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TERRESTRIAL ISOPODS (CRUSTACEA, ISOPODA) FROM NORTH-WESTERN ROMANIA: FAUNISTIC AND ECOLOGICAL RESEARCH

- PhD thesis abstract -

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Cluj-Napoca
2013

Key words:

Oniscidea,
distribution,
habitat type,
altitude,
shelters,
wetlands,
forests

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Introduction

Terrestrial isopods are a diverse group which provides the opportunity to study the diversity of adaptations to terrestrial environment, both morphological and physiological and ecological ones (Hornung 2011). Generally, isopods are considered the crustacean group with the largest ecological valences (Radu & Tomescu 1975). The adaptation of isopods to terrestrial life involved several changes, these still evolving, for example, in the direction of some new solutions of chemical perception in the terrestrial environment (Harzsch et al. 2011). Modification of the structure of terrestrial isopod assemblages due to habitat alteration can cause cascading effects on ecological cycles, due to their particular importance (Magrini et al. 2011). Terrestrial isopods have an essential role in nutrient cycles (Magrini et al. 2011), representing a group with important role in litter decomposition (Hassall et al. 1987).

It has recently been established the value of terrestrial isopods as bioindicators (Paoletti & Hassall 1999), these being considered promising indicators of the degree of habitat disturbance (Paoletti et al. 2007). The special importance of terrestrial isopods has recently led to their use as indicators in various studies in different parts of the world (Dallinger et al. 1992, Paoletti & Hassall 1999, Souty-Grosset et al. 2005, Tuf & Tufová 2008, Hornung et al. 2009). It has also recently begun to be posed more stringently the problem of the importance of invertebrates in biodiversity conservation, cataloguing of invertebrate species being thus extremely important for adequate management of biodiversity of protected areas (McGeoch et al. 2011). Currently, the proportion of different groups of living beings in situations concerning the level of threat of biodiversity is obviously disproportionate, the protection level still largely taking into account their complexity and taxonomical position (Martín-López et al. 2011).

The anthropogenic affectation of habitats leads primarily to the disappearance of rare and specialized species (Paritsis & Aizen 2008) and to the natural fauna replacement by a uniform and simplified community (Wethered & Lawes 2005, Stephens & Wagner 2007, Zahn et al. 2009, Wiezik et al. 2007, Gardner et al. 2008; Paritsis & Aizen 2008; Turner & Foster 2009). Such events are taking place following deforestation and replacement of autochthonous forests by plantations. Romania is not absolved from such activities which have massively decreased and are still decreasing the forested areas (Borlea et al. 2006, Rozylowicz et al. 2011, Bohatereț 2012). A highly affected area from Romania, both by massive deforestations and regularization and drainage of wetlands, is the north-western part of the country (Badea et al. 2011, Măhăra 1977, Szűcsné-Murguly 2006). Both phenomena are equally obvious in the region, as there were numerous forests and wetlands here in the past, the existence of forests being established in the neighbouring areas of Hungary, including in the last glacial period (Willis et al. 1995). In addition to deforestations and drainages, other negative anthropogenic effects have also been recorded in north-western Romania (expansion of localities and road network, storage of wastes in natural habitats, presence of some pits, agricultural areas, etc.).

In order to conserve the last natural areas from north-western Romania, several protected natural areas have recently been established, their number increasing nationally in the last years (Iojă et al 2010). Unfortunately, these were almost exclusively assigned based on some plant or vertebrate species, and concerning the invertebrate fauna which ultimately allows the working of the ecosystem, being very few data. Such a little known group in north-western Romania, despite its basic importance in ecosystems functioning (Hassall et al. 1987) is represented by terrestrial isopods. Thus, only a few studies explicitly devoted to this group have been carried out in the region until 2010 (Tomescu et al. 2008, Hotea et al. 2003, Hotea & Hotea 2008, 2009), sporadic data being occasionally present in volumes of general composition (Ardelean & Karácsonyi 2005). Besides, in Romania, recent data on

the geographical distribution of terrestrial isopod fauna are generally quite scarce (Tomescu 1992, Giurgincă & Ćurčić 2003, Giurgincă & Ilie 2003, Giurgincă et al. 2006 a, b, 2007, Tomescu et al. 2011), more numerous being the ecological data (Hotea et al. 2003, Hotea & Hotea 2008, 2009, 2010, Tomescu 2010, Ivanov 2011), including those from neighbouring areas of north-western Romania such as Apuseni Mountains (Tomescu et al. 1992, 1995, 2000, 2001, 2002a, 2008, Mureşan et al. 2003). However, faunistic data are of primordial importance as studies that use isopods as indicators can be conducted only after the composition of terrestrial isopod fauna of an area has been established.

In the light of what was mentioned above, this study started on the need of accurate knowledge of the composition and geographical distribution of terrestrial isopod fauna in north-western Romania, in order to its subsequent protection and use as a tool for measuring the degree of anthropogenic affectation of habitats. Thus, at first we wanted to determine the autochthonous terrestrial isopod fauna of the area, studying mainly natural areas. We have also investigated but to lesser extent anthropized, yet at least in part semi-natural habitats, in order to determine the terrestrial isopod species that accommodate to partial modification of habitats following anthropization. However, we did not investigate completely anthropized habitats, such as agroecosystems. Taking account of the importance of terrestrial isopods as indicators of the disturbance level of habitats (Paoletti et al. 2007) these results can be used later, providing a basis of comparison concerning the terrestrial isopod fauna from north-western Romania.

The main objectives of the study were:

1. to assess the terrestrial isopod fauna in north-western Romania and the species distribution in the investigated area;
2. to assess the habitat types inhabited by the terrestrial isopod species in the investigated area;
3. to determine the isopod species endangered by habitat destruction and to propose some protection measures;
4. to analyse some quantitative ecological parameters of the isopod assemblages from different investigated habitats;
5. to analyse the terrestrial isopod assemblages in the close vicinity of some basins, channels with thermal waters from western Romania.

The accomplishment of this study would not have been possible without the assistance of several peoples to whom I am extremely grateful. Thus, firstly I express my sincerest thanks to the advisor of this work, Mr. Prof. Dr. Tomescu Nicolae. From him I learned how to identify isopods and the working methods specific to this group. I am also grateful to him for the way in which he knew to coordinate my activity meanwhile leaving me the freedom to relate myself to the group in my own manner. I also have to thank the herpologists from Oradea for initiation in the scientific research and in the interpretation of the geographical distribution of fauna. Not at least I have to thank them for their support in the field. I also have to thank for their help in different stages of the study to my colleagues: Sas-Kovács István, Sas-Kovács Éva-Hajnalka, Cicort-Lucaciu Alfred-Ştefan and Ianc Raluca. For the research in the protected areas of the region I am grateful to their custodians, Freies Europa Weltanschauung Foundation regarding the Carei Plain protected natural area and Transylvanian Carpathian Society regarding the Tur River protected natural area. I am also grateful to Freies Europa Weltanschauung Foundation for its support in conducting some field trips and for the doctoral scholarship given in 2010/2011.

1. Description of investigated area

1.1. Geographical location of the area

The study area is situated in the north-western part of Romania (fig. 1), comprising Satu Mare County and sectors from western Maramureş County and northern Bihor County. The predominant landform in the investigated area is plain, represented by Someş Plain, Ier Plain, Carei Plain, Crasna Plain. In north-western Romania the high relief is not missing either, being represented by hills and mountains. The hills are situated in the southern part of the investigated area, being represented by Codru Hills and Crasna Hills. The mountains are represented by Oaş Mountains and partially by Igniş Mountains.

Fig. 1 Location of the investigated area (shown in red)

1.2. Habitats where sampling was carried out with pitfall traps

In placing the pitfall traps we tried to cover as many geographic units as possible from north-western Romania (fig. 2, table 1). Thus, the quantitative studies on terrestrial isopods assemblages have been conducted in mountain, hilly and plain areas.

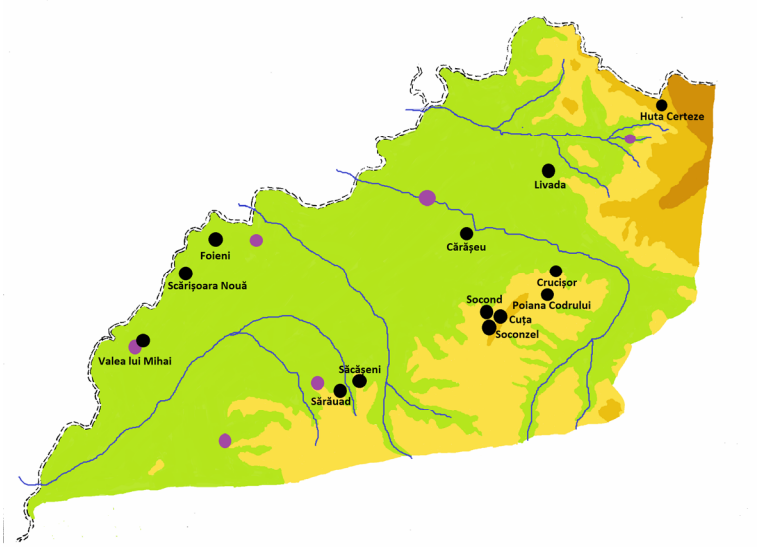

Fig. 2 Localities in north-western Romania in which samples were collected using pitfall traps(● – towns, ● – complexes of habitats from which samples were collected)

Table 1 Localities in north-western Romania where terrestrial isopods were collected using pitfall traps, their altitude and geographic coordinates, number of traps set and year of sampling

Locality	Sector	Habitat characterization	Altitude	Geographic coordinates	Traps / month	Sampling year
Huta Certeze	1	beech forest	579	47°57`30.48``N/23°30`22,56``E	5	2008
	2	mixed beech and spruce forest	584	47°57`26,26``N/23°30`38,68``E	5	
Poiana Codrului	1	oak forest edge	279	47°36`58,56``N/23°14`52,34``E	4	2009
	2	mixed oak and beech forest	272	47°37`04,09``N/23°14`31,37``E	4	
Crucişor	1	oak forest	165	47°41`09,29``N/23°16`08,48``E	4	2009
	2	open area	158	47°41`12,09``N/23°16`08,45``E	4	
Soconzel	-	marsh	199	47°31`47,17``N/22°59`07,52``E	4	2009
Cuţa	-	pine plantation	189	47°33`35,25``N/22°57`56,71``E	3	2009
Socond	-	regeneration	182	47°32`19,01``N/22°57`38,34``E	4	2009
Săcăşeni	1	meadow	226	47°27`47,08``N/22°42`43,05``E	4	2009
	2	oak forest edge	227	47°27`48,12``N/22°42`42,48``E	4	
Sărăuad	1	oak forest edge	152	47°29`02,20``N/22°38`33,21``E	4	2009
	2	oak forest - inside	154	47°29`01,76``N/22°38`33,96``E	4	
Cărăşeu	-	wet meadow near a canal	131	47°43`41,33``N/23°06`24,41``E	3	2009
Valea lui Mihai	-	marsh	126	47°31`10,22``N/22°08`31,60``E	4	2009
Foieni	1	open sand dune	131	47°42`46,30``N/22°18`50,85``E	5	2008
	2	marsh	130	47°42`56,07``N/22°18`54,77``E	5	
	3	sand dune – oak forest edge	136	47°43`05,21``N/22°18`58,01``E	5	
	4	oak forest on sand dune	140	47°43`06,43``N/22°18`55,63``E	5	
Livada	1	marsh at oak forest edge	142	47°50`51,27``N/23°13`46,79``E	5	2008
	2	oak forest - inside	143	47°50`52,14``N/22°13`44,88``E	5	
	3	oak forest at roadside	146	47°51`00,50``N/23°13`46,55``E	5	
	4	oak forest - inside	153	47°50`48,46``N/23°14`47,56``E	5	
	5	regeneration	163	47°50`47,52``N/23°14`51,63``E	5	

1.3. Habitats where qualitative samples were collected (direct collection)

A total number of 336 qualitative samples were collected from all geographic units in north-western Romania, from a widest possible variety of habitats. In order to interpret the data and to determine the habitat preferences of terrestrial isopods, the habitats were pooled in 22 categories (fig. 3). Of these, forests were represented by 4 types, wetlands by 5 types, plantations by 4 types and anthropogenically modified habitats by 6 types. However, beside these 19 habitat types there were also 3 habitats difficult to assign to a more general typology, namely sand dunes, disturbed meadows (mainly overgrazed) and roadsides (fig. 3). The number of samples taken from each habitat type reflects the distribution of that habitat type in the surveyed area. Preferably, the samples were collected from natural, secondarily naturalized or anthropogenic habitats such as cellars and graveyards. No samples from agricultural fields were collected.

