2021). Isopods were conserved in test tubes with alcohol and were identified in laboratory using the identification keys (Radu 1983, 1985, Tomescu et al. 2015). The data were processed both for total as well as broken down by habitat types and shelter types. We calculated each species percentage abundance as well the total percentage abundance and frequency of occurrence. The minimum, medium and maximum number of species and individuals/sample were also considered. The diversity was calculated with Shannon index, and the similarity with the Bray-Curtis index. The significance of the differences between habitats and shelter types was first estimated with the Kruskal-Wallis test. The Mann-Whitney U test was used as a post-hoc test. The statistical analysis was realised with the Past program (Hammer et al. 2001).

Results

On the abandoned railway we collected 285 individuals, belonging to 17 isopod species. Only 15 species could be determined: *Hyloniscus riparius* (Koch, 1838), *Haplophthalmus mengii* (Zaddach, 1844), *H. danicus* Budde-Lund, 1879, *Mesoniscus graniger* (Frivaldsky, 1865), *Platyarthrus hoffmannseggii* Brandt, 1833, *Cylisticus convexus* (De Geer, 1778), *Protracheoniscus politus* (Koch, 1841), *Porcellium collicola* (Verhoeff, 1907), *Trachelipus nodulosus* (Koch, 1838), *Porcellionides pruinosus* (Brandt, 1833), *Porcellio scaber* Latreille, 1804, *Armadillidium vulgare* Latreille, 1804, *A. nasatum* Budde-Lund, 1833, *A. versicolor* Stei, 1859 and *A. carniolense* Verhoeff, 1901. Also, we collected individuals from the genera *Trichoniscus* and *Trachelipus*, which could not be determined, as they were only females and juveniles. In 11 cases we identified only one individual/location. The maximum number of individuals/location (registered in two cases) was 20. The average number of individuals/location was of 5.93. The minimum number of isopod species/location was one, and the maximum number was six. *A. vulgare* and *T. nodulosus* occupied the first positions both as percentage abundance and frequency of occurrence, and *M. graniger* and *A. carniolense* occupied the last positions (Table 1). The total diversity of isopod assemblages was H = 2.24.

Between the three habitat types, the number of species, number of individuals and species diversity were different (Table 2). Only five species were present in all three habitat types and seven species were present in only one habitat type each (Table 2). In all habitat types, *A. vulgare* had high percentage abundance (Table 2). Most individuals were collected from buildings, but most species were registered on the line. Although on the culverts the number of individuals and species was low, the diversity was not much lower than in the other two habitats (Table 2). According to the Bray Curtis similarity index, the railway stations and the line were relatively close in respect of the terrestrial isopod fauna, but culverts were distinct (Fig. 1a). According to the Kruskal-Wallis test, the differences between the habitat types were significant ($p = 0.019$). According to the Mann-Whitney test, the differences between the line and the buildings were not significant ($p = 0.74$), but significant differences were registered between the line and culverts ($p = 0.02$), and between buildings and culverts ($p = 0.011$).

None of the species was found in all shelter types. Four species were present in four shelter types, and five species in one shelter type. Percentage abundance was different between the five shelter types, as different species were better represented

Table 1. Percentage abundance, frequency of occurrence, distribution, ecology and origin (after: Radu 1983, 1955, Vona-Túri et al. 2017, Pop et al. 2019) of terrestrial isopods from the railway.

