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Ground-dwelling arthropod (Araneae, Coleoptera: Carabidae, Isopoda: Oniscidea) assemblages on Hungarian main road verges

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Abstract: In this study, we research ground-dwelling arthropods along four road stretches, which represent the main verge habitats (arid grassland, agricultural area, forest, and wetland) of Hungary. Besides the faunistic investigation of arthropod communities, we described and compared dominance relation and species composition. We identified 83 carabids, 81 spiders, and 4 isopod species. Seven beetle species and one spider species are included in the invertebrate Red List of Hungary. The registered species were dominant on main road verges bordering arid grassland and wetland. Main road verges proved to be a diverse habitat; hence, it is important to carry on more investigation.

Keywords: spider, beetle, woodlice, species richness, abundance, diversity

1. Introduction

The establishment of road networks is one of the most prevalent ways of land usage these days with more and more studies focusing on the effect of roads on biodiversity [1]. Road ecology is a new discipline nowadays [2]. Researchers of roadside and highway verges provide several data about beetles [3, 4, 5, 6, 7, 8, 9], spiders [3, 6, 7, 10], and isopods [11, 12, 13, 14]. Trombulak and Frissell [15] examined the short- and long-term effects of roads on environment. The studies of Holderegger and Di Giulio [16] targeted the effects of barriers on mortality and gene replacement; also, Forman et al. [2] have closely investigated the flora and fauna of roadside verges. All of this referred literature shows that the effects of roads on wildlife are multiple, which can be positive or negative. The negative effects of roads on organisms are changing habitats, changing the environment's chemistry and physics, road kills, changing behaviour of animals, chemical pollution, acting as barrier and intensifying the dispersal of invasive and also exotic species [15, 7]. However, roadside verges function as ecological corridors, serve as suitable habitat sources and conditions for organisms [17, 18, 19, 20, 21, 22, 7]. All of these potential effects are dependent on the complex interactions between species infrastructure and landscape [23, 24].

Owing to the ecological and biological features of beetles [25, 26], spiders [27], and woodlice [28, 29], they are excellent biological indicators. They can be also called hitchhiker insects as their spreading along roads has widely influenced the traffic. In addition to traffic, the quality of the habitat, the interactions between populations and the structure of the landscape also affect the spreading of arthropods and the composition of the communities [30, 31, 32, 33].

The main objective of this paper is to report on the spider, isopod, and ground beetle fauna of main road verges situated beside different habitat types that represent the main verge habitats of Hungary. Besides faunistic research, the effects of the different vegetation of main road verges on wildlife should also be investigated.

2. Material and methods

Along the Hungarian main roads, four sampling sites were selected, representing the main types of verge habitats. The first sampling area, Pilisjászfalú (Budapest–Esztergom, Pest County), was along Road No 10 and consisted of arid grassland with some small bushes shown in *Fig. 1*. The second sampling area, Mány (Budapest–Győr, Fejér County), was situated along Road No 1 between two roads in agricultural areas, in the lowlands and the hilly landscape of Hungary, shown in *Fig. 2*. The third sampling area, Herceghalom (Budapest–Győr, Pest County), was located along Road No1 between the road and the forest, shown in *Fig. 3*. The fourth sampling area, Agárd (Budapest–Székesfehérvár, Fejér County), was along Road No 7, crossing a wetland area in the western section of Lake Velence, shown in *Fig. 4*.

Figure 1. Pilisjászfalu sampling sites along Road No 10

Arthropods were sampled using 15-15 pitfall traps on each site and the distance between the traps was 5 m. The 60 pitfall traps used in the study were transparent plastic cups filled with a 65% aqueous solution of ethylene glycol as a preservative fluid [34]. The traps were in the fields for three weeks, placed four times a year in different seasons (early spring, spring, summer, and autumn).