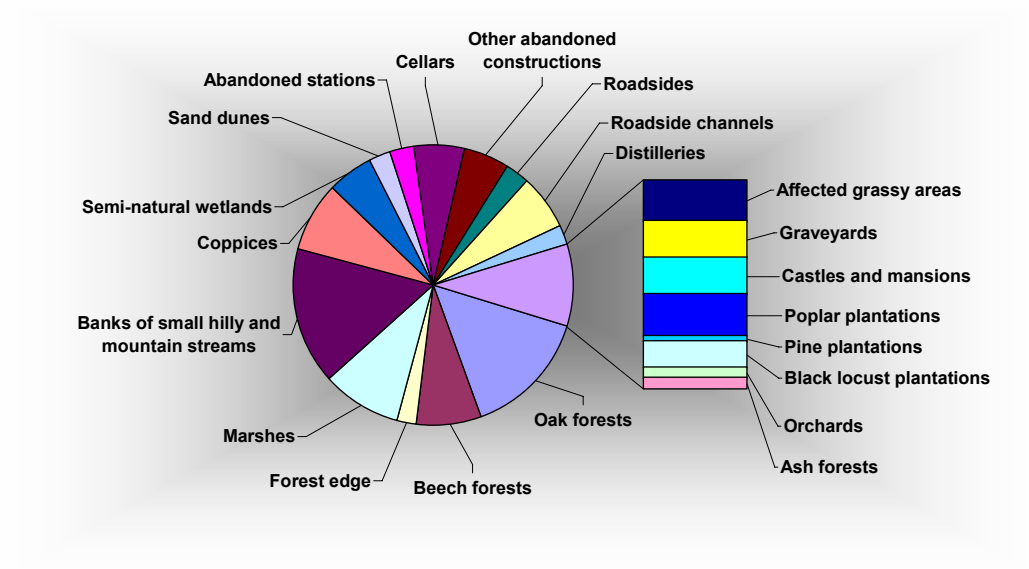

Fig. 3 Percentage abundance of the 22 habitat types from which qualitative samples were taken using the direct method

1.4. Thermal habitats where winter active terrestrial isopods have been identified

In general, the thermal habitats from western Romania are artificial ones, resulted from the drilling of some wells or from the operation of some thermal swimming pools and can be classified into four categories: **1.** thermal channels, **2.** relatively natural habitats (streams and thermal lakes), **3.** abandoned basins and **4.** grasslands inundated with thermal water. Of the 35 thermal habitats, 29 fall into the category of artificial thermal channels and only three of the remaining six habitats can be considered somewhat natural.

2. Research methods

The studies were conducted between 2008 and 2012 during the warmer seasons of the years, with emphasis on spring and autumn collection. Field research was also carried out in winter, during the cold seasons of 2010/2011 and 2011/2012 in the vicinity of thermal waters. Terrestrial isopods were collected using different methods depending on the aimed purposes.

2.1. Qualitative methods

Qualitative methods have been applied during 2010-2012. 336 samples were taken from 178 localities from north-western Romania. The direct method has also been used successfully in other studies (Stoyenoff 2001, Giurgincă 2006, Vilisics & Lapanje 2005, Tomescu et al. 2011), some authors recommending the combination of sampling methods (Tomescu et al. 2005, Farkas 2007). To standardise direct sampling the assigned time unit in each site was around 20-30 minutes. Isopods were collected either by hand (large isopods) or by tweezers (smaller isopods) or by a blade of grass (very small species, to avoid destruction of the body). The captured isopods were preserved in ethanol

70% in test tubes and identified in the laboratory. Determination of terrestrial isopods was performed in the laboratory using a stereo microscope and the specialty literature (Radu 1983, 1985, Frankenberger 1959, Vandel 1960, 1962, Schmältzer 1965, Schmidt 1997), according to the currently accepted nomenclature (Schmalfuss 2003). In some cases there were also made microscopic preparations.

2.2. Quantitative methods

These studies were performed in 2008-2009 from April until September. The samples were collected from 12 localities using pitfall traps, in some of these from several habitat types. A number of 512 samples were gathered throughout the two years of quantitative studies. This method is effective in capturing species with a high abundance and mobility (Stoyenoff 2001, Farkas & Krčmar 2004, Spuņģis 2008). The traps were arranged either in row, circle or in square. Traps were made of plastic containers, filled with a solution of antifreeze (ethylene-glycol) and water, a solution also used is other studies (Magura et al. 2005, Balog et al. 2012). To these a small amount of detergent was added and, for a better conservation, a little 4% formalin solution, as recommended by other authors as well (Magrini et al. 2011). Each trap was covered with a rectangular lid. Identification of isopods was performed in the laboratory using the methods mentioned above. Interpretation of results was done according to the relief of the area and the habitat types. The seasonal variation of terrestrial isopods within communities was also pursued and the sex ratio as well.

2.2.3. Statistical calculation methods

Several statistical parameters were used to analyse the results: average numbers of individuals / trap (numerical or absolute abundance), relative abundance, frequency of occurrence of species, constancy, species richness (S), Shannon-Wiever diversity index, evenness, Jaccard index of similarity, Mann-Whitney test of significance.

2.4. Research on terrestrial isopods from the vicinity of thermal waters

Field study was conducted between December-February in 2010/2011 and 2011/2012 using the direct method. Fieldwork involved the surveying of the thermal habitats from western Romania where winter active amphibians have been reported (Covaciu-Marcov et al. 2006, 2010, 2011, Sas et al. 2007, Bogdan et al. 2011), thus of those sites where the conditions from thermal waters induced changes of the biology and ecology of some cold-blooded animals.

3. The terrestrial isopod fauna of north-western Romania

The first cataloguing of the world fauna of terrestrial isopods was made in 2003 (Schmalfuss 2003). Thus, in Romania there are 13 families, 29 genera and 92 species of terrestrial isopods. Of these, we have identified 29 species (table 2) in north-western Romania using different methods, which represents 31.52% of the total number of isopod species from Romania. The identified species belong to 15 genera, thus 51.72% of the total genera from Romania are represented in north-western Romania. Those 9 families present in north-western Romania represent 69.23% of the total number of terrestrial isopod families from the country.

In total, we recorded 734 distribution localities of those 29 species of terrestrial isopods in the 178 surveyed localities in north-western Romania. By the 336 samples collected using the direct method we gathered 3930 individuals of terrestrial isopods. To our knowledge, in the investigated region only 36 distribution localities for just 16 isopod species have been previously reported in the literature (Tomescu et al. 2008, Hotea et al. 2003, Ardelean & Karácsonyi 2005, Vilisics 2008, Hotea & Hotea 2008, 2009). Some of these papers focused on localities from the investigated area, but others have considered only geographical units without indicating localities (Hotea et al. 2003). Nevertheless, these data have also been included on the distribution maps of the species in question. Data on isopod assemblages are also available from the vicinity of the studied area, from Baia-Mare Depression (Hotea & Hotea 2008, 2010). Thus, following field investigations a high number of isopod species and distribution localities of these were identified in a premier in north-western Romania. The species identified, to our knowledge, for the first time in north-western Romania are: *Trichoniscus carpathicus, T. pusillus, T. pygmaeus, Androniscus roseus, Haplophthalmus danicus, H. mengii, Platyarthrus hoffmannseggi, Cylisticus transsilvanicus, Oniscus asellus, Trachelipus ratzeburgii, Protracheoniscus major, Porcellio spinicornis, Armadillidium carniolense*. The most common isopod species from north-western Romania was *Armadillidium vulgare,* identified in 105 localities.

Table 2 Terrestrial isopod species collected using pitfall traps and the direct method (ecological categories were adjusted according to the results obtained in the field in north-western Romania)

Family	Species	Collected by pitfall traps	Collected by the direct method	Ecological categories
Ligiidae	*Ligidium germanicum*	X	X	Paludicolous
	Ligidium hypnorum	-	X	Paludicolous
Trichoniscidae	*Hyloniscus riparius*	X	X	Paludicolous
	Hyloniscus transsilvanicus	X	X	Paludicolous
	Trichoniscus pygmaeus	-	X	Endogeous / paludicolous
	Trichoniscus carpathicus	X	X	Paludicolous
	Trichoniscus pusillus	-	X	Paludicolous
	Androniscus roseus	X	X	Endogeous / paludicolous
	Haplophthalmus danicus	X	X	Paludicolous
	Haplophthalmus mengii	-	X	Synanthropic
Platyarthridae	*Platyarthrus hoffmannseggi*	-	X	Mirmecophylous
Oniscidae	*Oniscus asellus*	-	X	Synanthropic
Cylisticidae	*Cylisticus convexus*	X	X	Synanthropic
	Cylisticus trassylvanicus	-	X	Paludicolous
Agnaridae	*Protracheoniscus politus*	X	X	Sylvan
	Protracheoniscus major	-	X	Synanthropic
Trachelipodidae	*Porcellium collicola*	X	X	Paludicolous
	Porcellium conspersum	X	X	Paludicolous
	Trachelipus difficilis	X	X	Sylvan
	Trachelipus arcuatus	X	X	Euritop
	Trachelipus nodulosus	X	X	Praticolous
	Trachelipus rathkii	X	X	Euritop
	Trachelipus ratzeburgii	X	X	Sylvan
Porcellionidae	*Porcellionides pruinosus*	-	X	Synanthropic
	Porcellio scaber	X	X	Synanthropic
	Porcellio spinicornis	-	X	Synanthropic
Armadillidiidae	*Armadillidium vulgare*	X	X	Synanthropic
	Armadillidium carniolense	-	X	Synanthropic
	Armadillidium versicolor	X	X	Euritop

3.1.1. *Ligidium hypnorum* (Cuvier, 1792)

It is present only in the mountain and hilly areas in north-western Romania, which is consistent with the data from the literature (Kontschán 2004, Farkas & Vilisics 2006, Tomescu et al. 2011). However, it was also found at the border between plain and the neighbouring higher areas (fig.

4), being also observed at 153 m altitude. It generally inhabits forested wetlands.

3.1.2. *Ligidium germanicum* Verhoeff 1901

It has a distribution similar to that of the previous species in north-western Romania (fig. 4), being found in the same habitat types.

3.1.3. *Hyloniscus riparius* C. L. Koch 1838

It is a common species in the area, being present both in the plains and the higher areas (fig. 4). It occurs in natural wetlands both forested and unforested ones, but in moist anthropized habitats as well.

3.1.4. *Hyloniscus transsilvanicus* Verhoeff 1901

It is a common species in the area, even more widespread than the previous one. It is well represented both in the highlands and in the plains (fig. 4), although in the past it was considered in Romania characteristic to hilly and mountainous areas (Tomescu et al. 2011). However, in north-western Romania it occurs even at 110 m altitude, in plain areas. It inhabits wetlands, mainly natural, but it was also found in anthropogenically affected areas where it is also present on the bank of roadside channels. Initially, it inhabited the large natural marshes in the plain, but after their drainage some populations surveyed in roadside channels. The explanation of the presence of this species at plain is probably given by the colder and wetter climate in north-western Romania (Stoenescu et al. 1996). The same climate is also responsible for the presence of the two species of the genus *Ligidium* at the border between plain and higher units, mountain species being found at plain in north western Romania in other groups as well (Karacsonyi 1987, Covaciu-Marcov et al. 2004, 2008, 2009).

3.1.5. *Trichoniscus pygmaeus* Sars 1899

It has been identified in a single locality (fig. 4), in an artificial habitat, in the vicinity of some cellars in Roşiori village.

3.1.6. *Trichoniscus carpathicus* Tăbăcaru 1974

It is distributed in hilly and mountain areas (fig. 4), in moist, forested, natural habitats.

3.1.7. *Trichoniscus pusillus* Brandt 1833

It is a rarer species than the previous one in the surveyed area, but it occurs in the same geographical units (fig. 4) and habitat types.

3.1.8. *Androniscus roseus* C. Koch 1838

It was found in seven localities, situated in plain and hilly areas (fig. 4). It inhabits wetlands, forested areas, but sometimes occurs also in anthropized habitats.

3.1.9. *Haplophthalmus danicus* Budde-Lund 1880

It is present in all geographical units from the investigated region (fig. 5). It was found in moist habitats, both natural and artificial ones, being relatively common near distilleries.

3.1.10. *Haplophthalmus mengii* (Zaddach, 1844)

It is rarer than the previous species, being identified only in plain areas (fig. 5). Most of the occupied habitats are anthropized and are represented by graveyards or cellars.

3.1.11. *Platyarthrus hoffmannseggi* Brandt 1833

It is a rare species in the region (fig. 5), present only in plain areas in artificial habitats, being found always with ants.

3.1.12. *Oniscus asellus* Linnaeus 1758

It was identified in a single locality of the region at Medieşu Aurit (fig. 5), being a very rare species. It was found at the ruins of an abandoned castle. Its presence is probably due the human activities from the past.

3.1.13. *Cylisticus convexus* (De Geer, 1778)

It is a species present in the entire investigated area (fig. 5) in very diverse habitats, generally anthropogenically affected ones, but in natural areas as well.

3.1.14. *Cylisticus transsilvanicus* Verhoeff 1908

It is a very rare species in the area, being found only in four localities in Someş Plain (fig. 5). Unlike the previous species, it solely inhabits moist natural habitats. It is an endemic species in Romania (Schmalfuss 2003), these localities being, to our knowledge, the first records from west of the Carpathian Mountains.

