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Isopod communities of Black locust (*Robinia pseudoacacia* L.) plantations in Transdanubia (Hungary)

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Abstract: Terrestrial isopod communities were studied in 27 Black locust forest in Transdanubia between 1995 and 2011 by hand sampling and pitfall trapping. The investigations yielded 17 species. The most common isopod species of Transdanubia (*Porcellium collicola, Armadillidium vulgare, Trachelipus rathkii, T. nodulosus* and *Hyloniscus riparius*) proved to be frequent in the Black locust plantations, too. All of these species are generalists. The assemblages consisted of 4-5 species. Dominant species of the communities were *A. vulgare* or *P. collicola,* alternatively. Species diversity and evenness of the assemblages were low. Strong association was pointed out between *A. vulgare, P. collicola* and *T. rathkii* while negative association was calculated between *T. nodulosus* and *H. riparius*.

Keywords: woodlice, soil fauna, forest plantation, diversity

Introduction

In 2002, 3% of the world's forests were plantations (FAO 1999). Forest plantations are established artificially in order to produce high volume of wood in a short period of time. Such plantations are usually large scale and characterized by a single tree species arranged in even-age blocks. The planted trees are often exotic and their monoculture stands provide a greatly altered environment in comparison to the indigenous vegetation. Contribution to the total forest area is uneven: it is 20% in New Zealand and over 90% in Great Britain (FAO 1999). In Hungary, this proportion is over 32% [1].

It is commonly accepted that eradication of indigenous woods and establishment of forest plantations will have a negative effect on biodiversity (Freedman et al. 1996; Wagner et al. 1998). Despite a few cases (e.g Palik and Engstrom 1999) when forest plantations supported higher animal diversities relative to the native forests, we must bear in mind that species richness is a weak measure of habitat naturalness, as it does not tell anything about ecological functions of species, e.g. their role within the trophic networks.

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Soil macroarthropods, such as millipedes and isopods, are common organisms in temperate forests contributing to decomposition processes of dead plant matter, thus to soil formation on the forest floor (DAVID and GILLON 2002). As the available leaf litter is a main driver of soil fauna composition (HÄTTENSCHWILER et al. 2005), it is presumable that forest plantations support different isopod fauna than the adjacent native forests.

The isopod fauna of typical Hungarian geographical forms (e.g. hills, floodplains) and biotopes (e.g. meadows, native broadleaf forests), as well as nature reserves and other protected areas have been studied in the past half century (ALLSPACH and SZLÁVECZ 1990, ILOSVAY 1983, KONTSCHÁN 2001a,b, 2002, LOKSA 1962, 1966, 1977, SALLAI 1993, SZLÁVECZ 1991, SZLÁVECZ and LOKSA 1991, VILISICS et al. 2008). Forest plantations, on the other hand, received little attention, regardless to their remarkably large land cover in Hungary.

Black locust (*Robinia pseudoacacia* L.) was introduced to Europe in 1601 (ERNYEI 1926; KERESZTESI 1984). After its first introduction to France, the species became popular and spread rapidly due to its economic values and wide ecological tolerance (JÁRÓ 1965). This tree is able to survive in more than one hundred of different plant habitat types in the temperate deciduous forests in Europe (BARTA et al. 2006). Black locust provides a tough hardwood suitable for columns, buildings, sleepers, and hafts, as well as firewood. The Black locust is an esteemed honey plant in the USA and Europe, while its flower and bark are used as naturopathic medicines. Black locust trees were introduced to Hungary between 1710 and 1720, and the first plantation was established in 1750. Multitudinous cultivation started in 1863 on the Great Hungarian Plain to locate the shifting sand, to which no native tree species was capable. Today, due to long-practiced forestry management and rapid spontaneous dispersion, Black locust forest is the second most common forest type in Hungary after the oaks. It constitutes 22-23% of the Hungarian forests (BARTA et al. 2006, RÉDEI et al. 2008).

Southern Transdanubia, south-western part of Hungary, has 20.2% of Black locust forest of the total forest cover. This 73500 ha is the second biggest surface covered by Black locust plantations in the country.