Figure 2. Mány sampling sites along Road No1

Figure 3. Herceghalom sampling sites along Road No1

Figure 4. Agárd sampling sites along Road No 7

The characterizations of the ground-dwelling arthropod communities were based on species richness and abundance. For the analysis of the data, we used the PAST Paleontological Statistic suite. We counted Shannon-Wiener (H) diversity for an accurate characterization of the examined isopod communities. We studied the species' preference for habitat using correspondence analysis.

3. Results and discussion

The sampling resulted 7,563 ground-dwelling arthropods from 168 species along main road verges. In total, 1,139 beetles from 83 species, 2,212 spiders from 81 species, and 4,212 isopods form 4 species were collected as shown in *Table 1*. Seven beetle species (*Carabus convexus*, *Carabus coriaceus*, *Carabus germarii*, *Carabus granulatus*, *Carabus scheidleri*, and *Carabus violaceus*) and one spider species (*Nemesia pannonica*) are included in the invertebrate Red List of Hungary [35]. The total Shannon-Wiener diversity was relatively high (2.69). On each verge, the Shannon-Wiener diversity of spiders was the highest (3.58), followed by beetles (3.32) and isopods (0.36).

In this study, beetles was the richest group of species. With regard to the size of beetles, the species can be grouped into small-sized species and medium-sized species [36]. Based on food reference, the omnivoreous or phytophagous and spermophagous species (*Amara* and *Harpalus* genus) were dominant [37]. According to wing development, the macropterous and dimorphous or polimorphous species (*Amara* and *Harpalus* genus) [36] were frequent. The majority of the species are common in Hungary, except the seven protected beetle species, among which *C. cancellatus* (42 individuals) was the dominant, followed by the *C. coriaceus* (36 individuals). *Brachinus explodens* (167 individuals) was recorded with the highest abundance, followed by *Harpalus tardus* (130 individuals) and *Bembidion properans* (100 individuals). *H. tardus* in arid grassland and the other two mentioned species in wetland were predominant. The sporadic *Pterostichus elongatus* benefits from wet sodic habitats [38, 39] and flies towards light [40]. *P. incommodus* is not a common species either [41], but its lifestyle is less known, except that it lives in open forests and wooded steppe [36]. In the Netherlands,Vermeulen [4] collected several rare carabid beetles on roadside verges. This and our results indicate that roadsides have a potential conservation value. In the case of beetles, wetland verges were prominent as they were found to dispose of the highest species richness and abundance as shown in fig-s 5, 6, and 7.

Lycosidae and *Gnaphosidae* of spider families were dominant. The highest species richness was observed in arid grassland verges and the abundance of spiders in the wetland verges was the highest as shown in fig-s 5, 6, and 7. *Pardosa lugubris* (263 individuals), *Alopecosa trabalis* (216 individuals), and *Alopecosa pulverulenta* (155 individuals) of spiders were observed as having the highest abundance.

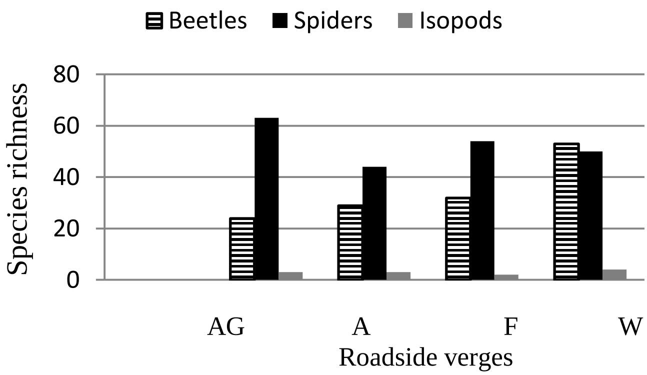

Figure 5. Species richness of ground-dwelling arthropods on the four roadside verges

In this regard, we have to mention *Pardosa bifasciata* (148 individuals), *Xysticus kochi* (147 individuals), and *Pardosa agrestis* (133 individuals). While *P. lugubris*, *P. bifasciata*, *P. agrestis*, and *X. kochi* dominated the wetland, *A. trabalis* was present in arid grassland and *A. pulverulenta* in agricultural landscapes with a high number of individuals.