3.1.15. *Protracheoniscus politus* (C. Koch 1841)

It is mainly present in hilly and mountain areas, only seldom occurs in plain (fig. 5). Being a sylvan species (Radu 1985) it occurs in forests or close to them, its rarity at plain being a consequence of the scarcity of forests in these areas.

3.1.16. *Protracheoniscus major* (Dollfus, 1903)

It was identified in a single locality, at Sălacea (fig. 5), in an artificial habitat, represented by the entrance of some cellars. Probably, its spread is favoured by human activities.

3.1.17. *Porcellium conspersum* (C. Koch, 1841)

It was only found in the wetlands from Oaş Mountains (fig. 6) in the vicinity of some forests, which is in agreement with its requirements (Kontschan 2003, Tomescu et al. 2005, 2012).

3.1.18. *Porcellium collicola* (Verhoeff, 1907)

It is much more widespread in north-western Romania compared to the previous species, being present both in mountain, hilly and plain areas (fig. 6). It was identified both in some natural and anthropized wetlands. In the anthropogenically affected plain areas it occurs in roadside channels like the species of genus *Hyloniscus*.

3.1.19. *Trachelipus difficilis* (Radu, 1950)

This species mainly occurs in hilly and mountain areas; however it is also present in the plain areas north of Someş (fig. 6). It is a sylvan species (Radu 1985) being found, for the most part, in forested areas. It is also present in wetlands.

3.1.20. *Trachelipus arcuatus* (Budde-Lund 1885)

It is widespread in north-western Romania, occurring over the whole investigated area (fig. 6). Although it is considered a sylvan species (Radu 1985), most of the populations have been identified

in wetlands.

3.1.21. *Trachelipus nodulosus* (C. Koch 1838)

It is one of the most common terrestrial isopod species in north-western Romania. Although it occurs over the whole region, most of its distribution localities are situated in plain (fig. 6), *T. nodulosus* being a xerophilous species (Farkas 2010), present in grassy areas (Tomescu et al. 1995). It is present in almost all habitat types from north-western Romania both natural and anthropized ones.

3.1.22. *Trachelipus rathkii* (Brandt, 1833)

It is also present over the entire surveyed area (fig. 6). It seems to be more widespread in wetlands, but occurs also in forests.

3.1.23. *Trachelipus ratzeburgii* (Brandt, 1833)

It was solely found in the southern part of the investigated region, at plain and at Crasna Hills (fig. 6). It inhabits natural areas, such as oak forests and wetlands, being found nearly always under fallen logs and bark.

3.1.24. *Porcellionides pruinosus* (Brandt, 1833)

It was found over the whole investigated area, but it is much rarer in hill and mountain than in plain (fig. 6). It was generally found in anthropized habitats and under artificial shelters.

3.1.25. *Porcellio scaber* Latreille, 1804

It is also present over the entire investigated region (fig. 7), but just like the previous one it is related to anthropized habitats and artificial shelters.

3.1.26. *Porcellio spinicornis* Say, 1818

It is a rare species in north-western Romania, identified only in five localities (fig. 7). It was found exclusively at some abandoned constructions, under rubble.

3.1.27. *Armadillidium vulgare* (Latreille, 1804)

It is the commonest species of terrestrial isopods in north-western Romania, present throughout the region (fig. 7). It was found in almost all habitat types from the area, both natural and artificial ones, but in most of the situations it was collected from under artificial shelters.

3.1.28. *Armadillidium carniolense* Verhoeff, 1901

It was present in a single locality (Roşiori), in some ruins at the railway station (fig. 7). Its presence in the region is unusual, *A. carniolense* being previously identified in south-western Romania and in the Apuseni Mountains (Radu 1985, Tomescu et al. 1995, 2000) in forested, natural habitats. However, in the investigated area it occurs in an artificial habitat, its presence being probably a consequence of the railway related activities.

3.1.29. *Armadillidium versicolor* Stein 1859

It is present over the whole surveyed area, being rarer in Oaş Mountains (fig. 7). It was found both in natural and anthropized habitats, but generally under artificial shelters.

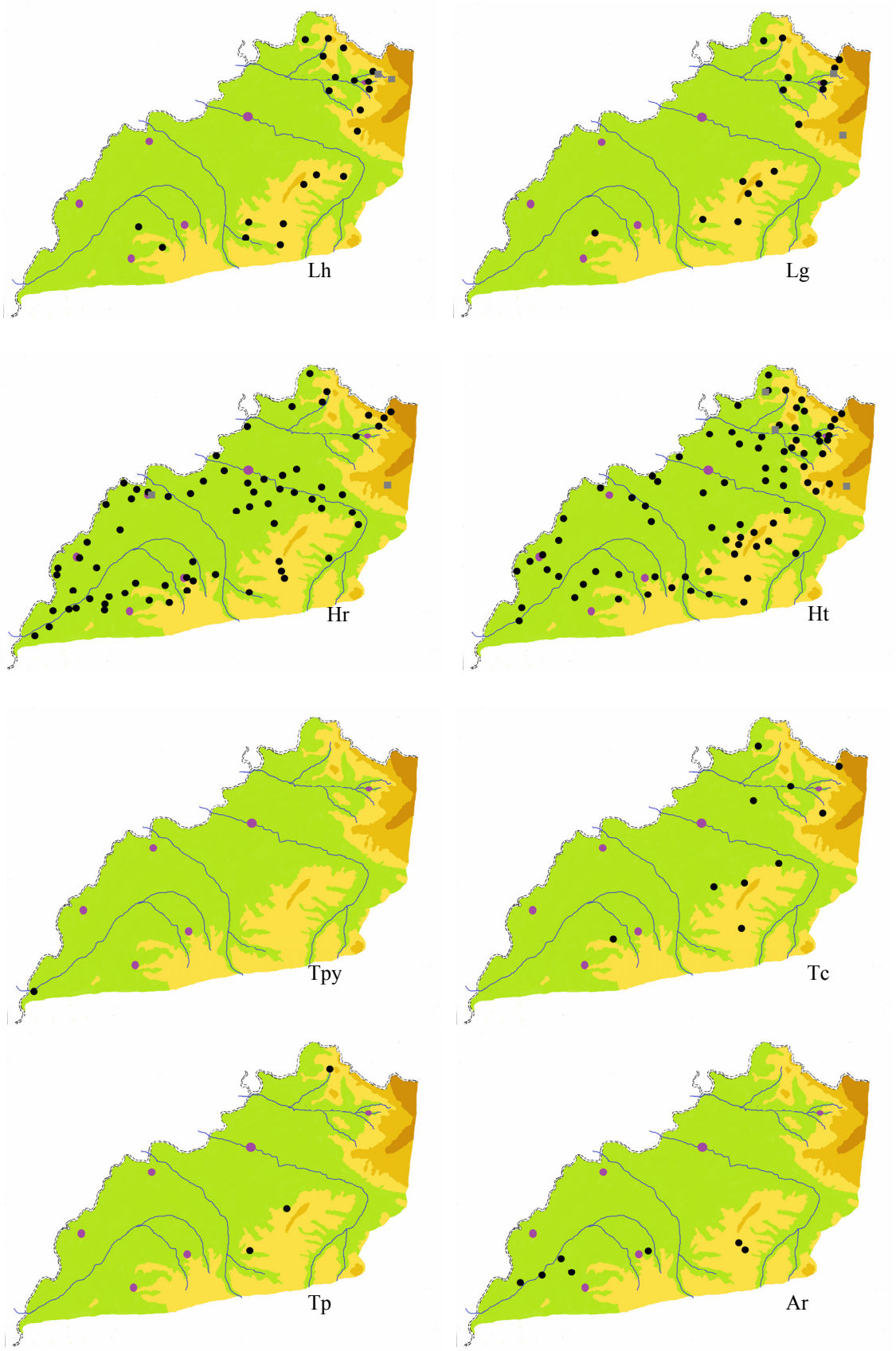

Fig. 4 Distribution of the species *L. hypnorum* (Lh), *L. germanicum* (Lg), *H. riparius* (Hr), *H. transsilvanicus* (Ht), *T. pygmaeus* (Tpy), *T. carpathicus* (Tc), *T. pusillus* (Tp) and *A. roseus* (Ar) in north-western Romania (● - towns, ■ – previously indicated distribution localities, ● – new distribution localities found in our own reserach)

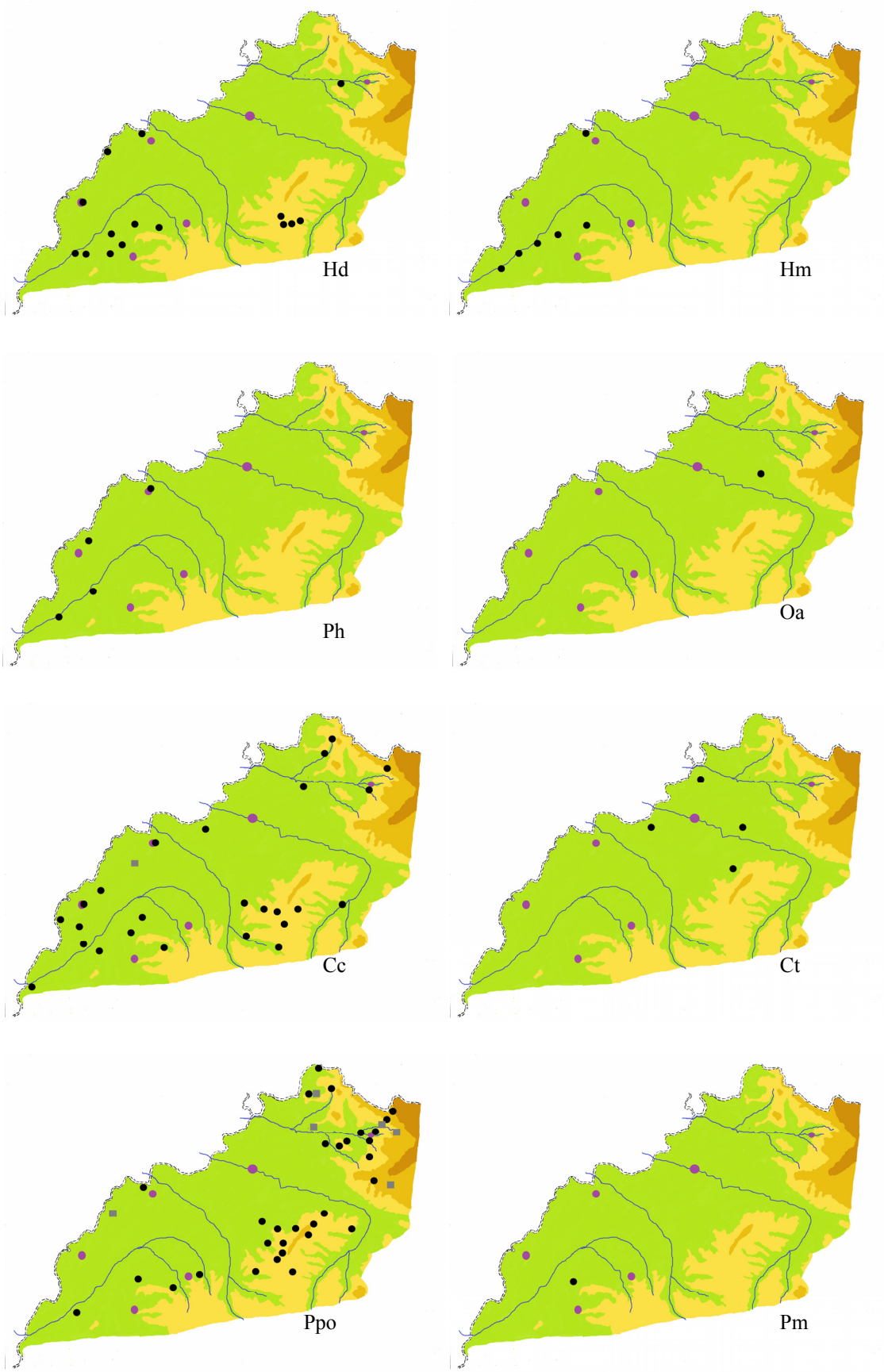

Fig. 5 Distribution of the species *H. danicus* (Hd), *H. mengii* (Hm), *P. hoffmannseggi* (Ph), *O. asellus* (Oa), *C. convexus* (Cc), *C. transsilvanicus* (Ct), *P. politus* (Ppo) and *P. major* (Pm) in north-western Romania (● - towns, ■ – previously indicated distribution localities, ● – new distribution localities found in our own reserach)

