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ECOLOGICAL AND ZOOGEOGRAPHICAL SIGNIFICANCE OF TERRESTRIAL ISOPODS FROM THE CAREI PLAIN NATURAL RESERVE (ROMANIA)

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Abstract - In the Carei Plain natural reserve we identified 15 terrestrial isopod species: *Haplophthalmus mengii, Haplophthalmus danicus, Hyloniscus riparius, Hyloniscus transsylvanicus, Plathyarthrus hoffmannseggii, Cylisticus convexus, Porcellionides pruinosus, Protracheoniscus politus, Trachelipus arcuatus, Trachelipus nodulosus, Trachelipus rathkii, Porcellium collicola, Porcellio scaber, Armadillidium vulgare* and *Armadillidium versicolor.* The highest species diversity is found in wetlands, while the lowest is in plantations and forests. On the Carei Plain, there are some terrestrial isopods that are normally connected with higher altitudes. Moreover, some sylvan species are present in the open wetlands. Unlike marshes, sand dunes present anthropophilic and invasive species. The diversity of the terrestrial isopods from the Carei Plain protected area is high due to the habitats' diversity and the history of this area. Thus, the composition of the terrestrial isopod communities from the area underlines its distinct particularities, emphasizing the necessity of preserving the natural habitats.

Key words: Terrestrial isopods, diversity, habitats, wetlands, anthropogenic influence, protected area, Romania

INTRODUCTION

At present, the protection level of organisms is highly influenced by their taxonomic position and complexity (Martín-López et al., 2011). In this context, the upper groups are well researched, whereas detailed studies of the lower taxa are necessary (Martín-López et al., 2011). Among invertebrates, isopods are a group that has been given little attention, despite their importance (Hassall et al. 2005). As a result, few isopods are included in the IUCN Red List (IUCN 2011). Isopods have been recently represented in studies connected to the biodiversity of some protected areas (Szlávecz, 1991; Sallai, 1993; Almerao et al., 2006; Vilisics et al., 2008, 2011; Messina et al., 2011). Although in the past years the conservation of biodiversity in Romania has increased, raising the number of protected areas (Iojă et al. 2010), there are few studies of terrestrial isopods (Tomescu, 1992; Tomescu et al., 1995, 2011; Giurginca et al., 2006, 2007). In this respect, it is extremely important to catalogue invertebrate species in order to adequately manage the biodiversity of the protected areas (McGeoch et al. 2011). An important protected area from Romania is the Carei Plain natural reserve. Its importance is illustrated by the presence of some plant and animal species characteristic to the mountainous areas in Romania, a fact that indicates a special past of this region (Karacsonyi, 1987; Covaciu-Marcov et al. 2008, 2009). Despite these facts, studies of invertebrates from the region are very rare, the data regarding the terrestrial isopods from the area and the ones neighboring it being limited (Tomescu et al. 2008, 2010). Therefore, our objective was to in-

vestigate the terrestrial isopods from the Carei Plain natural reserve in order to establish areas with high biodiversity and conservative value.

MATERIALS AND METHODS

The Carei Plain protected area is situated in northwestern Romania, near the border with Hungary. The protected area is located on a plain, with a slightly uneven surface, formed by an alternation of sand dunes and wetlands, with some streams situated between the dunes. The altitude of the region is approximately between 100 and 150 m.

The study was performed in 2010-2011. We investigated different types of habitats from 16 localities (Table 1). We collected isopods from 43 stations in the region. The investigated stations can be grouped into five habitat types: sand dunes, wetlands, natural forests, plantations and other degraded zones, abandoned buildings. Therefore, we investigated both the natural habitats representative for the region, such as wetlands and sand dunes, as well as artificial or anthropically affected habitats. Isopods were collected by hand from under different shelters, forest litter, or from the soil nearby some wet areas. At each station, we tried to spend the same time collecting isopods (approximately 20 minutes). The species were identified using the scientific literature (Frankenberger, 1959; Radu 1983, 1985), following the current nomenclature (Schmalfuss, 2003). The data were statistically processed, interpretations being related to both the localities and the habitat type. We established the number of species from different localities and habitats. The species' frequency from the investigated habitats was expressed in percentages, indicating their importance in the protected area. The Shannon-Wiener (H) index was calculated in order to establish species diversity in the habitat types (Magurran, 1988). The composition similarity between different habitat types of terrestrial isopod communities was estimated using Jaccard's index (Real and Vargas, 1996). In order to estimate the significance of the diversity differences between the habitats we applied the Mann-Whitney test (Zar, 1999).