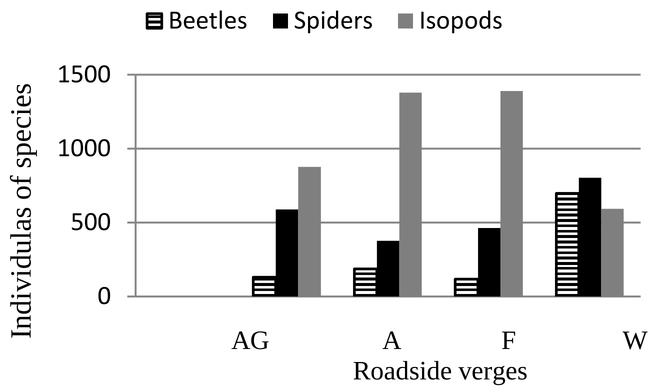

Figure 6. Individuals of species of ground-dwelling arthropods on the four roadside verges

Table 1. Distribution of species based on habitat types. Habitat types: AG: arid grassland, A: agricultural area, F: forest, W: wetland.

Species	**Verges types**			
	AG	**A**	**F**	**W**
Carabidae				
Abax parallelepipedus (Piller & Mitterpacher, 1783)			x	
Amara aenea (Degeer, 1774)	x	x	x	x
Amara anthobia (A. et G. B. Villa, 1833)	x			x
Amara apricaria (Paykull, 1790)		x		
Amara consularis (Duftschmid, 1812)			x	
Amara convexior (Stephens, 1828)	x		x	
Amara equestris (Duftschmid, 1812)		x		
Amara familiaris (Duftschmid, 1812)	x		x	x
Amara lucida (Duftschmid, 1812)				x
Amara ovata (Fabricius, 1792)			x	
Amara saphyrea (Dejean, 1828)			x	x
Amara similata (Gyllenhal, 1810)			x	x
Amara tibialis (Paykull, 1798)				x
Anchomenus dorsalis (Pontoppidan, 1763)		x	x	x
Anisodactylus binotatus (Fabricius, 1787)				x
Badister bullatus (Schrank, 1798)			x	
Bembidion properans (Stephens, 1828)				x
Bembidion quadrimaculatum (Linnaeus, 1761)				x
Brachinus crepitans (Linnaeus, 1758)			x	x
Brachinus explodens (Duftschmid, 1812)		x	x	x
Brachinus ganglbaueri (Apfelbeck, 1904)				x

Species	**Verges types**			
	AG	**A**	**F**	**W**
Bradycellus harpalinus (Audinet-Serville, 1821)				x
Calathus ambiguous (Paykull, 1790)		x		x
Calathus cinctus (Motschulsky, 1850)		x		
Calathus fuscipes (Goeze, 1777)		x	x	x
Calathus melanocephalus (Linnaeus, 1758)	x			x
Callistus lunatus (Fabricius, 1775)	x			
Carabus cancellatus (Illiger, 1798)				x
Carabus convexus (Fabricius, 1775)				x
Carabus coriaceus (Linnaeus, 1758)		x	x	x
Carabus germarii (Sturm, 1815)				x
Carabus granulatus (Linnaeus, 1758)				x
Carabus scheidleri (Panzer, 1799)	x		x	
Carabus violaceus (Linnaeus, 1758)		x		
Chlaenius festivus (Panzer, 1796)				x
Chlaenius nigricornis (Fabricius, 1787)				x
Chlaenius nitidulus (Schrank, 1781)				x
Chlaenius spp.				x
Dischyrius globosus (Herbst, 1784)			x	
Harpalus affinis (Schrank, 1781)				x
Harpalus azureus (Fabricius, 1775)		x	x	x
Harpalus calceatus (Duftschmid, 1812)		x		
Harpalus puncticeps (Stephens, 1828)	x			
Harpalus cribricollis (Dejean, 1829)		x		
Harpalus distinguendus (Duftschmid, 1812)			x	x
Harpalus flavicornis (Dejean, 1829)	x	x		x
Harpalus griseus (Panzer, 1796)	x		x	
Harpalus pumilus (Sturm, 1818)	x	x		
Harpalus caspius roubali (Schauberger, 1928)	x			
Harpalus rubripes (Duftschmid, 1812)	x			
Harpalus sabulicola (Panzer, 1796)		x		
Harpalus rufibarbis (Fabricius, 1792)				x
Harpalus rufipes (De Geer, 1774)		x	x	x
Harpalus serripes (Quensel in Schönherr, 1806)		x	x	x
Harpalus signaticornis (Duftschmid, 1812)	x			
Harpalus smaragdinus (Duftschmid, 1812)		x		
Harpalus tardus (Panzer, 1796)	x	x	x	x
Leistus ferrugineus (Linnaeus, 1758)	x	x	x	x
Microlestes maurus (Sturm, 1827)				x
Microlestes minutulus (Goeze, 1777)				x
Nebria brevicollis (Fabricius, 1792)				x
Notiophilus spp.			x	x