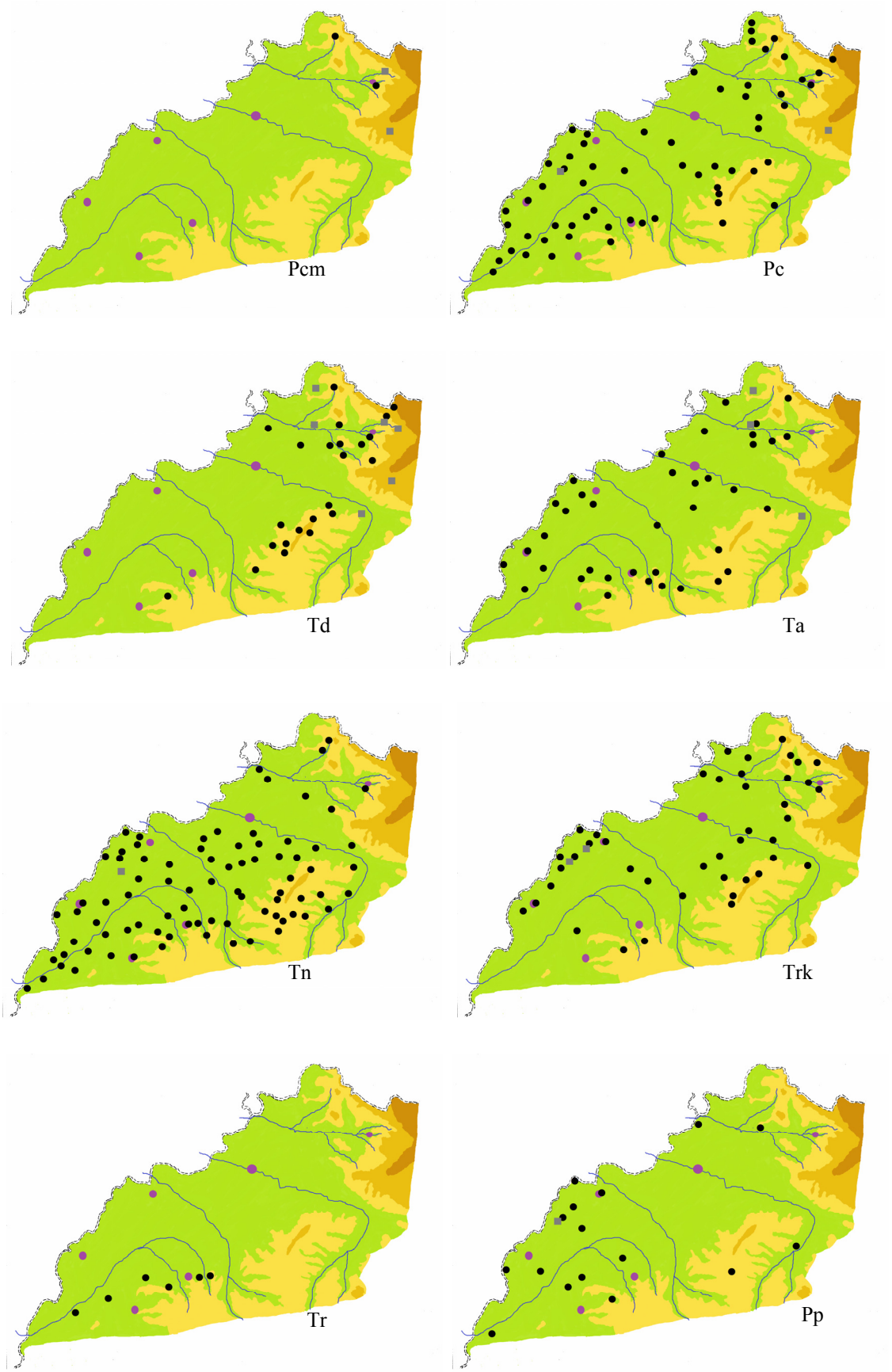

Fig. 6 Distribution of the species *P. conspersum* (Pcm), *P. collicola* (Pc), *T. difficilis* (Td), *T. arcuatus* (Ta), *T. nodulosus* (Tn), *T. rathkii* (Trk), *T. ratzeburgii* (Tr) and *P. pruinosus* (Pp) in north-western Romania (● - towns, ■ – previously indicated distribution localities, ● – new distribution localities found in our own reserach)

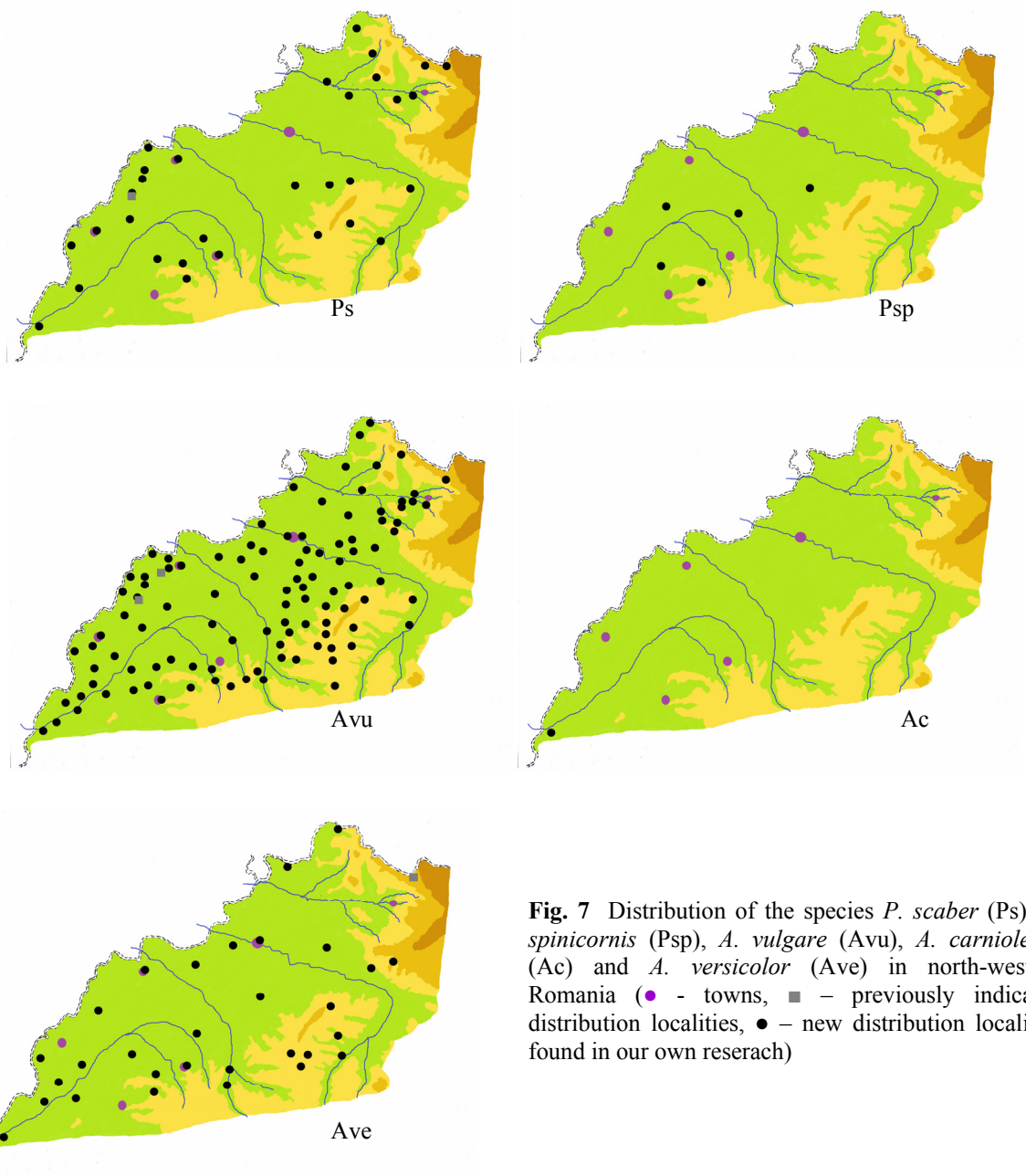

Fig. 7 Distribution of the species *P. scaber* (Ps), *P. spinicornis* (Psp), *A. vulgare* (Avu), *A. carniolense* (Ac) and *A. versicolor* (Ave) in north-western Romania (● - towns, ■ – previously indicated distribution localities, ● – new distribution localities found in our own reserach)

4. Distribution of the terrestrial isopod fauna in the geographical units from north-western Romania

Most of the 29 species of terrestrial isopods from north-western Romania (19 species) have been found in all four geographical units of the region. The highest number of species was found in plain areas and the lowest number in mountain areas. The number of species found in Crasna Hills and Culmea Codrului Hills is similar (fig. 8). The high number of terrestrial isopod species in plain areas from north-western Romania represents probably a consequence of the large surface occupied by plains compared to that of mountains. However, the fact is actually a consequence of the anthropogenic impact which had affected the plain areas in the past. Thus, by subtracting the synanthropic species, the number of terrestrial isopod species from the plain areas from north-western

Romania decreases noticeable. Although a low number of terrestrial isopod species were found in mountain areas, these are species characteristic of some natural habitats, with high humidity. Probably, the plain areas also held greater importance in this respect in the past, as indicated by the presence of *C. transsilvanicus*, but the anthropogenic impact had restricted the range of these species.

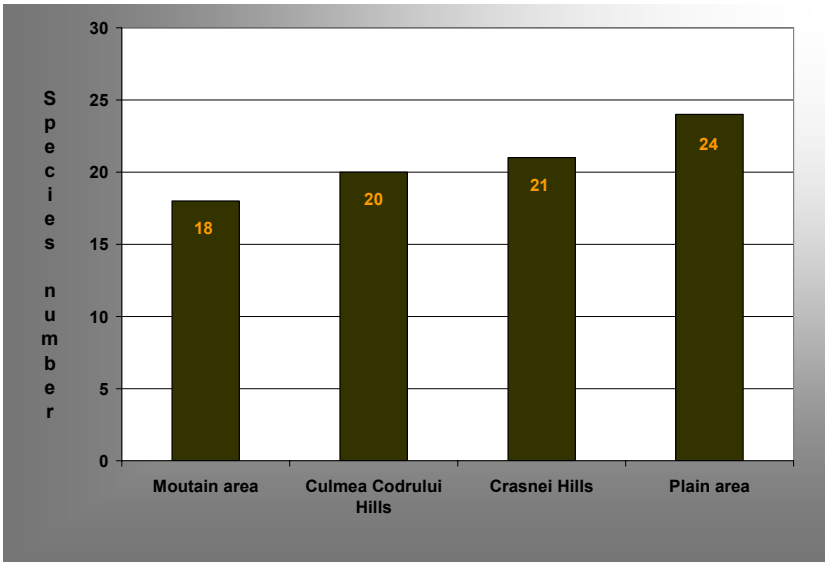

Fig. 8 The number of terrestrial isopod species identified in the geographical units from north-western Romania

5. Terrestrial isopod assemblages in the habitats from north-western Romania

The terrestrial isopod assemblages of the 22 habitat types from north-western Romania from which there were collected samples using the direct method, show great differences. Thus, the number of species from these is different and also the ecological requirements of species. The highest number of species occurs in natural habitats like wetlands and forests and the lowest number was found in the highly anthropogenically affected habitats, such as plantations. Most of the species (22 species) were found in the moist areas from the banks of small hilly and mountain streams and the lowest number (only two species) inhabited the pine plantations and orchards (fig. 9, 10).

6. Data about the cohabitation of congeneric species of terrestrial isopods from north-western Romania

Of the 10 genera of terrestrial isopods represented in north-western Romania by at least two species, five genera had species that inhabited the same habitats (table 3). The remaining five genera had species that were never found in the same habitat; sometimes they were not even present in the same locality or geographical region. In general, in the same habitat there are present two congeneric species, but concerning the genera *Trachelipus* and *Armadillidium* there were also habitats with three

species. Species of the genus *Trachelipus* seem to cohabitate more often in north-western Romania than in others regions of the country (Tomescu et al. 2002b).