However, the huge headway of Black locust has unfavourable upshots on nature conservation efforts in Hungary. Black locust takes advantage of forestry practices by spontaneously colonizing clear cuts and gaps. Species richness and diversity of vegetation in Black locust plantations is generally poor (BARTA et al., 2006). The even-aged forest has a single canopy level which enables more light to reach the ground than the native oak forests. C:N ratio of Black locust litter is higher than that of oaks, which accelerates fast decomposition resulting in bare forest floors. Moreover, nitrogen concentration of the upper 15 cm layer of the soil accumulates to an intolerable level to most plant species (BORING and SWANK 1984). Black locust has an allelopathic effect, and its intensive evaporation makes the upper soil layer dry (SZABÓ 1997, TERPÓ and PINTÉRNÉ 1974). Only the nitrophilic plants can tolerate, and survive under such ecological conditions. Black locust does not strike up with other tree species, only Black elder (*Sambucus nigra* L.) may constitute a shrub layer (TOBISCH et al. 2003).

Although this worldwide cultivated species is the second most frequently planted tree after *Eucalyptus* spp. (BARTA et al. 2006), the effect the plantations pose on local fauna is not fully known.

Research of Black locust and its stands have mainly focused on pest organisms (MELIKA et al. 2006, PAGONY 1979, TÓTH 1999, 2002), while invertebrate communities of the poor and rapidly decaying litter layer are lesser-known. By our best knowledge there isn't any published paper on isopod assemblages of Black locust plantations neither in Hungary, nor in Europe.

This paper deals with assemblages of litter inhabiting isopods of the most remarkable artificial forest type in Hungary. Based on both published and unpublished data of the last 15 years, we provide information on the species richness, calculated diversity and community structure of isopod assemblages of Black locust plantations.

Materials and methods

Study area

Sampling points were selected in 27 Black locust plantations in South Transdanubia (Hungary) and Baranya triangle (Croatia) between 1995 and 2011 (Fig. 1.). Sample site selection was based upon the 10×10 km UTM (Universal Transverse Mercator) grid system. Detailed information of the locations (UTM code, altitude, latitude and elevation) are given in Table 1 and in published papers (FARKAS 2004, 2005, 2006, 2007; FARKAS and KRČMAR 2004).

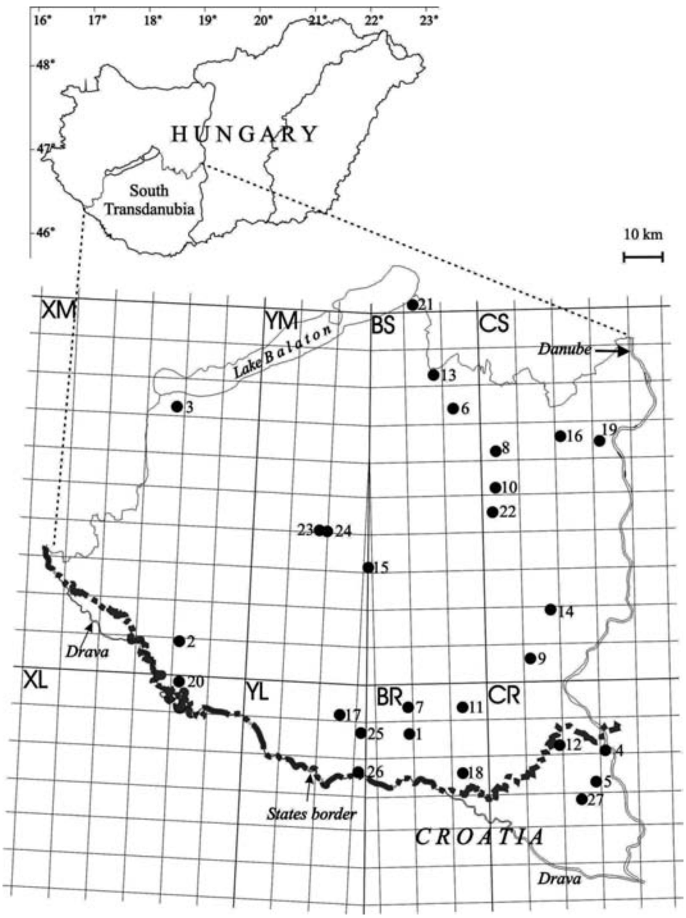

Fig. 1: The locations of sampled Black locust plantations. The data of the sites are given in Table 1.