RESULTS

We identified 15 terrestrial isopod species in the Carei Plain natural reserve: *Haplophthalmus mengii, Haplophthalmus danicus, Hyloniscus riparius, Hyloniscus transsylvanicus, Plathyarthrus hoffmannseggii, Cylisticus convexus, Porcellionides pruinosus, Protracheoniscus politus, Trachelipus arcuatus, Trachelipus nodulosus, Trachelipus rathkii, Porcellium collicola, Porcellio scaber, Armadillidium vulgare* and *Armadillidium versicolor.* In all, we collected 767 individuals (259 males, 462 females and 46 juveniles).

The highest number of species was recorded in the Sanislau and Urziceni localities (Table 1). With regard to the habitat, the highest number of species was identified in wetlands, followed by affected areas and sand dunes, and then in plantations. The fewest species were observed in the natural forests (ash and oak with sandy substratum) (Table 2). With regard to frequency, the most frequent species was *A. vulgare,* followed by *T. arcuatus*. Rare species were *H. mengii* and *P. hoffmannseggii*. These were only identified near some old abandoned constructions (Table 1). *P. hoffmannseggii* was found together with ants.

There were differences between habitat types regarding species diversity. In the case of the localities, diversity was influenced by the habitat types and number. The highest diversity and species richness was observed in wetlands, while the lowest value was recorded in plantations and natural forests (Table 3). A parallelism between the values of the number of species and their diversity in the same habitat type was observed. According to the Jaccard's index, high differences among species compositions were observed between the natural forests and the other habitat types (Table 4). The significance of the differences between the communities' diversity from different habitats was calculated using the Mann-Whitney test (U test). There were significant differences ($p<0.05$) between the wetlands and natural forests ($p=0.009$), wetlands and plantations ($p=0.01$), wetlands and abandoned constructions ($p=0.0005$), and between sand dunes and abandoned constructions ($p=0.04$).

Table 1. Terrestrial isopods from different localities and habitats from the Carei Plain Natural Protected Area (Hm-*Haplophthalmus mengii*, Hd-*Haplophthalmus danicus*, Hr-*Hyloniscus riparius*, Ht-*Hyloniscus transsylvanicus*, Ph-*Platyarthrus hoffmannseggii*, Cc-*Cylisticus convexus*, Pp-*Porcellionides pruinosus*, Prp-*Protracheoniscus politus*, Ta-*Trachelipus arcuatus*, Tn-*Trachelipus nodulosus*, Tr-*Trachelipus rathkii*, Pc-*Porcellium collicola*, Ps-*Porcellio scaber,* Av-*Armadillidium vulgare*, Ave-*Armadillidium versicolor*, No.- number of species)

Locality	Habitat type	Hm	Hd	Hr	Ht	Ph	Cc	Pp	Prp	Ta	Tn	Tr	Pc	Ps	Av	Ave	No.
Silindru	Pond shore			x									x				2
Vermes	Wetlands											x					1
Urziceni	Construction	x													x		2
	Ash forest				x				X				x				3
	Wetlands			x											x		2
	Forest, river shore			x						x		x	x		x		5
	Acacia forest, dune										x				x		2
	Wetlands		x	x	x								x				4
	Garbage							x			x				x		3
	Forest, dune									x	x						2
	Debris, barracks			x				x		x				x	x		5
Urziceni Forest	Stream									x			x				2
Foieni	Debris									x	x				x		3
	Wetlands			x								x	x		x		4
	Dune with oak												x		x		2
	Typical dune										x		x				2
	Oak forest									x							1
	Wetlands									x							1
Ciumesti	Quarry dune										x			x	x		3
	Poplars, road margin										x				x		2
Sanislau	Sand puddle							x						x			2
	Wetlands											x	x		x		3
	Poplar plantation									x					x		2
	Poplars road margin														x		1
	Dune							x		x	x			x	x		5
	Pine, acacia									x	x						2
	Dune near village							x						x			2
Horea	Garbage, village end										x				x		2
Resighea	Dune halt													x	x	x	4
	Rail station							x						x	x		3
	Wetlands									x			x		x		3
Towards Horea	Wetlands									x	x						2
Scarisoara Noua / Horia	Acacia road margin											x			x		2
Scarisoara Noua	Wetlands				x					x			x				3
Curtuiseni	Wetlands with alder			x						x		x	x		x		5
	Construction					x	x										3
	Wetlands with acacia									x					x		2
	Stream, alder			x									x		x		3
Valea lui Mihai	Dune, outskirt acacia										x				x		2
	Oak plantation			x			x			x							3
Simian	Canal									x	x				x		4
Voivozi	Wetlands			x	x					x			x		x	x	6
	Degraded dune						x	x			x			x	x		5
Species' frequency (%) in habitats		2.32	2.32	25.58	11.62	2.32	6.97	16.27	2.32	44.18	32.55	13.95	32.55	18.60	62.79	4.65	