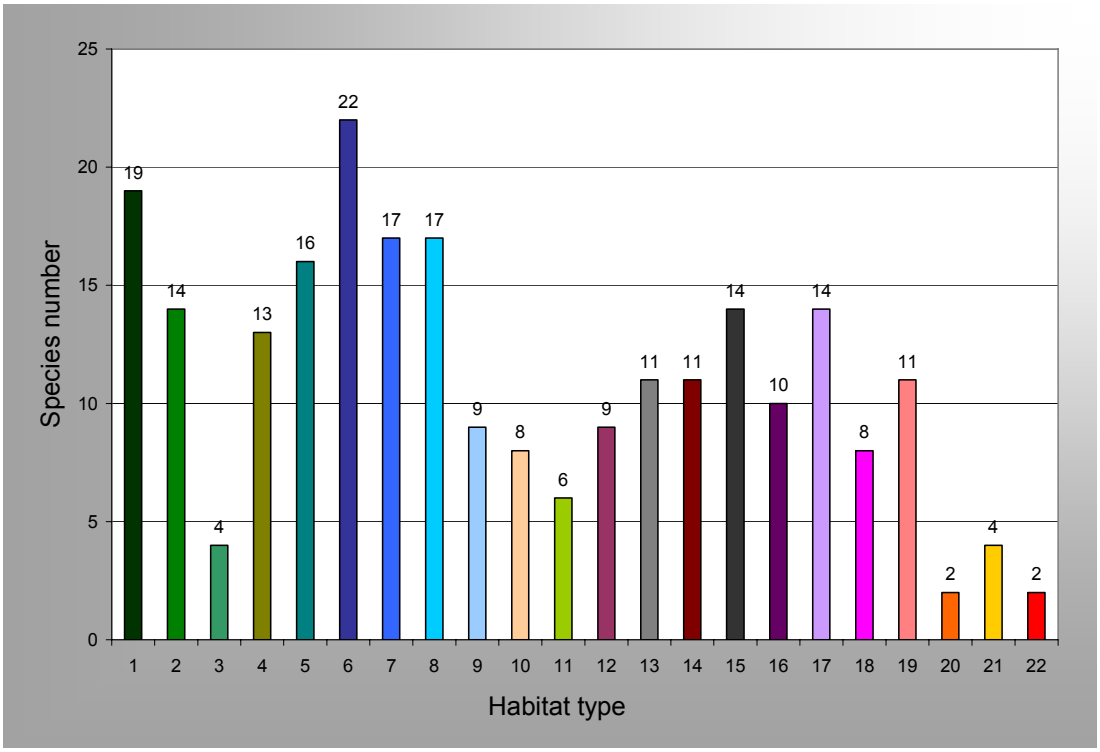

Fig. 9 The number of terrestrial isopod species identified in the 22 habitat types from north-western Romania (1-oak forest, 2-beech forest, 3-ash forest, 4-forest edge, 5-marsh, 6-banks of small hilly and mountain streams, 7-coppices, 8-semi-natural wetlands, 9-roadside channels, 10-sand dunes, 11-affected grassy areas, 12-abandoned stations, 13-graveyards, 14-castles and mansions, 15-cellars, 16-distilleries, 17-other abandoned constructions, 18-roadsides, 19-poplar plantations, 20-pine plantations, 21-black locust plantations, 22-orchards)

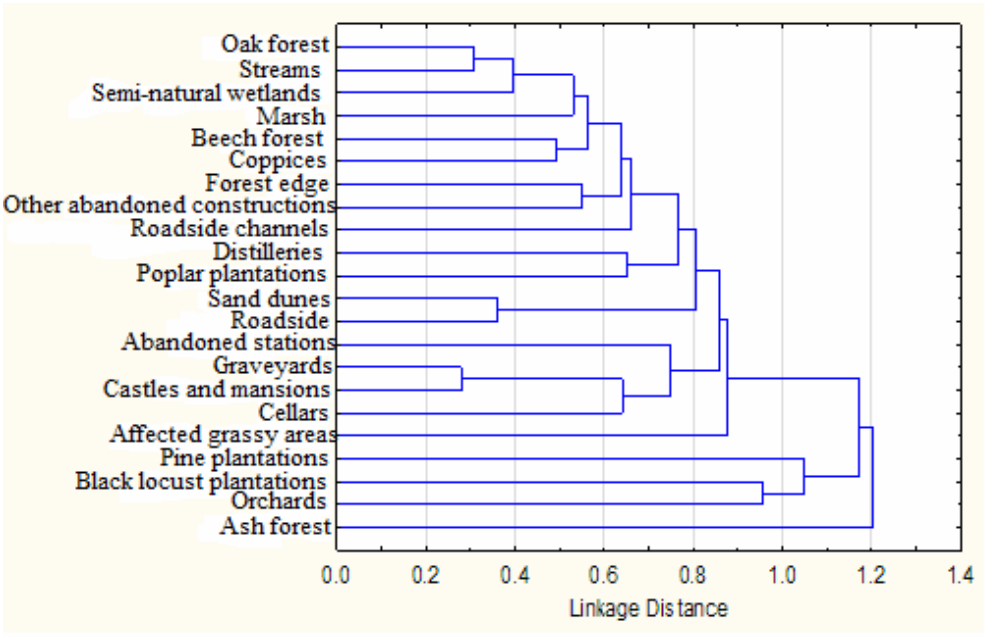

Fig. 10 Similarity of the terrestrial isopod assemblages from the 22 habitat types in north-western Romania

Tabelul 3 The habitat types with congeneric species of terrestrial isopods in north-western Romania(1-oak forest, 2-beech forest, 3-ash forest, 4-forest edge, 5-marsh, 6-banks of small hilly and mountain streams, 7-coppices, 8-semi-natural wetlands, 9-roadside channels, 10-sand dunes, 11-affected grassy areas, 12-abandoned stations, 13-graveyards, 14-castles and mansions, 15-cellars, 16-distilleries, 17-other abandoned constructions, 18-roadsides, 19-poplar plantations, 20-pine plantations, 21- black locust plantations, 22-orchards, *Lg - Ligidium germanicum, Lh - L. hypnorum, Hr - Hyloniscus riparius, Ht - H. transsilvanicus, Pc - Porcellium collicola, Pcm - P. conspersum, Td - Trachelipus difficilis, Ta - T. arcuatus, Tn - T. nodulosus, Tr - T. rathkii, Tratz - T. ratzeburgii, Av - Armadillidium vulgare, Ac - A carniolense, Ave - A. versicolor*)

Habitat type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**Total**
Lh / Lg	X	X	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**5**
Pc / Pcm	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
Hr / Ht	X	-	-	-	X	X	X	X	X	-	-	-	-	X	-	X	-	-	-	-	-	-	**8**
Av / Ave	X	-	-	-	X	-	-	-	X	X	-	X	-	X	X	X	X	X	-	-	-		**10**
Av / Ave / Ac	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	**1**
Tn / Td / Ta	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
Tn / Tr / Ta	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**
Tn / Ta / T. ratz	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
T ratz / Tn	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
T ratz / Ta	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
Tr / Tn	-	-	-	-	X	-	-	-	X	-	-	-	X	X	-	-	X	-	-	-	-	-	**5**
Tr / Td	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**
Tr / Ta	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	**2**
Td / Tn	X	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**3**
Td / Ta	X	-	-	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**4**
Ta / Tn	X	-	-	X	X	X	-	X	X	X	X	-	-	-	-	X	-	-	-	X	-	-	**10**
Total	**11**	**1**	**1**	**3**	**6**	**8**	**4**	**4**	**4**	**2**	**1**	**2**	**1**	**3**	**1**	**3**	**3**	**1**	**-**	**1**	**-**	**-**	

7. Quantitative ecological research on terrestrial isopod assemblages from north-western Romania

A number of 11264 individuals were collected in the 512 pitfall traps in north-western Romania. There are great differences between the compositions of terrestrial isopod assemblages from different geographical units but also between the different habitats of the same locality.

7.1. Research in the mountain area (Huta-Certeze) in Oaş Mountains

In the two habitats from Huta Certeze (beech forest and mixed beech / conifers forest) we have identified 7 terrestrial isopod species (table 4) belonging to several ecological categories (after Vandel 1960, 1962, Radu 1983, 1985): *L. germanicum, Trichoniscus sp., H. transsilvanicus, P. politus, T. difficilis, P. collicola* and *P. scaber*. Six species have been identified in the beech forest and 4 species in the mixed forest. Overall, in the two sectors we collected 751 individuals. Some species constitute the base of the isopod fauna from the two habitats (the three species in common: *P. politus, L. germanicum, Trichoniscus* sp.). Besides these, there are also species characteristic of each habitat. Two of these are typical of forest habitats (*T. difficilis* and *P. collicola*) and one is eurytopic (*P. scaber*) (Radu 1985). Deciduous forests are generally more favourable to terrestrial isopods than the coniferous ones, the acid soil of the latter damaging their shell (Radu 1983). It was also observed that the leaves of conifers are inefficient for isopod growth (Sousa et al. 1998). Thus, in the specialty

literature, a lower number of species has also been recorded previously in mixed forests (Tomescu et al. 2002a). This is also noticeable at Huta Certeze, both species richness and diversity being higher in the beech forest. *P. politus* is a common species in both habitats from Huta Certeze (fig. 11, 12), being a sylvan species, reported often in forested areas (Mureşan et al. 2003, Hotea et al. 2003, Topp et al. 2006, Tomescu et al. 2008, 2011).

Table 4 The identified terrestrial isopod species in the Huta Certeze mountain area

Species	Ecological category	Beech forest	Mixed forest
Ligidium germanicum	paludicolous	X	X
Trichoniscus sp.	paludicolous	X	X
Hyloniscus transsilvanicus	paludicolous	-	X
Protracheoniscus politus	sylvan	X	X
Trachelipus difficilis	sylvan	X	-
Porcellium collicola	sylvan	X	-
Porcellio scaber	euritop	X	-

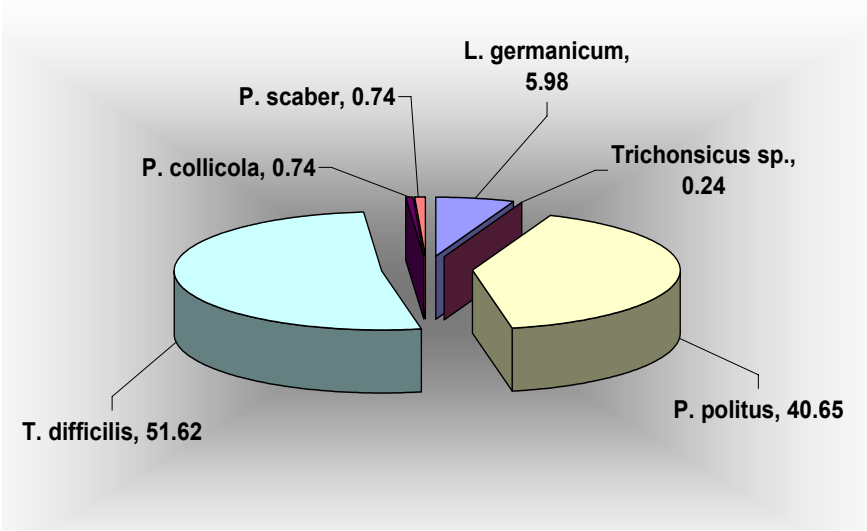

Fig. 11 Relative abundance (A%) of the terrestrial isopod community in the beech forest from Huta Certeze

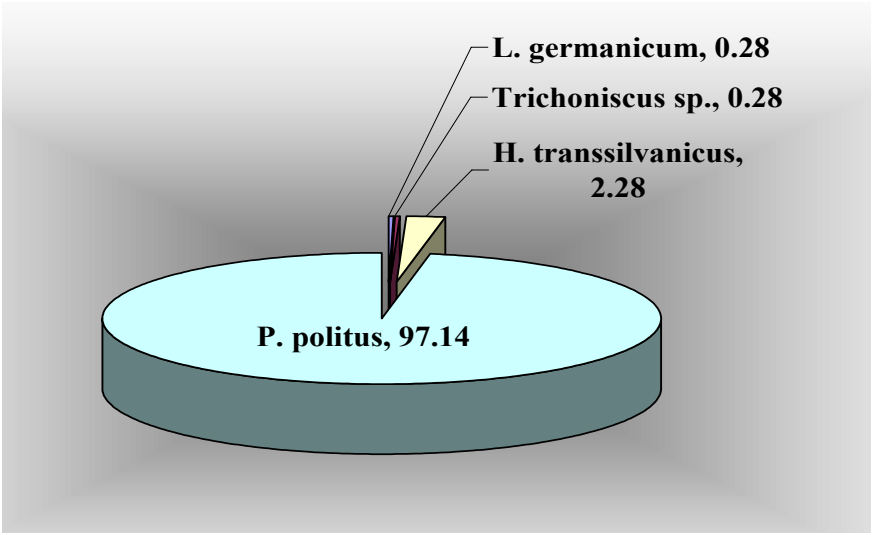

Fig. 12 Composition of the terrestrial isopod community in the mixed forest from Huta Certeze

7.2. Ecological research in hilly areas in north-western Romania

7.2.1. Analysis of terrestrial isopod assemblages from habitats situated in Culmea Codrului area

In the seven habitats (Poiana Codrului - forest edge; Poiana Codrului - oak/beech forest; Crucişor - pasture with bushes; Crucişor - oak forest; Cuţa - pine plantation; Socond - forest in regeneration; Soconzel - marsh) analyzed in the Codru Hills area we identified 11 species of terrestrial isopods: *Trichoniscus sp., H. riparius, H. transsilvanicus, P. collicola, P. politus, T. difficilis, T. arcuatus, T. rathkii, T. nodulosus, A. vulgare, A. versicolor*. These 11 species had a different distribution depending on the habitat type (table 5). In the 141 pitfall traps we identified a total number of 1769 terrestrial isopod individuals. Thus the numerical abundance was 12.54 individuals / trap. Females prevailed in each habitat and species. There are differences in species richness and similarity (fig. 13) depending on the degree of anthropogenic affecting of habitats. Thus, the number of species is approximately equal between natural forests and pastures, but it is lower in regeneration and extremely low in the pine plantation, which had only one species. Plantations have been shown unfavourable for terrestrial isopods in other situations as well (Lachat et al. 2006, Tomescu et al. 2011), but also for other soil macrofauna communities (Anichkin et al. 2007, Gardner et al. 2008). Litter from plantations seems to affect negatively the *A. vulgare* species also (Abelho & Molles, Jr. 2009).