Species	Distribution	Ecology	Origin	Percentage abundance	Frequency of occurrence
Hyloniscus riparius	Largly distributed	Wetland	Native	10.87	18.75
Trichoniscus sp.	-	-	-	5.96	10.41
Haplophthalmus mengii	Largly distributed	Wetland	Native	14.73	27.08
Haplophthalmus danicus	Largly distributed	Wetland	Native	1.05	4.16
Mesoniscus graniger	Carpatho-dinaric	Cave / Endogeic	Native	0.70	2.08
Platyarthrus hoffmannseggii	Largly distributed	Mirmecophylous	Native	4.21	10.41
Cylisticus convexus	Largly distributed	Eurytopic	Native	2.10	6.25
Protracheoniscus politus	Largly distributed	Forest	Native	2.80	14.58
Porcellium collicola	Largly distributed	Wetland	Native	3.25	6.25
Trachelipus sp.	-	-	-	1.40	4.10
Trachelipus nodulosus	Largly distributed	Eurytopic	Native	16.14	41.66
Porcellionides pruinosus	Largly distributed	Eurytopic	Cosmopolitan	2.80	10.41
Porcellio scaber	Largly distributed	Eurytopic	Cosmopolitan	1.40	2.08
Armadillidium vulgare	Largly distributed	Eurytopic	Cosmopolitan	28.42	56.25
A. nasatum	Largly distributed	Eurytopic	Non-native	1.75	4.16
A. versicolor	Largly distributed	Eurytopic	Native	1.75	10.41
A. carniolense	Largly distributed	Forest	Native	0.70	2.08

under different shelter types (Table 2). According to the similarity index, the assemblages under stones and debris were the closest, and those on railway sleepers, soil and tree trunks were more and more different (Fig. 1b). According to the Kruskal-Wallis test, the differences between the communities from the five shelter types were significant ($p < 0.05$). Analysing the differences with the Mann-Whitney test, the differences were mostly significant. Thus, the differences were significant between the assemblages under stones and under railway sleepers, soil and fallen logs ($p < 0.05$), those between the assemblages under rubble, and those under railway sleepers, soil, and logs ($p < 0.05$), those between assemblages on sleepers and under stones and rubble ($p < 0.05$), those between soil and stone and rubble ($p < 0.05$), as well as those between tree trunks, stone, and rubble ($p < 0.05$).

Discussion

This abandoned railway seems a positive example about how an artificial structure could become once again part of nature. The isopod assemblages on the railways are rich, and their importance as decomposers (e. g. Hornung 2011) facilitate the reintegration of the railway in nature. On the railway, there were more species than in some areas of western Romania, like Oaș Mountains (Ferenți et al. 2013b) or Carei Plain (Ferenți et al. 2012). However, the species number was slightly smaller than in the Tur River basin (Ferenți et al. 2013a) or Pădurea Craiului Mountains (Ianc & Ferenți 2014). Unlike natural areas with more species (Ferenți et al. 2013a, Ianc & Ferenți 2014), on the abandoned railway species from genus *Ligidium* or *Hyloniscus transsilvanicus* are missing, considered mountain and wetlands species (e. g. Radu 1983, Tomescu et al. 2011). Their absence is not due to the altitude, as they were also identified subsequently in plains (Ferenți et al. 2012, 2013a, Ferenți & Covaciu-Marcov 2014), but because wet habitats are missing from the railway. Abandoned railway buildings are situated in affected, open areas, the line is located on top of the hills where no permanent stream is present, and the track ballast does not retain rainwater. At the same time, on the line only few species from the genus *Trachelipus* are present, compared to those that are present in the region (e. g. Ianc & Ferenți 2014, Tomescu et al. 2015). Thus, only *T. nodulosus* was identified, a species of dry and open areas (Radu 1985, Farkas 2010, Tomescu et al. 2015). Although the genus *Trachelipus* includes more forest species in western Romania (e. g. Tomescu et al. 2015), they were missing from the railway, where a forest species from another genus (*P. politus*) was well represented. However, *P. politus* is present in the leaf litter, where it is usually abundant (e. g. Radu & Tomescu 1980-1981, Tuf & Tufová 2005, Antonović et al. 2012). Thus, *P. politus* is easier to encounter, unlike the forest species from the *Trachelipus* genus, which usually shelter under barks (e. g. Tomescu et al. 2015). The railway, although invaded by forest, does not have yet older trees under whose bark *Trachelipus* species could take shelter. If the number of isopod species on the railway is intermediate compared to the natural areas in the region, it is larger compared to the region's towns (Bodin et al. 2013, Ferenți et al. 2015, Herle et al. 2016, Laza et al. 2017, Pal et al. 2019) or at most equal (Bodog et al. 2018). This is probably a consequence of the fact that the town's negative impact is more intense, and it continues even nowadays, while the impact of the railway was reduced (except for its construction period), and now it is stopped. The railway cuts only a small part from the natural habitats, it is still surrounded by nature, and after abandonment it was colonized by nature, meanwhile cities affected (and still do) a large area, and are often surrounded by abandoned industrial sites (e. g. Laza et al. 2017, Bodog et al. 2018, Pal et al. 2019).