Table 1. Data of sampling sites. (P: pitfall traps; H: hand sampling)

	Sampling place	UTM	Altitude-latitude	Elevation (m)	Sampling
1	Babarcszőlős	BR 78	N 45º53'40" - E 018º07'49"	120	P
2	Bakháza	XM 80	N 46º06'40" - E 017º21'12"	118	P
3	Balatonszentgyörgy	XM 77	N 46º40'22" - E 017º18'56"	192	H
4	Batina	CR 38	N 45°51'12" - E 018°51'13"	110	H
5	Draž	CR 27	N 45°49'13" - E 018°45'30"	106	P
6	Fornád	BS 97	N 46°41'03" - E 018°17'21"	126	H
7	Görcsöny	BR 79	N 45°57'26" - E 018°08'41"	149	P
8	Gyönk	CS 06	N 46°34'47" - E 018°27'14"	149	H
9	Hímesháza	CS 10	N 46°03'58" - E 018°34'50"	184	H
10	Hőgyész	CS 05	N 46°28'59" - E 018°26'13"	141	H
11	Kisherend	BR 99	N 45°57'14" - E 018°19'30"	155	H
12	Kneževo	CR 18	N 45°52'10" - E 018°39'48"	98	P
13	Magyarkeszi	BS 88	N 46°46'06" - E 018°12'13"	203	H
14	Mórágy	CS 11	N 46°12'30" - E 018°38'44"	188	H
15	Nagyberki	BS 63	N 46º19'58" - E 017º58'34"	225	H
16	Nagydorog	CS 26	N 46°37'02" - E 018°40'00"	96	H
17	Okorág	YL 29	N 45°56'40" - E 017°53'53"	99	P
18	Old	BR 97	N 45°48'11" - E 018°20'38"	101	P
19	Paks	CS 36	N 46°36'04" - E 018°49'05"	117	H
20	Péterhida	XL 89	N 46°00'45" - E 017°21'23"	110	P
21	Szabadi-Sóstó	BT 80	N 46º55'59" - E 018º07'01"	141	H
22	Tevel	CS 04	N 46°25'49" - E 018°27'08"	224	H
23	Toponár, Deseda 1	YM 14	N 46°24'17" - E 017°48'38"	146	P
24	Toponár, Deseda 2	YM 14	N 46°24'22" - E 017°48'34"	143	P
25	Vajszló	YL 38	N 45°52'36" - E 018°00'17"	101	P
26	Vejti	YL 37	N 45°47'36" - E 017°58'28"	105	P
27	Vinograd	CR 26	N 45°45'42" - E 018°45'18"	108	P

Sampling methods

Pitfall trapping (13 localities) and manual sampling (14 localities; Table 1.) were used as collecting methods. For pitfall traps we used plastic cups (volume 450 ml, opening diameter 9-10 cm) with 65% ethylene glycol to preserve and kill animals fall in the trap. Five to ten traps per site were placed in two or three parallel lines, five to ten meters apart. A plastic roof protected the traps from rain and organic debris. Traps were emptied every two or three weeks from March to November, usually 10 times a year. We store the collected specimens in 75% ethyl-alcohol at University of Kaposvár. For identification we used the keys of GRUNER (1966) and SCHMÖLZER (1965).

Data analyses

To calculate the diversity and evenness of the isopod communities Shannon-Wiener's and Pielou's indices were used. To measure the association between species the modified Sørensen index was applied (WHITTAKER and FAIRBANKS 1958; SOUTHWOOD 1984):

$$I_{ai} = 2\left[\frac{J}{A+B} - 0.5\right]$$

where J is the number of individuals in sampling sites where A and B species occurred together, respectively A and B are the numbers of the two species in total of the samples. The value of I ranges between 1 (maximum association) and – 1 (negative association). Zero means no association between the species.

Results and discussion

A total of 12,431 individuals of 17 terrestrial isopod species were collected in 27 Black locust forests during the study years (Table 2). This is cc. 30% of the known isopod species in Hungary.