Table 5 Terrestrial isopod species identified in the habitats from Culmea Codrului (1-Poiana Codrului, forest edge; 2 - Poiana Codrului, oak / beech forest; 3 - Crucişor, pasture with bushes; 4 - Crucişor, oak forest; 5 - Cuţa, pine plantation; 6 – Socond, forest in regeneration; 7 – Soconzel, marsh)

Species	Ecological category	1	2	3	4	5	6	7
Trichoniscus sp.	paludicolous	-	-	-	-	-	X	-
Hyloniscus riparius	paludicolous	-	-	-	X	-	-	X
Hyloniscus transsilvanicus	paludicolous	X	-	-	-	-	X	X
Porcellium collicola	paludicolous	X	-	X	-	-	-	X
Protracheoniscus politus	sylvan	X	X	X	X	X	X	X
Trachelipus difficilis	sylvan	-	X	X	X	-	X	X
Trachelipus arcuatus	sylvan	-	-	X	-	-	-	X
Trachelipus rathkii	euritop	X	X	X	X	-	-	X
Trachelipus nodulosus	euritop	X	X	-	-	-	-	X
Armadillidium vulgare	synanthropic	X	X	X	X	-	-	X
Armadillidium versicolor	synanthropic	-	X	-	-	-	-	-

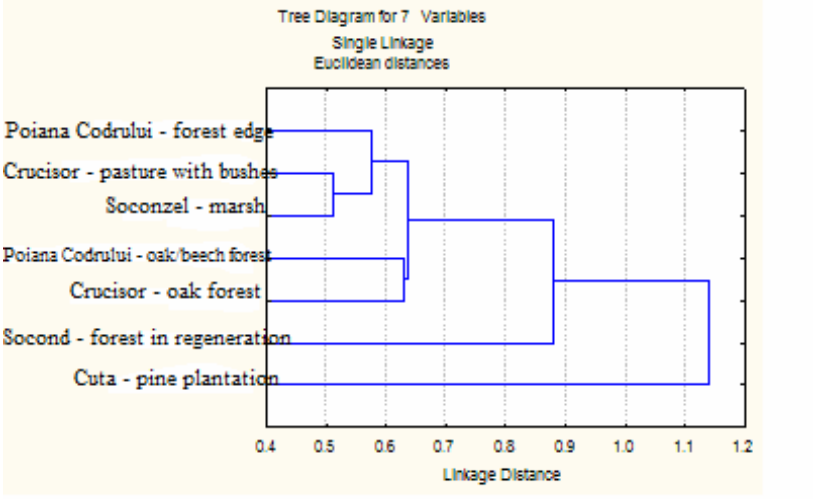

Fig. 13 Similarity of the terrestrial isopod assemblages in the habitats from Codru Hills

The marsh from Soconzel shelters more terrestrial isopod species compared to the other habitats. The moist areas with dense herbaceous vegetation provide the favourable microhabitats for species related to high humidity (*H. transsilvanicus* and *P. collicola*). Wetlands have previously been shown to be important for the diversity of terrestrial isopods (Sfenthourakis & Triantis 2009, Farkas & Vadkerti 2003). The location of the marsh from Soconzel leads both to the existence of some wetland related species (*T. arcuatus* and *T. rathkii*), to the survival of some sylvan species (*T. difficilis*) and to the penetration of some open area species from the neighbouring habitats (*T. nodulosus*).

The name of the region, Culmea **Codrului** ('Forest Peak'), is also confirmed by the composition of terrestrial isopod assemblages from it. Thus, the only species present in all studied habitat was *P. politus*, a sylvan species (Radu 1985). However, *P. politus* occurs also in unforested areas (the marsh from Soconzel or the pasture with bushes from Crucişor). This species has also been found in unforested meadows in other situations, but in a mountain area (Tomescu et al. 2002a) while in Culmea Codrului the phenomenon occurs at a much lower altitude. This probably indicates that these habitats were also forested in the recent past and the species has survived after deforestation due to the high humidity of the area (Stoenescu et al. 1966). The importance of natural forests for terrestrial isopod assemblages is highlighted, besides higher diversity, by the fact that in the pine plantation and in the forest in regeneration there are very few species. Compared to the plantation a higher diversity and species richness are found in the forest in regeneration. Nevertheless, the number of species and the diversity are generally lower in this habitat also than in the natural forests, a fact noticed in other situations as well (Baini et al. 2012). Thus, it becomes obvious that for terrestrial isopods is more beneficial if the deforested land is left to recover naturally instead of being planted forests with alien species.

7.2.2. Analysis of terrestrial isopod assemblages from Crasna Hills area

In the four habitats from Crasna Hills (Săcăşeni, meadow; Săcăşeni, forest edge; Sărăuad, forest edge; Sărăuad, forest) we determined seven species of terrestrial isopods (table 6) of different ecological categories, in accordance with the inhabited habitats. Thus, we have identified the following species: *H. riparius*, *H. transsilvanicus*, *A. roseus*, *P. politus*, *P. collicola*, *T. nodulosus* and *T. ratzeburgii*.

Table 6 The species identified in the habitats from Crasna Hills area (1 – Săcăşeni, meadow, 2 – Săcăşeni, forest edge, 3 – Sărăuad, forest edge, 4 – Sărăuad, forest)

Species	Ecological category	1	2	3	4
Hyloniscus riparius	paludicolous	-	-	-	X
Hyloniscus transsilvanicus	paludicolous	-	-	X	X
Androniscus roseus	endogeous	-	-	X	-
Protracheoniscus politus	sylvan	-	-	-	X
Porcellium collicola	praticolous	-	X	X	-
Trachelipus nodulosus	euritop	X	X	-	X
Trachelipus ratzeburgii	sylvan	-	X	-	X

In the habitats from Crasna Hills a total number of 468 terrestrial isopod individuals were collected from 61 pitfall traps. Thus, numerical abundance in this area was 7.67 individuals / trap. Generally, females prevail in each habitat. The fact that no species occurs in all habitats reflects their heterogeneity concerning environmental conditions. The habitats can be divided into two categories:

dry ones (the meadow and forest edge from Săcăşeni) and those with high humidity (the forest edge and oak forest from Sărăuad). The species overlap from the terrestrial isopod assemblages between the four habitats (fig. 14) is very small, the driest and the moistest habitat having no common species. The species composition in open areas and forests is also different.

In the dry habitats the xerophilous species *T. nodulosus* prevails, this being the only species present in the meadow from Săcăşeni. Unlike in the meadow, in the forest edge from Săcăşeni the composition of the community is completed by the praticolous species *P. collicola* and the sylvan species *T. ratzeburgii*, respectively. In the moistest habitat, the forest edge from Sărăuad, the praticolous species *H. transsilvanicus* prevails and in the forest the sylvan species *P. politus*. The mono-dominance of the *T. nodulosus* species in the meadow from Săcăşeni can be explained by the fact that this meadow has formed recently after cutting the forest and this is the only species that could survived in the meadow exposed to sun and thus dry, which has formed in the place of the forest.

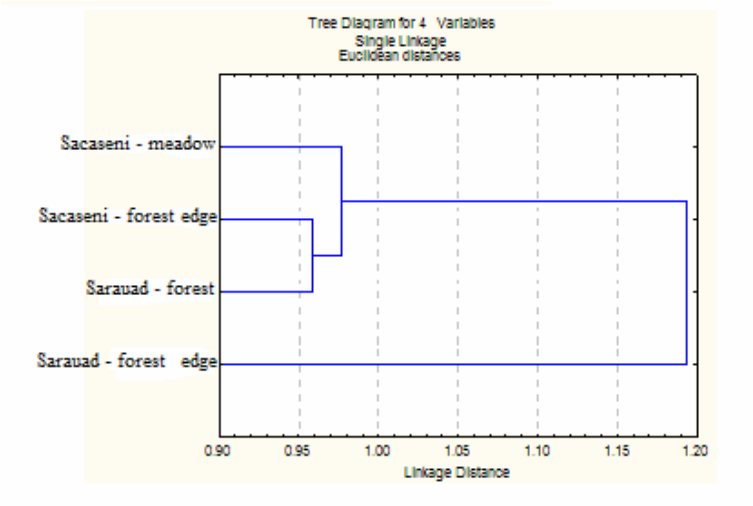

Fig. 14 Similarity of the terrestrial isopod assemblages in the four habitats from Crasna Hills

7.3. Ecological research in the plain area

7.3.1. Analysis of the terrestrial isopod assemblages from the banks of the artificial channel from Cărăşeu

In the wet area from the edge of the channel from Cărăşeu we identified five terrestrial isopod species, belonging to several ecological categories: paludicolous (*H. riparius*), sylvan (*T. arcuatus*), eurytopic (*T. rathkii*) and praticolous species (*T. nodulosus* and *A. vulgare*), the latter also having synanthropic tendencies (Radu 1983, 1985). Of these, *H. riparius* and *T. arcuatus* occurred in very low number having a low relative abundance (fig. 15). Overall, we collected 212 terrestrial isopod individuals, of which 106 were males, 88 females and 18 juveniles. These individuals were collected from 14 traps, the numeral abundance being 15.14 individuals / trap. *T. rathkii* had the highest frequency of occurrence, followed by *A. vulgare* and *T. nodulosus*. Considering constancy, *T. rathkii* was the euconstant species, *T. nodulosus* and *A. vulgare* were constant species and *H. riparius* and *T. arcuatus* accidental species.

The presence of *T. arcuatus*, a sylvan species (Radu 1985) in the unforested habitat from Cărăşeu can be explained in terms of other similar situations recorded in the Western Plain. The

presence of some species with very different ecological requirements has been explained by the existence of a high diversity of microhabitats found on the banks of channels (Tomescu et al. 2005), such as the artificial channel from Cărăşeu. Recently, in north-western Romania there have been frequently reported mountain species in plain areas, in atypical habitats (Covaciu-Marcov et al. 2004, 2005, 2008, 2009). The situation seems to be valid for isopods as well, a group for which it has been recently reported a sylvan species in a treeless marsh, located away from the forest, in north-western Romania (Tomescu et al. 2010). The occurrence of *T. arcuatus* at Cărăşeu expands the territory in which, this seeming anomaly, has also been recorded for isopods. Probably, the explanation is similar to that provided in the previous case (Tomescu et al. 2010). Thus, the neighbouring area of Cărăşeu locality was probably covered with forests in the past and the sylvan isopods survived after deforestations in the wet areas near channels.

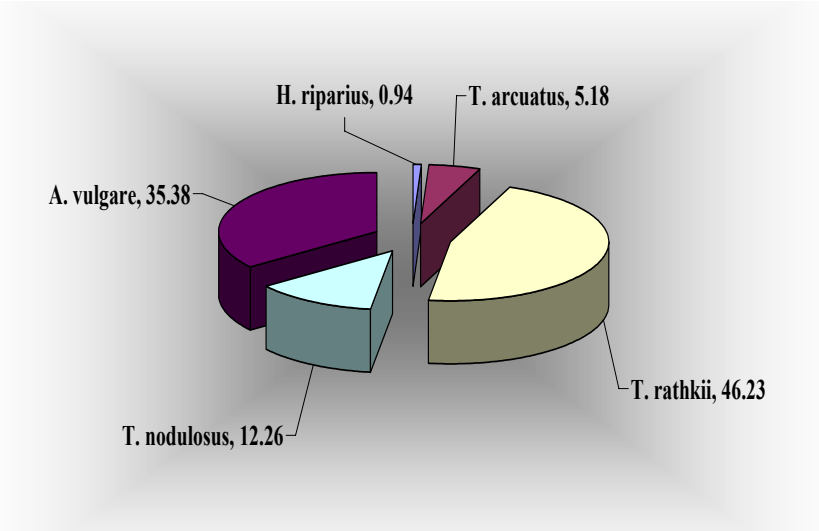

Fig. 15 Relative abundance of the terrestrial isopod species in the wet area near the channel from Cărăşeu

4.3.2. Analysis of terrestrial isopod community in the marsh from Valea lui Mihai

In the marsh from Valea lui Mihai we identified 9 terrestrial isopod species: *H. riparius*, *H. transsilvanicus, H. danicus, C. convexus, P. collicola, T. arcuatus, T. rathkii, T. nodulosus, A. vulgare*. Of the 674 individuals identified in the traps, 273 were males and 401 females. The isopods were collected from 16 traps, so that the numeral abundance was 42.12 individuals / trap. Males belonged to only seven species, while females were identified in each of the nine species. In this marsh *H. riparius, T. arcuatus* and *A. vulgare* were the most frequent species and had a high relative abundance (fig. 16). Concerning constancy, *A. vulgare, H. riparius* and *T. arcuatus* were euconstant species, *H. danicus, C. convexus* and *P. collicola* were accessorial species and remaining species (*H. transsilvanicus, T. rathkii, T. nodulosus*) were accidental ones.