Among the native species on the railway, *M. graniger* is the only endemic one, as it is present in the Carpathian and Dinaric Mountains (Giurginca 2009). It is considered a cave species, usually reported in caves and only sometimes outside, as in Romania it is present in the Carpathians (Giurginca 2009). In Tășad Hills it was not previously mentioned, but it was recorded 35 km to the east, in Pădurea Craiului Mountains, in caves (Giurginca 2009, Ianc & Ferenți 2014), but also in two cases on the soil surface, in natural humid forest edges (Ianc & Ferenți 2014). On the railway, *M. graniger* was recorded at a low altitude, outside caves and in an artificial habitat. It was identified at the highest point of the railway, in a forest, under a stone culvert, with a 2 m high and 1 m wide archway, made up by stone and cement. The two *M. graniger* individuals were found at the culvert entrance, under the vegetation and in the wet soil. Endogeic *M. graniger* populations were identified not only in Apuseni Mountains (Giurginca 2009, Ianc & Ferenți 2014), but recently also in the Vâlsan River basin (Ferenți & Covaciu-Marcov 2016). Nevertheless, the most surprising record is that of an endogeic population in Blahnița Plain, which, as in Tășad Hills, was present under a bridge, but a road bridge (Ferenți & Covaciu-Marcov 2018). This railway population proves that the species is endogeic, and not only cavernicolous, but it is easily recorded in caves (see in: Ferenți & Covaciu-Marcov 2018). Probably, the foundation of the culvert is situated deep in the ground, and *M. graniger* individual come

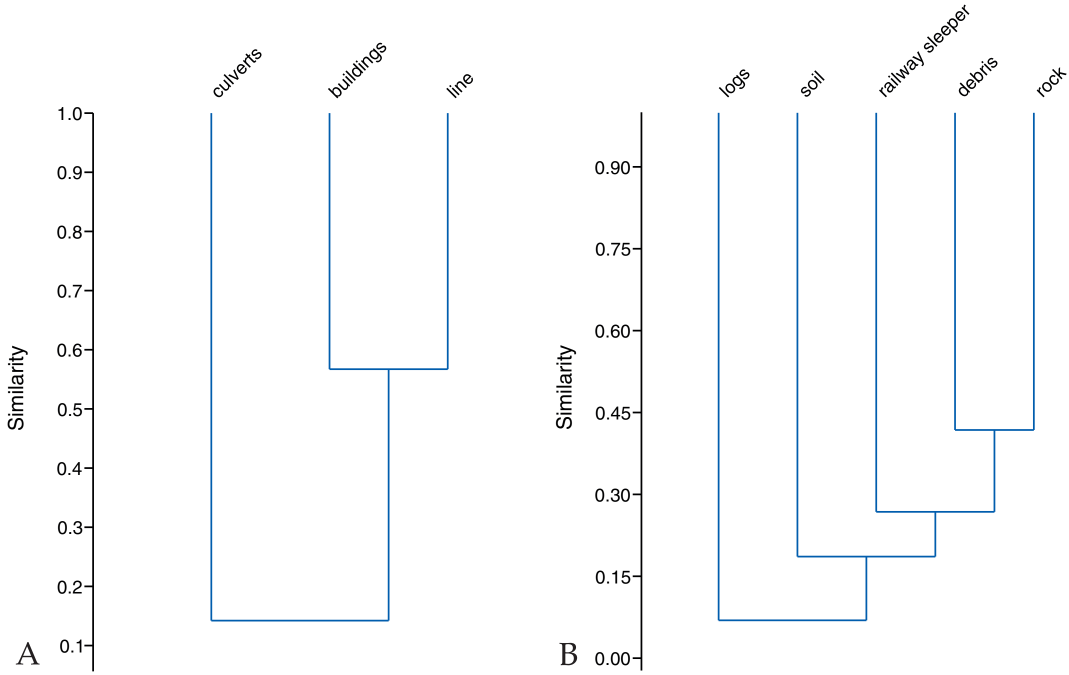

Fig. 1. Similarity between the terrestrial isopod assemblages from different habitat types (**A**) and shelter types (**B**).