Table 2. Isopod distribution regarding the habitat type (see legend from table 1)

Habitat type	Hm	Hd	Hr	Ht	Ph	Cc	Pp	Pr	Ta	Tn	Tr	Pc	Ps	Av	Ar	No
Sand dunes						x	x		x	x		x	x	x	x	8
Wetlands		x	x	x			x		x	x	x	x	x	x		10
Natural forests				x				x	x			x				4
Plantations and degraded areas			x			x	x		x	x	x			x		7
Abandoned constructions	x		x		x	x	x		x				x	x		8

Table 3. The diversity (Shannon-Wiener, H) index of the species in different habitat types

Habitat type	H
Sand dunes	1.66
Wet areas	2.18
Natural forests	1.08
Plantations and degraded areas	1.47
Abandoned constructions	1.66
Total	2.32

Table 4. The species composition similarity between different habitat types (Jaccard index)

	Sand dunes	Wet areas	Natural forests	Forest plantations	Abandoned constructions
Sand dunes	0	0.416	0.800	0.500	0.545
Wetlands		0	0.750	0.500	0.642
Natural forests			0	0.900	0.909
Plantations and degraded areas				0	0.500
Abandoned constructions					0

DISCUSSION

Previously, in the Carei Plain natural reserve 6 terrestrial isopod species were identified in one locality (Tomescu et al., 2008). We have re-identified all of them, signaling nine more species (*H. mengii, H. danicus, H. riparius, H. transsylvanicus, P. hoffmannseggii, C. convexus, T. arcuatus, T. nodulosus, A. versicolor*). Regarding the number of species identified in the area, it is similar to the data recorded in other regions (Hamaïed-Melki et al., 2010). In comparison with other areas from Romania (Tomescu et al., 1995, 2000, 2002; Hotea et al,. 2003; Giurginca et al., 2006), the number of species from the Carei Plain is high. This is a consequence of the different collecting methods and the habitats' diversity, the species richness being a result of certain favourable environmental conditions (Messina et al., 2011). Some species are also present in the neighboring areas from Hungary (Szlávecz, 1991). In other protected areas, a reduced species diversity has been observed, but with a higher frequency of the rare ones (Vilisics et al., 2008). The collecting method allowed the capture of low mobility species such as *H. mengii* and *H. danicus*, which cannot be captured with Barber traps (Tomescu et al., 2008). *H. danicus* was identified in the wet areas from the Carei Plain, as in other regions (Sallai 1993). The species' presence in the region was to be expected, both regarding its preferences for wet habitats that are rich in organic matter (Wijnhoven,

2000), as well as from a zoogeographic perspective, it being an expansive species in Europe (Garcia and Cruz, 1996). On the contrary, *H. mengii* is rare, being, according to Romanian literature (Radu 1983), found primarily in the western part of the country. Probably, it has not been previously identified in the area due to its secluded life; the species presents a vertical movement behavior in the soil (Wijnhoven, 2000). At the same time, *H. mengii* is less thermophilic than *H. danicus* (Wijnhoven, 2000), being mentioned on several occasions in areas with higher altitude (Radu, 1983; Kontschan, 2004).

The *Hyloniscus* genus is represented in the Carei Plain by *H. riparius* and *H. transsylvanicus*. The presence of *H. riparius* is expected as it has a large distribution (Radu, 1983), colonizing even North America (Jass and Klausmeier, 2003). It is typical for flooded areas, and it is thought that its distribution may be a consequence of floods (Wijnhoven, 2000). On the contrary, *H. transsylvanicus* prefers high altitudes, being a Carpathian species (Vilisics et al., 2008). In Romania, it was observed in mountainous and hilly areas (Tomescu et al., 2011). Thus, its identification at altitudes of 100-150 m is surprising. However, the Carei Plain is a region where other mountainous species have been identified at low altitudes (Karacsonyi, 1987; Covaciu-Marcov et al., 2008, 2009). *H. transsylvanicus* has also been recorded at low altitudes in the plain area of Hungary (Kontschán, 2003). The explanation of its presence at the low altitudes of the Carei Plain is probably similar to that for other species found in the same situation (Covaciu-Marcov et al., 2009): these have survived in the region through the last glacial periods, afterwards remaining in the area because of the wide wetlands. This fact is confirmed by the existence of some forests, including deciduous ones, from the last maximum glacial in the Pannonian basin (Willis et al., 1995, 2000). Together with low altitude, the habitats in which *H. transsylvanicus* was identified are also surprising, the species populating open wetlands with grassy vegetation. In the past, in Romania *H. transsylvanicus* was identified in hilly regions only in forests, in open areas being present only in mountain meadows (Tomescu et al., 2011).