The community structure of terrestrial isopods in the marsh from Valea lui Mihai is similar to that of the natural wetlands from Carei Plain (Ferenți et al. 2012). This was explicable because in the past these marshes were united between them. However, compared to the isopod fauna found in the vicinity of the antropized channel from Cărăşeu (Ferenți & Dimancea 2012), in the marsh from Valea lui Mihai the terrestrial isopod community is much more diversified, the number of species being higher. This highlights that the natural marshes are much more favourable for the terrestrial isopod

fauna from north-western Romania. Although artificial channels can shelter a part of the original marshes' fauna, at least concerning terrestrial isopods this is only limited to a small part.

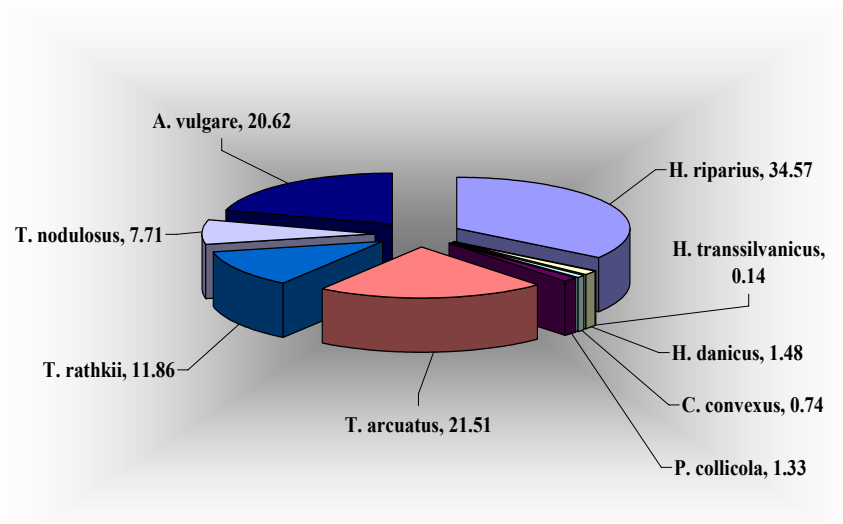

Fig. 16 Relative abundance of terrestrial isopod species from the community of the marsh from Valea lui Mihai

4.3.3. Analysis of terrestrial isopod assemblages from different habitats in Carei Plain (Foieni area)

In the four habitats from Foieni (sand dune, marsh, forest edge, oak forest) we collected 951 specimens of terrestrial isopods. Thus, numerical abundance was 10.68 individuals / trap. The composition of terrestrial isopod assemblages of the area is remarkably uniform, regardless of the habitat type, here being identified only five species: *P. collicola, T. arcuatus, T. nodulosus, T. rathkii* and *A. vulgare*. These species belonged to five ecological categories, species richness differing very slightly depending on the habitats (table 7). Four of the five terrestrial isopod species were common to all habitats, having a different relative abundance (fig. 17, 18, 19, 20), only *T. nodulosus* was present in just two habitats. Data from Foieni indicate a surprising uniformity of the terrestrial isopod assemblages between the four analysed habitats, but also a poorness compared to data obtained previously using direct methods. The explanation of uniformity lies probably in the history of the region. Thus, probably the marshes are indeed the habitats in which the terrestrial isopod fauna of the region survives (Ferenți et al. 2012). The assemblages from marshes had colonized all neighbouring habitats, probably due to the high humidity of the region, being represented by the same species even if in different proportions.

Table 7 The terrestrial isopod species identified in the four habitats from Foieni (1 – sand dune, 2 – marsh, 3 – forest edge, 4 – oak forest)

Species	Ecological category	1	2	3	4
Porcellium collicola	paludicolous	X	X	X	X
Trachelipus arcuatus	sylvan	X	X	X	X
Trachelipus nodulosus	praticolous	X	X	-	-
Trachelipus rathkii	euritop	X	X	X	X
Armadillidium vulgare	synanthropic	X	X	X	X

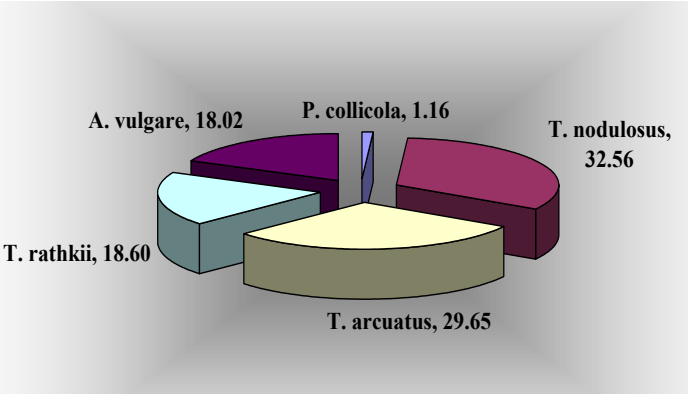

Fig. 17 Relative abundance of the terrestrial isopod species in the sand dune from Foieni

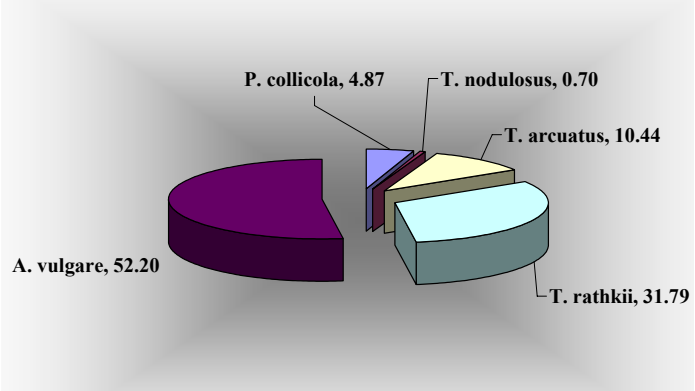

Fig. 18 Relative abundance of the terrestrial isopod species in the marsh from Foieni

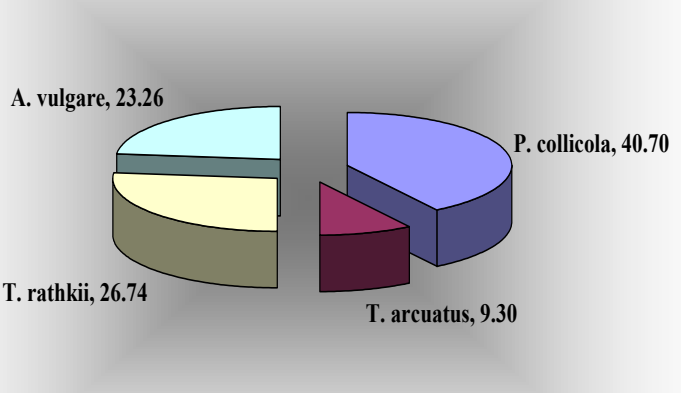

Fig. 19 Relative abundance of the terrestrial isopod species in the forest edge from Foieni

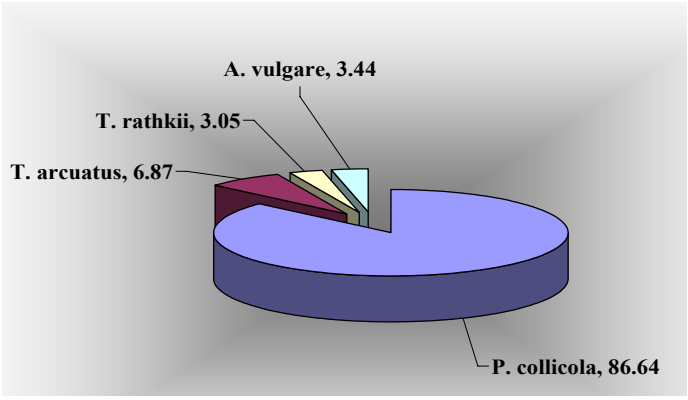

Fig. 20 Relative abundance of the terrestrial isopod species in the oak forest from Foieni

7.3.4. Analysis of terrestrial isopod assemblages in different habitats in the forest from Livada

In the five investigated habitats (marsh, forest near marsh, forest near railway, oak forest, regeneration) in the forest from Livada we collected a total number of 6439 specimens of terrestrial isopods belonging to 10 species: *Trichoniscus* sp., *H. riparius, H. transsilvanicus*, *P. collicola, P. conspersum, P. politus, T. difficilis, T. arcuatus, P. scaber, A. vulgare*. Of these species, *T. difficilis* was the commonest. The species *A. vulgare* was well represented in the first three habitats, missing from the last two. In these the commonest species was *P. politus*, which was missing in the first three habitats (table 8). The forest from Livada is heterogeneous in terms of the terrestrial isopod fauna. Thus, depending on humidity and degree of anthropogenic affectation, the species composition varies greatly even within the same area of the forest (fig. 21).

Table 8 The terrestrial isopod species identified in the five habitats from Livada (1 – marsh, 2 – forest near marsh, 3 – forest near railway, 4 – oak forest, 5 – regeneration)

Species	Ecological category	1	2	3	4	5
Trichoniscus sp.	paludicolous	X	-	-	-	-
Hyloniscus riparius	paludicolous	-	-	X	-	-
Hyloniscus transsilvanicus	paludicolous	X	X	X	-	-
Porcellium collicola	praticolous	X	X	X	-	-
Porcellium conspersum	praticolous	-	-	X	-	-
Protracheoniscus politus	sylvan	-	-	-	X	X
Trachelipus difficilis	sylvan	X	X	X	X	X
Trachelipus arcuatus	sylvan	-	-	X	-	-
Porcellio scaber	euritop	-	-	-	X	-
Armadillidium vulgare	euritop	X	X	X	-	-

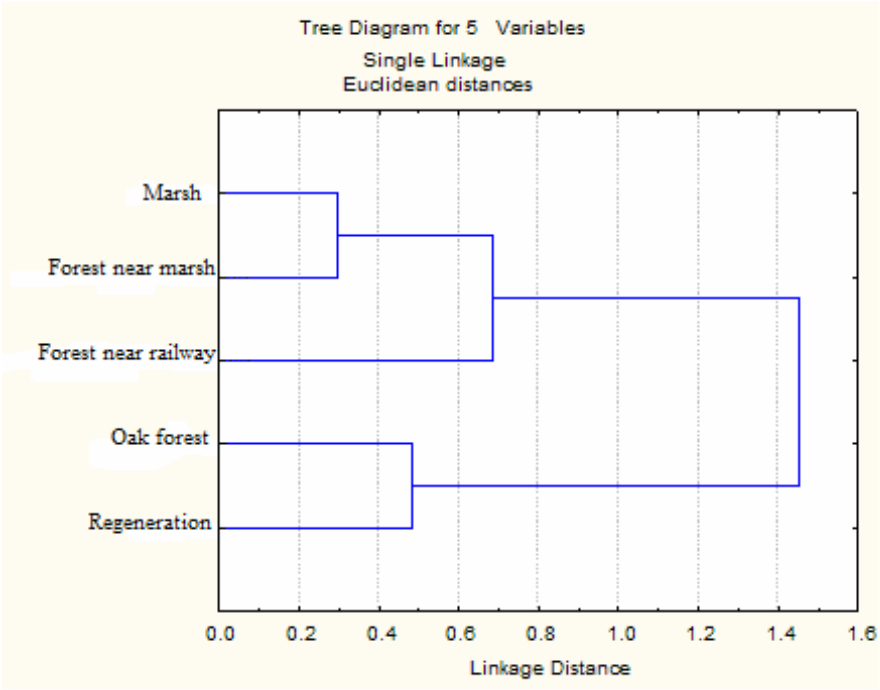

Fig. 21 Similarity of the terrestrial isopod assemblages in the habitats in the forest from Livada

8. Research on terrestrial isopod assemblages in habitats located in close vicinity to the thermal waters from western Romania

We have identified terrestrial isopods active in the cold season in 35 of the 58 investigated thermal habitats (fig. 22). The isopods inhabit only the sectors adjacent to water where the land does not freeze even in the coldest periods. The width of this band varies depending on the habitat due to the volume and temperature of thermal water. In habitats without winter-active isopods the water banks do not meet the ecological requirements of isopods, being too steep, without shelters, without vegetation or exposed directly to the cold air and freezing till the close vicinity of water.