Table 2. Percentage abundance of terrestrial isopod species depending on habitat and shelter.

Species	Habitat types			Shelter types				
	line	buildings	culverts	rock	debris	railway sleeper	soil	logs
Hyloniscus riparius	3.47	17.64	-	6.06	14.43	-	-	-
Trichoniscus sp.	9.56	1.96	17.64	15.15	1.60	6.25	25.00	-
Haplophthalmus mengii	24.34	7.84	11.76	21.21	6.95	87.6	8.33	-
Haplophthalmus danicus	0.85	1.30	-	1.51	1.06	-	-	-
Mesoniscus graniger	-	-	11.76	-	-	-	16.66	-
Platyarthrus hoffmannseggii	-	7.84	-	-	6.41	-	-	-
Cylisticus convexus	0.86	2.61	5.88	1.51	2.13	-	8.33	-
Protracheoniscus politus	4.34	0.65	11.76	6.06	0.53	6.25	16.66	-
Porcellium collicola	0.86	5.22	-	1.51	4.27	-	-	-
Trachelipus sp.	3.47	-	-	1.51	1.60	-	-	-
Trachelipus nodulosus	17.39	16.99	-	15.15	17.64	-	-	75.00
Porcellionides pruinosus	-	5.22	-	-	4.27	-	-	-
Porcellio scaber	-	-	23,52	-	2.13	-	-	-
Armadillidium vulgare	27.82	30.06	17.64	25.75	32.08	-	25.00	25.00
A. nasatum	4.34	-	-	-	2.67	-	-	-
A. versicolor	0.86	2.61	-	1.51	2.13	-	-	-
A. carniolense	1.73	-	-	3.03	-	-	-	-
Number of species	13	12	7	12	15	3	6	2
Number of individuals	115	153	17	66	187	16	12	4
Percentage abundance	40.35	53.68	5.96	23.15	65.61	5.61	4.21	1.4
Diversity	1.97	2.03	1.87	2.01	2.13	0.46	1.7	0.56

to the surface along its walls. Probably, in Tășad Hills, endogeic populations are continuously distributed, and the culvert makes a connection between deeper soil layers and the surface, as in karst areas the species is present in the soil between 25 and 65 cm depth (Rendoš et al. 2016). In recent years, both isopods and other invertebrates considered cave species were identified in the ground or on the soil surface (Ferenți et al. 2016, Tuf et al. 2017). The presence of *M. graniger* here indicates that an abandoned railway could also favour the underground fauna, unlike abandoned tunnels which are completely isolated from their surroundings (Covaciu-Marcov et al. 2017).

Although on the railway most species were native, there are also some non-native or naturalized species. Among these, *A. nasatum* is a species native to the western Mediterranean region, which has colonized large areas in Europe (Cochard et al. 2010). In Romania, it was rarely recorded, only in artificial habitats (Radu 1985, Giurginca et al. 2017). It was not mentioned in north-western Romania (Tomescu et al. 2008, Ferenți et al. 2012, 2013a,b, Ianc & Ferenți 2014), not even in urban areas (Bodin et al. 2013, Ferenți et al. 2015, Herle et al. 2016, Laza et al. 2017, Bodog et al. 2018, Pal et al. 2019). Nevertheless, in other regions it is characteristic for urban areas (Vilisics & Hornung 2009, Vilisics et al. 2012, Giurginca et al. 2017), or artificial habitats like roadsides (Vona-Túri et al. 2017). On the railway, *A. nasatum* was observed only near Oradea city, in Cordău village, in an area with a lot of rubble on the track. This species presence is probably related with the vicinity of Oradea city, where it was probably introduced, although it did not move yet to other urban settlements (Bodin et al. 2013, Ferenți et al. 2015, Herle et al. 2016, Laza et al. 2017, Bodog et al. 2018, Pal et al. 2019). Although *A. nasatum* is an invasive species, it is unlikely that it will spread further along the railway, as beyond Cordău natural forested habitats begin. Besides *A. nasatum*, another three species of this genus are present on the railway, making this the most common genus on the railway. Among them, *A. vulgare* and *A. versicolor* are common in the region (Ferenți et al. 2012, 2013a, Ianc & Ferenți 2014). Unlike these, *A. carniolense* is a species characteristic for south-western Romania (Radu 1985), rare in the region even in natural habitats (Ianc & Ferenți 2014). Thus, near Oradea city, on the railway numerous synanthropic, non-native, generalist species are present, probably because of the city influence. Unlike this, in the forested hills, there are more native species, related with wet areas and forests. Thus, the isopod assemblages on the railway appear to be influenced by the vicinity of the city.