Species	Verges types			
	AG	A	F	W
Panagaeus bipustulatus (Fabricius, 1775)	x		x	x
Panagaeus crux-major (Linnaeus, 1758)				x
Parophonus complanatus (Dejean, 1829)		x		
Parophonus maculicornis (Duftschmid, 1812)		x	x	
Platyderus rufus (Duftschmid, 1812)			x	
Poecilus cupreus (Linnaeus, 1758)	x			x
Poecilus Lepidus (Leske, 1785)				x
Poecilus sericeus (Fischer von Waldheim, 1823)		x		
Poecilus versicolor (Sturm, 1824)				x
Pterostichus elongatus (Dufrschmid, 1812)				x
Pterostichus incommodus (Schaum, 1858)		x		
Pterostichus melanarius (Illiger, 1798)				x
Pterostichus niger (Schaller, 1783)				x
Pterostichus vernalis (Panzer, 1795)			x	
Stenolophus discophorus (Fischer von Waldheim, 1824)				x
Stenolophus mixtus (Herbst, 1784)			x	x
Stenolophus teutonus (Schrank, 1781)				x
Syntomus pallipes (Dejean, 1825)		x		
Tachys diabrachys bisbimaculatus (Chevrolat, 1860)				x
Trechus quadristriatus (Schrank, 1781)	x	x		x
Zabrus tenebrioides (Goeze, 1777)	x	x		
Araneae				
Nemesiidae				
Nemesia pannonica (Herman, 1879)	x			
Segestriidae				
Segestria senoculata (Linnaeus, 1758)				
Dysderidae				
Dysdera erythrina (Walckenaer, 1802)	x	x	x	
Dysdera spp. juvenilis	x	x	x	
Harpactea rubicunda (C. L. Koch, 1838)	x	x	x	
Mimetidae				
Ero furcata (Villers, 1789)			x	
Theridiidae				
Asagena phalerata (Panzer, 1801)	x	x	x	x
Enoplognatha thoracica (Hahn, 1833)		x	x	
Euryopis flavomaculata (C. L. Koch, 1836)	x			
Euryopis quinqueguttata (Thorell, 1875)			x	
Steatoda albomaculata (De Geer, 1778)		x		x
Linyphiidae				
Centromerus sylvaticus (Blackwall, 1841)	x		x	x
Diplostyla concolor (Wider, 1834)			x	x