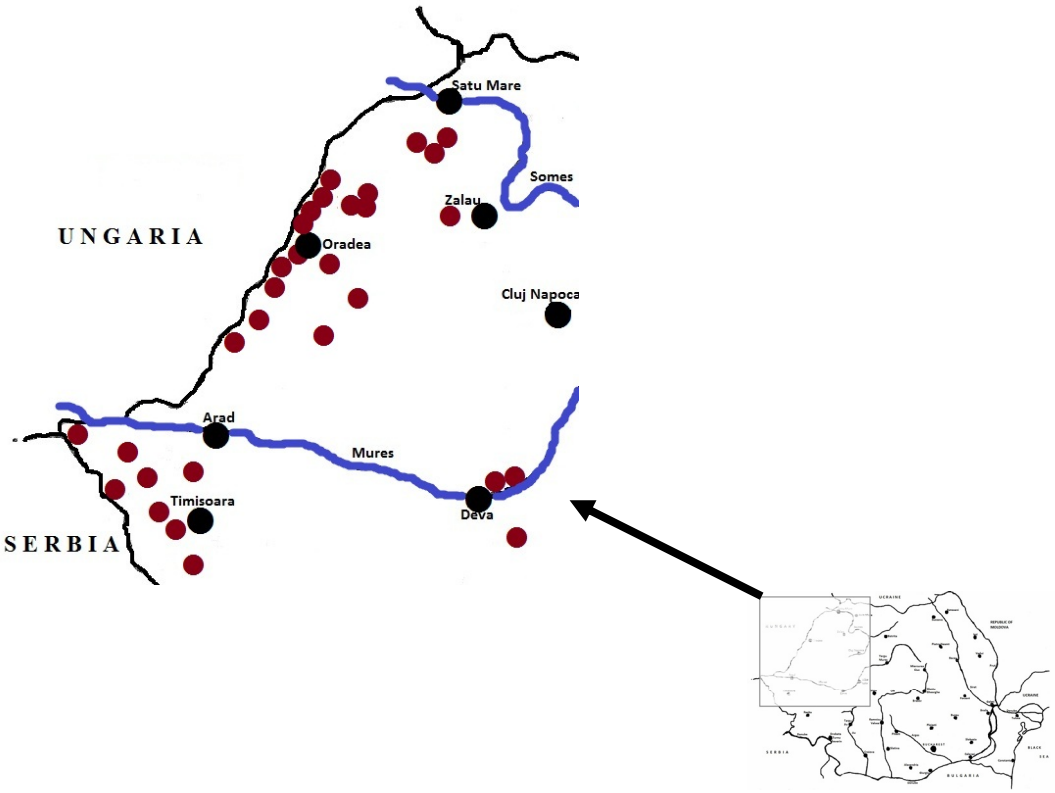

Fig. 22 Geographical location of the thermal habitats (●) from western Romania with winter-active terrestrial isopods

In the 35 thermal habitats from western Romania we have identified a total number of 12 winter-active terrestrial isopod species. Number of species varies between habitats. The highest number is recorded in the larger and relatively natural habitats, which are also the oldest in the same time. The commonest species in winter in the neighbouring areas of thermal waters is *T. nodulosus* (fig. 23). There are species present in only one habitat each, due to the fact that the ecological requirements of those species are fulfilled only in that habitat. However, the winter-active terrestrial isopod species generally inhabited several thermal habitats. At the same time, the species identified in several habitats, having therefore a high frequency, also had a high relative abundance (fig. 23). Overall, 313 individuals of terrestrial isopods were collected, of which 89 were males, 161 females and 63 juveniles.

Along with the disappearance of the phenomenon of hibernation some terrestrial isopod species from certain thermal habitats also present an other modification induced by the thermal regime, namely the modification of breeding period. Thus, in February at Băile 1 Mai, Băile Călan and

Tărian there were identified several females with marsupium (fig. 24). The modification of breeding period was observed in three terrestrial isopod species only: *A. roseus*, *H. riparius* and *H. transsilvanicus*.

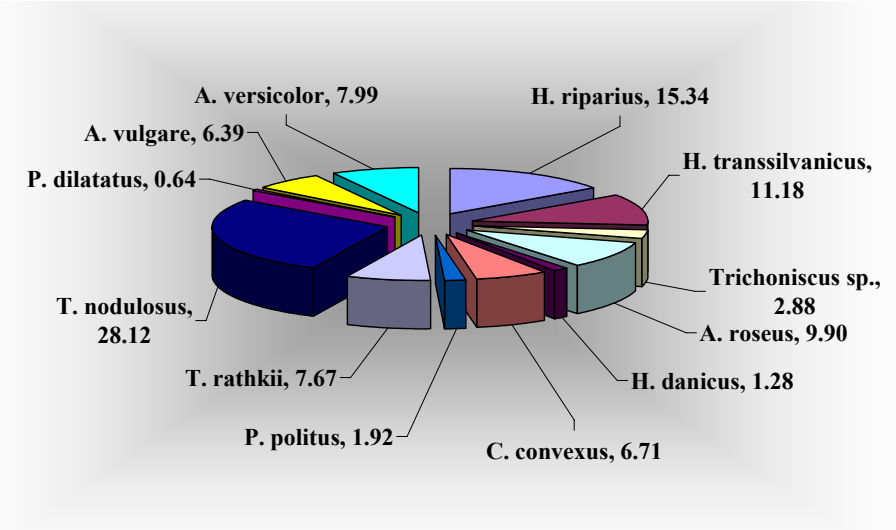

Fig. 23 Relative abundance of the terrestrial isopod species identified in the thermal habitats from western Romania

Fig. 24 Female *H. riparius* with marsupium from the thermal habitat from Tărian (collected in 8th February 2011)

Conclusions

- In the natural and anthropogenic habitats studied in 178 localities from north-western Romania (Satu Mare County, northern Bihor County and south-western Maramureş County) we identified 29 terrestrial isopod species: *Ligidium germanicum, L. hypnorum, Hyloniscus riparius, H. transsilvanicus, Trichoniscus pygmaeus, T. carpaticus, T. pusillus, Androniscus roseus, Haplophthalmus mengii, H. danicus, Platyarthrus hoffmannseggi, Oniscus asellus, Cylisticus convexus, C. transsilvanicus, Protracheoniscus politus, P. major, Porcellium collicola, P. conspersum, Trachelipus difficilis, T. arcuatus, T. nodulosus, T. rathkii, T. ratzeburgii, Porcellionides pruinosus, Porcellio scaber, P. spinicornis, Armadillidium vulgare, A carniolense, A. versicolor*.
- The isopod species present in north-western Romania fall into the following ecological categories: sylvan, paludicolous, praticolous, synanthropic, eurytopic and epigean species. We reported a total of 734 distribution points of the 29 terrestrial isopod species in the 178 investigated localities in north-western Romania.
- The diversity of ecological categories in which the terrestrial isopod species fall into, reflects the ecological diversity of the surveyed area, with a relatively large number of habitats and microhabitats.
- The species with the largest distribution in north-western Romania are: *A. vulgare*, present in habitats from 105 localities, *T. nodulosus*, present in habitats from 82 localities and *H. transsilvanicus*, present in habitats from 78 localities.
- The lowest distribution, being present in a single locality, is recorded for the following species: *T. pygmaeus, O. asellus, P. major* and *A. carniolense*.
- A faunistic particularity of the area from north-western Romania is the presence of species characteristic of wet habitats located at high altitudes, *L. germanicum, L. hypnorum* and *H. transsilvanicus*, in wet habitats located in places with low altitudes, below 200 m. The presence of these species in these habitats can be explained by the existence of a local climate with lower average temperatures, similar to the average temperatures existent in other areas at higher altitudes.
- In north-western Romania there were also identified species endemic to the Romanian fauna: *T. carpathicus* and *C. transsilvanicus*, the latter being a rare species. In addition, in the region there were also identified species endemic to the Carpathian Mountains area: *H. transsilvanicus* and *T. difficilis*.
- In the investigated anthropogenic habitats the following synanthropic species have been identified: *O. asellus, P. pruinosus, P. scaber*. Upon entering the cellars there have been identified the species: *T. pygmaeus, P. major* and *H. mengii*.
- In the anthropogenic habitats there have also been identified species which live in natural habitats, but also have anthropophilic features, occupying also habitats such as: parks around some buildings, graveyards, usually areas with herbaceous and woody vegetation arranged by man. These species are: *P. spinicornis* and *A. vulgare*.
- The number of species identified in the investigated habitats from north-western Romania varies within relatively narrow limits: in the Oaş Mountains area 18 species, in the habitats from Culmea Codrului 20 species, in the habitats from Crasna Hills 21 species and in the habitats from the plain area 24 species have been identified.

- Analyzing the distribution of species in the natural and anthropogenic habitat types it comes out that most of the species live in natural habitats, mainly in the habitats with moist microhabitats; forests with streams and marshy areas (22 species), oak forests (12 species), coppices (17 species), marshes (16 species). In anthropogenic habitats the number of terrestrial isopod species is lower. Old cellars and the areas around abandoned constructions had 14 species each. The lowest number of species has been identified in pine plantations and orchards, 2 species in each type, and in the black locust plantations there were present 4 species. The number of species from habitats reflects the degree of ecological diversity, i.e. the number of microhabitats that can be inhabited by species with different ecological requirements.
- The terrestrial isopod species from north-western Romania generally inhabit natural habitats, being identified under natural shelters. In general, the species related to forests and wetlands have been identified only under natural shelters. However, occasionally they may also use artificial shelters (rubble and other wastes), but only when these were present in natural habitats. Although the terrestrial isopod species from north-western Romania have generally been identified in the specific habitats, we have also encountered exceptions. Thus, *T. arcuatus*, though considered a sylvan species, was more frequently found in wet areas than in forests. Unlike this species, the synanthropic ones are present in artificial habitats, under artificial shelters.
- The analysis of the specific structure of terrestrial isopod assemblages from north-western Romania indicate a high impact of the human activities on natural habitats, by deforestations, pine and black locust plantations on deforested areas, drainage of wet habitats, etc. This changes generated in natural habitats had strongly influenced the terrestrial isopod assemblages too. Thus, some species from the initial assemblages disappeared and in certain situations they were replaced by species which had migrated from the neighbouring habitats. In many plain areas from north-western Romania, the terrestrial isopod assemblages are present almost exclusively in the roadside channels, which represent the last vestiges of natural wetlands.
- The quantitative and qualitative analysis of terrestrial isopod assemblages from the investigated area highlight the importance of forests and wetlands in the conservation of the terrestrial isopod fauna from north-western Romania, occasionally of some rare, endemic species endangered with extinction.
- Terrestrial isopod assemblages along with other animal groups show the “health” state of natural habitats and are undeniable arguments in order to take measures to protect them.
- The banks of thermal waters from the studied area are a refuge place for some terrestrial isopod species during winter, suppressing the winter rest period. The individuals that take refuge in these places are continuing their biological activities. In the vicinity of thermal waters we have identified 12 terrestrial isopod species. These are generally common species, but occasionally rare species like *A. roseus* are also present. In case of some small sized species (*H. riparius, H. transsilvanicus, A. roseus*) there were observed females carrying eggs in the marsupium in winter, which proves that in addition to the disappearance of hibernation period, the breeding period is also altered at certain species.
- Of the 29 species of terrestrial isopods identified in north-western Romania, we found that the congeneric species of 5 genera: g. *Ligidium*, g. *Hyloniscus*, g. *Porcellium*, g. *Trachelipus* and g. *Armadillidium* can cohabitate in certain habitats. It is a proof of the fact that their ecological requirements overlap to some extent, the ecological isolation of these species is not complete.

- The quantitative ecological analysis based on the number of captured individuals of each species displays the existence of some numerically dominant species in each community and of some accessorial species.
- In the natural habitats consisting of natural forests and coppices the sylvan species *P. politus* is numerically dominant and in forests with wet areas the species *H. transsilvanicus* is occasionally also important. In many forests the sylvan species *T. difficilis* is very well represented. In open habitats (meadows) the praticolous species *A. vulgare* and *T. nodulosus* are numerically dominant.
- In all investigated habitats there was recorded a dynamic of the populations of terrestrial isopods. Generally, the maximum number of individuals was captured in traps in the summer months, June-July-August. In addition, the number of captured individuals usually decreased in autumn.
- The importance of wetlands and forests for the autochthonous communities of terrestrial isopods from north-western Romania was also highlighted following the quantitative studies. Thus, the highest number of species and the greatest diversity occurred in wetlands and forests. Of forests, the most important for terrestrial isopods are the moist deciduous forests. Unlike these, the mixed deciduous and coniferous forests hold smaller terrestrial isopod assemblages. The most unfavourable are the plantations, in the pine plantation being present a single species, *P. politus*. The naturally regenerating forests, compared to plantations, shelter a higher number of terrestrial isopod species. This attests the importance of natural regeneration of deforested areas. Although forests have a high diversity of terrestrial isopods, the most favourable sectors for these living beings are the natural wetlands. Compared to these, the heavily anthropogenically modified wetlands such as roadside channels, harbour simplified terrestrial isopod assemblages. Open areas are less favourable for terrestrial isopods than wetlands or forests, in the grassy areas resulted from recent deforestations only *T. nodulosus* being present. Edges of forests have a higher diversity than the surrounding grassy areas, but generally lower than in forests.
- In most terrestrial isopod species identified in the area, the sex ratio is female-biased, the differences being higher in the anthropogenically affected habitats.

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