Together with zoogeographically and ecologically important species connected to natural areas, species that are directly or indirectly favored by man, are also present in the area. This is the case for *P. hoffmannseggii,* a myrmecophile species identified near some abandoned constructions together with ants. The species is thought to have been introduced into Eastern Europe together with invasive ants, and is frequent in Hungary (Hornung et al., 2005; Vilisics et al., 2005). Another synanthropic species is *C. convexus* (Radu, 1985), also recorded on the Carei Plain in areas affected by man. *P. pruinosus* represents the same category, the two species indicating high anthropogenic pressure (Korsós et al., 2002). However, the high frequency of *P. pruinosus* may seem surprising in an area where mountainous elements are present in the plain, this being a Mediterranean, invasive species (Radu, 1985). On the Carei Plain, *P. pruinosus* is not favored only by anthropogenic actions, but by the presence of sand dunes. As it avoids colder and wetter areas (Radu, 1985), the species is advantaged by sectors with a sandy and dry substratum. In other groups, southern species connected to warmer and drier areas are also present on the Carei Plain due to the sand dunes (Covaciu-Marcov et al., 2009).

The effect of the reduction of the natural sector from the protected area is felt by the species related to natural forested areas. This is the case of *P. politus*, which was observed only in the ash forest in Urziceni, being a typical sylvan species (Vilisics et al., 2008; Tomescu et al., 2008). Its absence from the oak forest in Foieni and the plantations indicates its sensibility towards environmental degradation, or in the first case the sandy substratum, poor in organic matter and lacking in humidity. High terrestrial isopod diversity was observed in other situations in open areas, with rare vegetation, these being more favourable than areas with dense vegetation or monodominant forests (Hamaïed-Melki et al., 2010). Also in our case, the diversity was low in natural forests and plantations. The low diversity in natural forests can be a consequence of the low number of forests in the area. In addition to plantations, the low diversity proves the negative effect of this habitat type upon

biodiversity. There are numerous acacia plantations in the Carei Plain, their negative impact upon terrestrial isopods being recognized (Sousa et al., 1998; Tomescu et al., 2011).

Species of the genus *Trachelipus* are typical to populated habitats, and were previously identified in the area (Tomescu et al., 2008). The high frequency of *T. rathkii* in the wetlands is due to its resistance to an excess of humidity, and even to inundations (Wijnhoven, 2000). The case of *P. collicola* is a special one as it was previously considered to be distributed in mountainous and hilly forests (Szlávecz, 1991). However, in the low areas of Hungary it was previously recorded in wet plain forests (Szlávecz, 1991; Sallai, 1993). The species' presence at low altitudes in the Carei Plain probably has the same explanation as in the case of *H. transsylvanicus. A. vulgare* and *P. scaber* were observed both in affected and natural habitats (Vilisics et al., 2008). *A. versicolor* is rarer, being present in only one habitat type. In Romania, it has been recorded in many regions (Tomescu, 1992; Tomescu et al., 2005, 2011), but in Hungary it is considered rare, being found only in the northern part of the country (Kontschán, 2003).

Terrestrial isopod assemblages from the Carei Plain are determined by the diversity of habitats accessible in the present and by the history of this area. The wetlands represent the richest and most diverse habitats for isopods from Carei Plain, being unique, not only by their diversity, but also by the community composition. The results underline the distinct conservative value of the wetlands from the Carei Plain. In addition, probably the oldest fauna from the region is found at their level (Covaciu-Marcov et al., 2009). Thus, in the case of terrestrial isopods, the wetlands represent areas where certain aspects of cold climate survive in the present. Meanwhile, sand dunes host isopod communities attached to warmer and drier areas. Therefore, the two ecological components of the Carei Plain, wetlands and sand dunes, also present the same particularities in case of terrestrial isopods as in other groups (Karacsonyi, 1987; Covaciu-Marcov et al., 2008; 2009).

Important zoogeographic species, such as *H. transsylvanicus*, or species typical to the natural areas, such as *P. politus,* are lacking from anthropogenically affected habitats. However, these habitats and abandoned constructions can be important for some rare species such as *P. hoffmannseggii* and *H. mengii*. Constructions have an isopod community composition that greatly differs from the natural areas; sometimes the disturbed habitats have a higher diversity (Vilisics and Hornung, 2009). Thus, the anthropogenic activity affects the capacity of the distinct habitats of the Carei Plain to maintain its rare and important terrestrial isopod species. This can have severe consequences, because preserving the quality of habitats is considered the most efficient means to protect the isopods (Vilisics et al., 2011). The study of the terrestrial isopod communities from the Carei Plain natural reserve confirms its ecological and zoogeographical particularities and underlines the present and past mechanisms that have led to the establishment of the region's biodiversity.

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