Species	Verges types			
	AG	A	F	W
Erigone dentipalpis (Wider, 1834)			x	x
Megalepthyphantes nebulosus (Sundevall, 1830)			x	
Prinerigone vagans (Audouin, 1826)				x
Stemonyphantes lineatus (Linnaeus, 1758)	x			
Tetragnathidae				
Pachygnatha degeeri (Sundevall, 1830)			x	x
Araneidae				
Agelenatea redii (Scopoli, 1763)	x			
Araneus diadematus (Clerck, 1757)			x	
Argiope bruennichi (Scopoli, 1772)	x			
Cercidia prominens (Westring, 1851)			x	
Lycosidae				
Alopecosa accentuata (Latreille, 1817)	x			
Alopecosa cuneata (Clerck, 1757)	x	x		x
Alopecosa pulverulenta (Clerck, 1757)	x	x	x	x
Alopecosa sulzeri (Pavesi, 1873)	x			
Alopecosa trabalis (Clerck, 1757)	x	x	x	x
Alopecosa spp. juv	x	x	x	x
Arctosa leopardus (Sundevall, 1833)				x
Aulonia albimana (Walckenaer, 1805)	x	x	x	x
Hogna radiata (Latreille, 1819)	x	x		x
Pardosa agrestis (Westring, 1861)	x	x	x	x
Pardosa amentata (Clerck, 1757)			x	
Pardosa bifasciata (C. L. Koch, 1834)	x	x	x	x
Pardosa lugubris (Walckenaer, 1802)	x	x	x	x
Pardosa paludicola (Clerck, 1757)			x	x
Pardosa proxima (C. L. Koch, 1847)				x
Pardosa riparia (C. L. Koch, 1833)	x	x	x	x
Pardosa spp. juv	x	x	x	
Trochosa robusta (Simon, 1876)	x	x	x	
Trochosa terricola (Thorell, 1856)	x	x	x	x
Trochosa spp. juv	x	x	x	x
Xerolycosa miniata (C. L. Koch, 1834)				x
Xerolycosa nemoralis (Westring, 1861)				x
Pisauridae				
Pisaura mirabilis (Clerck, 1757)	x	x	x	x
Agelenidae				
Allagelena gracilens (C. L. Koch, 1841)	x		x	x
Coelotes terrestris (Wider, 1834)			x	
Eratigena agrestis (Walckenaer, 1802)		x	x	x
Urocoras longispinus (Kulczynski, 1897)	x	x	x	

Species	Verges types			
	AG	A	F	W
Titanoecidae				
Titanoeca quadriguttata (Hahn, 1833)		x		
Titanoeca shineri (L. Koch, 1872)		x		
Eutichuridae				
Cheiracanthium virescens (Sundevall, 1833)	x			
Miturgidae				
Zora spinimana (Sundevall, 1833)	x	x	x	
Anyphaenidae				
Anyphaena accentuata (Walckenaer, 1802)		x	x	
Liocranidae				
Agroeca cuprea (Menge, 1873)	x			x
Liocranoeca striata (Kulczynski, 1882)				x
Scotina celans (Blackwall, 1841)			x	
Phrurolithidae				
Phrurolithus festivus (C. L. Koch, 1835)	x	x		
Clubionidae				
Clubiona pseudoneglecta (Wunderlich, 1994)	x			
Clubiona terrestris (Westring, 1851)			x	
Zodariidae				
Zodarion germanicum (C. L. Koch, 1837)	x			
Zodarion rubidium (Simon, 1914)	x			x
Zodarion spp. juv	x			
Gnaphosidae				
Drassodes cupreus (Blackwall, 1834)		x		
Drassodes lapidosus (Walckenaer, 1802)		x		
Drassodes pubescens (Thorell, 1856)	x	x	x	x
Drassyllus praeficus (L. Koch, 1866)	x	x	x	x
Drassyllus pusillus (C. L. Koch, 1833)		x		x
Drassyllus villicus (Thorell, 1875)		x	x	
Drassyllus spp. juv	x	x	x	x
Gnaphosa lucifuga (Walckenaer, 1802)			x	
Haplodrassus signifer (C. L. Koch, 1839)	x	x	x	x
Haplodrassus umbratilis (L. Koch, 1866)				x
Trachyzelotes pedestris (C. L. Koch, 1837)	x	x	x	x
Zelotes apricorum (L. Koch, 1876)	x		x	x
Zelotes electus (C. L. Koch, 1839)	x	x	x	x
Zelotes latreillei (Simon, 1878)	x		x	x
Zelotes longipes (L. Koch, 1866)	x		x	
Zelotes petrensis (C. L. Koch, 1839)	x			x
Zelote spp. juv	x		x	x
Philodromidae				