Five species proved to be prominently frequent, all of them known as widespread, common isopods in Hungary: *A. vulgare, H. riparius, P. collicola, T. nodulosus and T. rathkii*.

We found *A. vulgare* and *P. collicola* to be the most common isopods in Black locust forests, appearing with an incidence rate of 81.5% (22 locations) and 74.1% (20 locations), respectively. The third most common isopod, *H. riparius* was collected in slightly over the half of the sampling sites (51.85%). Individuals of *T. nodulosus* were captured in 13 Black locust plantations (48.15%), while *T. rathkii* was also relatively common with its 44.4% frequency.

The five most common species in Black locust forests, in fact, represent the most common isopods in Southern Transdanubia, in general, including floodplain forests, meadows, agricultural and urban areas. In previous studies in the basins of Drava river and Rinya stream *A. vulgare* and *P. collicola* were captured with incidence frequencies of 70-80% of the investigated 34 UTM units, dominating - along with *T. rathkii* - the local isopod assemblages (FARKAS 1999). FARKAS (2007) has also found these woodlice to be the most common ones in three counties (Baranya, Somogy, Tolna) of South Transdanubia as both species were found in 81% of the studied 175 UTM units. Both *A. vulgare* and *P. collicola* are surface active habitat generalists with wide ecological tolerance (HORNUNG et al., 2007) in Hungary. They are the most frequent terrestrial isopod species of Transdanubia, and do not show any specific habitat preferences (HORNUNG et al., 2009).

Table 2. List of the species, their frequencies, ecological types and habitat preferences. (E: epigean activity; S: soil dweller; NR: natural and rare; NF natural and frequent; DR: disturbed and rare; DF: disturbed and frequent; G: generalist)

		frequency (%)	n	microhabitat	distribution
1.	*Armadillidium opacum* (C. Koch, 1841)	7,41	2	E	NR
2.	*Armadillidium versicolor* Stein, 1859	3,7	1	E	DR
3.	*Armadillidium vulgare* (Latreille, 1804)	81,48	22	E	G
4.	*Armadillidium zenckeri* Brandt, 1833	3,7	1	E	NR
5.	*Cylisticus convexus* (De Geer, 1778)	22,22	6	E	DF
6.	*Haplophthalmus danicus* Budde-Lund, 1880	7,41	2	S	G
7.	*Haplophthalmus mengii* (Zaddach, 1844)	11,11	3	S	G
8.	*Hyloniscus riparius* (C. Koch, 1838)	51,85	14	E, S	G
9.	*Ligidium hypnorum* (Cuvier, 1792)	3,7	1	E	NF
10.	*Platyarthrus hoffmannseggii* Brandt, 1833	25,93	7	S	G
11.	*Porcellio scaber* Latreille 1804	3,7	1	E	DF
12.	*Porcellium collicola* (Verhoeff, 1907)	74,07	20	E	G
13.	*Protracheoniscus politus* (C. Koch, 1841)	22,22	6	E	NF
14.	*Trachelipus nodulosus* (C. Koch, 1838)	48,15	13	E	G
15.	*Trachelipus rathkii* (Brandt, 1833)	44,44	12	E	G
16.	*Trachelipus ratzeburgii* (Brandt, 1833)	18,52	5	E	NF
17.	*Trichoniscus pusillus* Racovitza, 1908	3,7	1	S	G

H. riparius, a small bodied isopod dwelling in the soil, is the third one among the most frequent isopods in the Drava basin (FARKAS 1999), and in South Transdanubia, too (77% of the sampling locations). Moreover, this woodlouse proved to be the second most frequent species within entire Transdanubia, occurring in 69% of the studied 243 UTM units (HORNUNG et al. 2009). This hygrophilous, generalist species can be found in natural and disturbed habitats, too. It is frequent in urban wood fragments, parks and gardens (HORNUNG et al. 2007). *T. rathkii* is the fourth, while *T. nodulosus* is the fifth most common isopod in South Transdanubia, according to previous studies (FARKAS 2007). Although both species are regarded as habitat generalist, surface inhabiting species (HORNUNG et al. 2007, 2009), *T. nodulosus* seems to prefer open habitats (e.g. dry grasslands), while *T. rathkii* occupies a wider range of biotopes from meadows to floodplain forest (GRUNER 1966, HORNUNG 1991, 1992, VILISICS et al. 2005).