The differences between isopod assemblages are also clear according to habitats and shelter types. Synanthropic species are better represented in buildings and rubble; native species are mostly present on the line, moist soil, or culverts. In the case of abandoned buildings, the human impact is still obvious nowadays, but the line itself is largely integrated into nature. The stations functioned for almost 100 years, they had staff, passengers, transported goods, so synanthropic isopods could be introduced, just like in urban areas (Vilisics & Hornung 2009). Unlike stations, the line and culverts did not have any other human impact, after the construction, except for the passing trains. Thus, it was expectable that abandoned railway station buildings will be colonized by a more synanthropic and less diverse isopod fauna. The situation is similar to urban areas, where old areas have a richer and more diverse fauna than new neighbourhoods (Pal et al. 2019, Pop et al. 2019). The number of terrestrial isopod species on the railway was equal to that in abandoned tunnels, but the species were not the same (Covaciu-Marcov et al. 2017). As tunnels are more humid, they are also populated by species related to wet areas (Covaciu-Marcov et al. 2017). The number of isopod species on the railway was higher than on some highway verges in Hungary, where the number of collected individuals was much higher, due to the use of pitfall traps (Vona-Túri et al. 2017, 2019). If highways appear to be a limiting factor for specialized isopods (Vona-Túri et al. 2017), not the same fact seems to apply to an abandoned railway. Compared to the previously studied active railway in southeastern Romania (Pop et al. 2021), here we registered more isopod species.

From the perspective of terrestrial isopods, abandoned railways are easily lost in the surrounding natural landscape, if it exists. If natural landscapes, such as forests, neighbour the abandoned railway, then it will be quickly and easily naturalized. If there are affected areas in the vicinity, then the railway will be colonized by isopods characteristic to these areas. Thus, on the railway there is a transition from assemblages related to human affected areas to assemblages of natural areas, similar to the urban-rural gradient (e. g. Ishitani et al. 2003, Magura et al. 2008, Kaltsas et al. 2014). As the railway moves away from the city, the generalist species are replaced by native, sometimes strictly specialized species. In the end, railways seem to have a smaller impact than urban areas, with more species in number and many natives. At the same time, railways are somewhat similar to cities, housing both native and non-native species (Vilisics & Hornung 2009), which proved to be also the case of railway flora (Májeková et al. 2021). Although the soil on the railways is sometimes polluted (e.g. Hiller 2000, Jiasheng et al. 2020, Vaiškūnaitė & Jasiūnienė 2020) and isopods are detritophages (e. g. Hornung 2011), assemblages on the abandoned railways are diverse. Thus, a disused railway can sustain a diverse terrestrial isopod assemblage, at least in the case of a secondary railway with low traffic in a still natural area. It is confirmed that railways are less harmful to the environment than roads (see in: Borda-de-Água et al. 2017). The railway is lost in the landscape; it is narrower and connected to the habitats, unlike the roads where the asphalt is a barrier. This does not mean that the railways should be abandoned, but if there is an alternative, also our data shows that it is better to construct a railway than a road, and when it is no longer used, it is swallowed up in no time and without any effort by nature.

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