Species	Verges types			
	AG	**A**	**F**	**W**
Thanatus arenarius (Thorell, 1872)	x	x		
Thanatus formicinus (Clerck, 1757)	x			
Thanatus spp. juvenilis	x	x	x	x
Tibellus spp. juvenilis	x			x
Thomisidae				
Ozyptila atomaria (Panzer, 1801)		x	x	
Ozyptila claveata (Walckenaer, 1837)	x	x	x	
Ozyptila praticola (C. L. Koch, 1837)		x		x
Ozyptila scabricula (Westring, 1851)	x			
Ozyptila simplex (O. P.-Cambridge, 1862)	x			x
Xysticus acerbus (Thorell, 1872)	x			
Xysticus cristatus (Clerck, 1857)	x			x
Xysticus luctator (L. Koch, 1870)				x
Xysticus kochi (Thorell, 1872)	x	x	x	x
Xysticus spp. juvenilis	x	x	x	x
Salticidae				
Euophrys spp. juv	x			
Heliophanus cupreus (Walckenaer, 1802)			x	
Pellenes tripunctatus (Walckenaer, 1802)	x			
Phlegra fasciata (Hahn, 1826)	x			
Salticus ssp. juvenilis	x			
Isopods				
Trachelipodidae				
Porcellium collicola (Verhoeff, 1907)	x	x	x	x
Trachelipus rathkii (Brandt, 1833)	x			x
Porcellionideae				
Porcelliodides pruinosus (Brandt, 1833)		x		x
Armadillidiidae				
Armadillidium vulgare (Latreille, 1804)	x	x	x	x

Only the arid grassland provides suitable habitats for the one registered protected species: *Nemesia pannonica*, which is one of the most valuable (10 000 HUF) nature conservation spider species in Hungary. The single Hungarian representative of the *Nemesiidae* family is submediterranean-distributed. Last year, a growing number of occurrences of this species were registered, such as in Pilis [42], East Mezőföld [43], and Mátra [44]. The presence of this species with special needs confirms that main road verges occasionally expand the area of nature reserves [4]. Web spiders (*Agelenidae* and *Araneidae* family) mainly selected the verges' borders with forests and meadows, which provide suitable conditions for spiders to make web. Crab spiders, generally waiting to prey on colourful flowers, were found near grasslands.

These findings demonstrate the importance of mowing for floral diversity [45, 46]. Each of the four registered ant-specialist species (*Zodarion rubidum*, *Zodarion germanicum*, *Asagena phalerata*, and *Thanatus arenarius*) was identified on arid grasslands as well and the *A. phalerata* stands out from among the others with its high abundance and incidence rate. Just few individuals of the rare *Drassodes cupreus*, *Coelotes terrestris*, and the previously mentioned ant specialist *Z. rubidum* were observed, and they did not show any habitat preference. The ant-specialist species show that ant as pioneer species are highly abundant on main road verges.

In this study, isopods proved to be the most poorly represented group of species. The highest abundance of species was found on the forested verges, but we also found the lowest species richness there as shown in fig-s 5 and 6.The ordination statistics demonstrates well that woodlice species prefer the wetland to other regions as shown in *Fig. 7*.