The most frequent elements of isopod assemblages in Black locust plantations are identical with the most prevalent species of Transdanubia. They have more common characteristics: all of them are regarded as habitat generalists (HORNUNG et al. 2007), surface active (with the exception of *H. riparius* which dwells in soil and litter) and they have no specific habitat preference in this part of the country.

The additional 12 species occurred in less than 26% of the sampled localities. A considerable ratio of this group includes small, soil dwelling, hygrophilous species which are very sensitive to the moisture content of the air (*H. danicus, H. mengii, T. pusillus*). These species are hardly able to tolerate the unfavourable circumstances (warm and dry soil surface in summer) of the Black locust plantations.

The number of species was an average of 4.44 (min: 1, max: 9) in the sampled forests. This value is similar to the averages that had been observed in different woodlands of the Drava basin where they were 3.87 in willow-poplar forests, 5.5 in secondary blackthorn-hawthorn shrubs, 4 in pine-groves, 4.66 in alder woods and 4.44 in oak woodlands (FARKAS 1999). LOKSA (1966) found isopod assemblages consisting of 1-4 species (average: 2.59) in 27 sampled shrub woodlands in the Hungarian Middle Mountains. On the basis of these data the isopod species richness of Black locust forests is not lower than in other woodland types.

Values of association between the five most frequent species are given in Table 3. The tightest connection was calculated between *A. vulgare* and *P. collicola*, which species occurred together in 15 sampling sites. The relationship between *P. collicola* and *T. rathkii* proved to be high, too. In nine locations all the three species were associated. Medium association was found between *H. riparius* and *P. collicola* (0.66) and *H. riparius* and *T. rathkii* (0.64). Consequently, three species from the quartet of *A. vulgare, P. collicola, H. riparius* and *T. rathkii* usually can be found together in a Black locust for-

Table 3. Association between the most frequent species by the modified Sørensen index (Avulg: *A. vulgare*; Pocol: *P. collicola*; Hyrip: *H. riparius*; Tnodu: *T. nodulosus*; Trath: *T. rathkii*).

	Avulg	Pocol	Hyrip	Tnodu	Trath
Avulg					
Pocol	0,95				
Hyrip	0,22	0,66			
Tnodu	-0,14	-0,8	-0,75		
Trath	0,25	0,9	0,64	-0,4	

est. Ecological needs of *P. collicola* are uncleared. In Transdanubia this species was pointed out in inordinately differing habitats, like dry Black locust plantations and muddy swamps (associated with the hygrophilous *A. zenckeri* in the latter habitat). The triad of *P. collicola, H. riparius* and *T. rathkii* were captured together in Black locust forests that were neighbouring oak woodlands (Babarcszőlős, Deseda1-2, Görcsöny) or where the soil possessed good water supply (Vejti, Paks, Okorág, Old). The thermophilous *T. nodulosus* missed from the 70% of the communities of these sampling sites. Middle or strong negative association was experienced between *T. nodulosus* and the troika of *T. rathkii, H. riparius* and *P. collicola* due to their different ecological requirements.

Four locations (Deseda 1-2, Babarcszőlős, and Vajszló) were dropped from quantitative analysis of pitfall samples because of the strong distortion effect of natural species (*P. politus, A. opacum, T. ratzeburgii*) immigrated from the neighbouring natural woodlands. On an average of 3.75 species (3-5) were found in the samples. *P. collicola* and *A. vulgare* were found in all of the samples while *A. opacum*, *T. ratzeburgii* and *P. scaber* were captured only in one location. Dominant (or subdominant, except Vinograd) species of the studied eight communities were *P. collicola* (5 locations) or *A. vulgare* (3 locations), alternatively. Individuals of these two species constituted the 77-99% (average: 84%) of the samples. The proportions of additional species were far few. The only variant sample was collected at Vinograd where *T. nodulosus* proved to be subdominant with its 43%. Shannon diversity values were low ranging between 0.15 (EH = 0.13) and 1.17 (EH = 0.13) (Table 4). Species diversity for isopod community was also low in pine plantations in the Bakony Mountains (KONTSCHÁN 2001b).