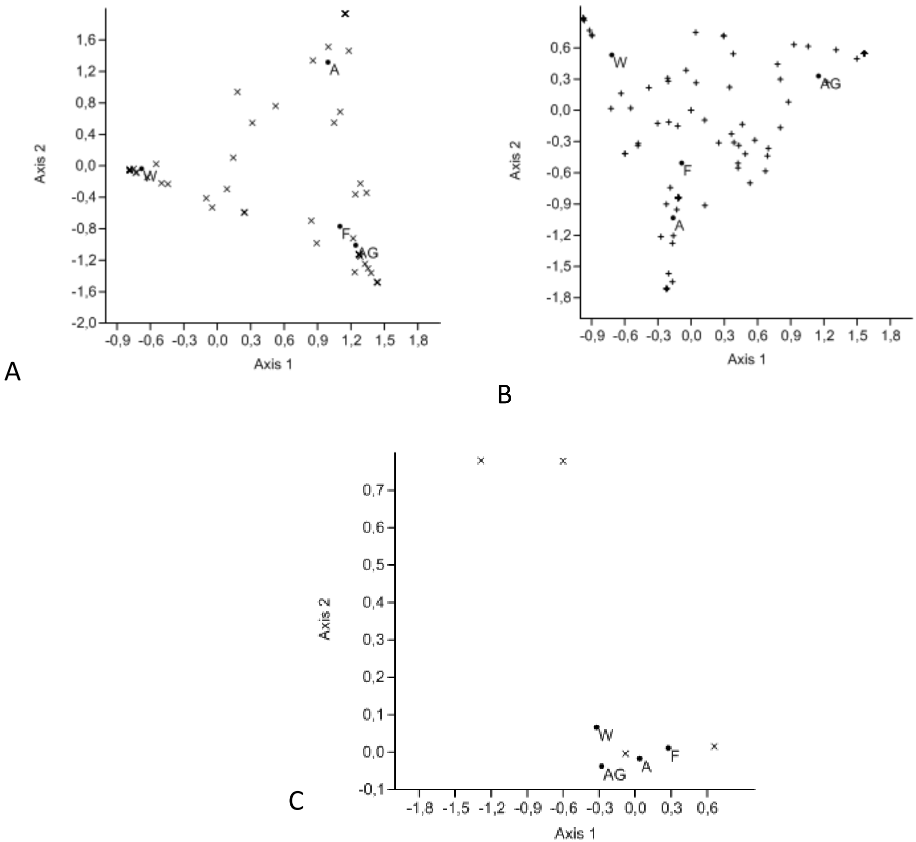

Figure 7. Correspondence analysis of carabidae (A), aranea (B), and isopod (C) species

Each of the four registered isopod species are habitat generalists – they are able to successfully adapt to most continental habitats, whether natural or not. In all of the four investigated sites, *Armadillidium vulgare* of the isopod species was the most prevalent, followed by *Porcellium collicola*. Both of these species were present with a high abundance in forested and agricultural verges. The typical indicator of anthropogenic impacts, the cosmopolitan *A. vulgare*, can be found in most habitats except for protected hardwood forests [47]. *P. collicola* is one of the most frequent species in Hungary – found especially in parks and gardens, it can also be detected in most continental landscapes, excepting densely populated urban areas and protected hardwood forests [47]. Few individuals of *Trachelipus rathkii* and *Porcelliodides pruinosus* occurred in only two types of main road verges. *T. rathkii* is a common species in Hungary [48]: it can be observed near synanthropic environments, moderately humid habitats, and river valleys [49, 50]. *P. pruinosus* is a cosmopolitan, widely spread species in Europe [51] and it can be found in synanthropic habitats indicating active human influence [52]. We expected the presence of exotic species because during our previous studies carried out along highways [13, 14] we have experienced that highway verges contribute to the creation of new habitats for several alien species. The explanation for this might be that highway networks are very different from lower-level roads [53, 54] and the number of sampling sites on main roads was different from the case of the highways.

4. Conclusions

Our study has clearly demonstrated that main road verges prove to be suitable habitats and provide necessary conditions for several carabid beetle and spider species, but isopods do not benefit from this landscape type. Roadside verges are frequently connected with natural reserves and urban habitats, allowing the spreading of species between them. These verges function as invasion pathways for arthropod species, but are also refuges for protected and endangered species in agriculture-dominated landscapes in Hungary. The different surrounding vegetation of the examined main road stretches substantially affects the diversity and the spreading of ground-dwelling arthropods. The observed high diversity of arthropods reflects that the main road verges are important in terms of species richness.

Acknowledgements

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