Eradication of native vegetation is the prelude to any forest plantations, effecting the ecosystem as a whole, including soil and litter dwelling decomposers. Composition of isopod assemblages in South Transdanubian Black locust stands clearly indicates the above mentioned remarkable changes. The plantations, without exception, are dominated by widely distributed, common isopods. Species of lower incidence rates are no exception: *P. hoffmannseggii, H. mengii, H. danicus* and *T. pusillus* group are extremely common in Hungary, while *C. convexus, P. scaber* and *A. versicolor* (in different extents) occur in sites under frequent human activity (HORNUNG et al. 2007).

Table 4. Number of captured individuals in pitfall samples, species diversity and evenness.

		Bakháza	Darázs	Görcsöny	Knezevo	Okorág	Old	Péterhida	Vinograd
1	*H. riparius*			16		74	184		
2	*P. scaber*	1							
3	*P. collicola*	154	4	2722	115	468	1514	199	6
4	*T. nodulosus*	104	2		24				66
5	*T. rathkii*			36		17	35	87	
6	*T. ratzeburgii*							19	
7	*A. opacum*			2					
8	*A. vulgare*	273	205	149	1	285	457	165	80
	Total number of individuals	532	211	2925	140	844	2190	470	152
	H	1,03	0,15	0,31	0,50	0,99	0,86	1,17	0,83
	E_H	0,74	0,13	0,19	0,45	0,71	0,62	0,85	0,75

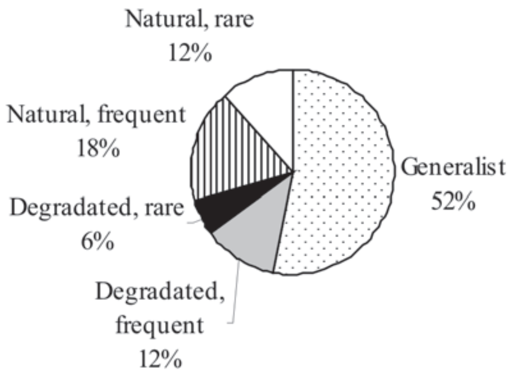

Fig. 2. The division of isopod species by their habitat preferences

The existence of native (and often rare) habitat specialists is occasional (Fig. 2.). Natural species (*A. zenckeri, A. opacum, P. politus, T. ratzeburgii, L. hypnorum*) presumably appear in Black locust forests by immigration when the plantation lays to adjacent unaffected habitats (oak or elder woodlands, marsh, stream, etc.).

Urban areas are dynamically changing heterogeneous landscapes, therefore only a few tolerant species are able to establish and gain dominance in the cities. The assemblage composition of Black locust plantations has resemblances to urban areas in Hungary. VILISICS and HORNUNG (2008, 2009) enumerated 27 isopod species in Budapest of which 89% is generalist (G) or is characteristic for disturbed habitats (D). The proportion of the G and D species in the Black locust plantations is also high (70%). The 82% (14 species) of the isopods sampled in Black locust plantations were found in Budapest, too. The most frequent species of Black locust forests are common in urban green islands like natural and artificial forest patches, botanic gardens with the exception of *T. nodulosus* that were found only in parks in Budapest. In outskirts of Baltimore, seven isopod species were also found that were captured in Black locust forests. *A. vulgare, T. rathkii* and *C. convexus* are prominently prevalent in other states of the USA (HORNUNG et al. 2007). *H. riparius,* which is a native species in Hungary, is characteristic in disturbed habitats in the USA as having strong tolerance against perturbation (HORNUNG et al. 2007). The occurrence and abundance of *T. rathkii* and *A. vulgare* was the highest in disturbed habitats of urban and suburban territories in Denmark (VILISICS et al. 2007).

As a conclusion, Black locust plantations support a relatively diverse isopod fauna, but their composition reflects to human influence. The dominance of cosmopolitan and synanthropic species and lack of local habitat specialists suggest an ongoing biotic homogenization accelerated by the century-long forestry practices and the invasive nature of Black locust.

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