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PRELIMINARY STUDY ON SOIL FAUNA AS A TOOL FOR MONITORING OF THE "SPRINGS COMPLEX OF CORBII CIUNGI" PROTECTED AREA -ROMANIA

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Abstract

The research objective was to demonstrate the use of soil fauna groups as a tool for monitoring of the "Springs Complex of Corbii Ciungi" protected area (the IUCN category 4), Dâmboviţa County, Romania. Some ecological indicators were quantified: taxonomic diversity, numerical abundance, dominance, evenness, equitability, Acari/Collembola ratio; Oribatida+Mesostigmata/Prostigmata+Astigmata ratio; correlations between the investigated communities and environmental factors (soil layer thickness, air temperature and humidity, soil temperature and moisture, soil pH, soil penetration resistance, exposure, slope, amount of organic carbon, total N, soil nutrients and the vegetation cover). Transects located near the water sources, were characterised by biological indicators with higher values. There was a significant interdependence between environmental variables. They influenced the abundance and distribution of the edaphic taxonomic groups. Statistical multivariate analysis showed that certain edaphic groups (from a total of 34 taxonomical taxa) are dependent especially on soil moisture e.g. Lumbricidae, Collembola and Oribatida.

Key words: *monitoring, soil fauna, environment factors, protected area.*

INTRODUCTION

Ecosystems that are maintained by direct or indirect access to groundwater, and are based on the flow or chemical characteristics of groundwater, are known as groundwater dependent ecosystems (GDE) (Aldous and Bach, 2011; Belvins and Aldous, 2011). GDEs provide valuable ecosystem services, such as supporting biodiversity (habitat for plant and animal species), providing basic river flows, water purification, flood control, water supply and recreational opportunities. Globally, GDEs are increasingly threatened because human exploitation often exceeds natural recharge rates (Gleeson et al., 2015). The types of surface GDEs are: spring, river / stream, wetland, estuary, accompanied by terrestrial vegetation, but they also occur in subterranean environments, such as aquifers, caves or hyporheic areas. From a water and ecological point of view, these are often connected to terrestrial and aquatic ecosystems, through transition zones (Tomlinson and Boulton, 2010). An important component of the biodiversity of this transition zones, as well as of terrestrial ecosystems that depend on groundwater is the soil fauna. Soil fauna include those animals that spend their entire life or only part of their development cycle in soil (Coleman and Hall, 2015).

The main objectives of the present study are the identification of some biological indicators within the soil fauna groups and description of the interrelationships between them and the analysed abiotic and biotic factors, in order to monitor the ecological quality of terrestrial ecosystems connected with GDEs (in our study the "Springs Complex of Corbii Ciungi" Protected Area).

MATERIAL AND METHODS

The study area

The Romanian protected area of Corbi Ciungi (*ca* 5 ha in extent) is of national interest and corresponds to the IUCN category 4 (*i.e.* floral and faunal nature reserve). It was declared a protected area in 1966. Although located in Dâmboviţa County, it lies right on the border with Giurgiu County. The reserve focuses upon a complex of springs that feed two rivulets – Lisandru Vlăduţ and Cacaleţilor – which are themselves tributaries of the Neajlov River. The protected area comprises the springs and the floodplains of the rivulets together with adjacent grasslands and scrub, not only between Lisandru Vlăduţ and Cacaleţilor but also immediately adjacent to the west side of Lisandru Vlăduţ and the north and east side of Cacaleţilor. The Neajlov River forms the southern boundary of the reserve. It is located at 44^{0}31'28.23" N and 25^{0}30'43.66" E (the northernmost point); 44^{0}31'01.47" N and 25^{0}31'09.51" E (the southernmost point). Between the two streams, as well as above the terrace I of Neajlov, there is agricultural land cultivated with annual or biennial crops, generally wheat and maize. The area is predominantly agricultural, over 70% of the total area (Figure 1).

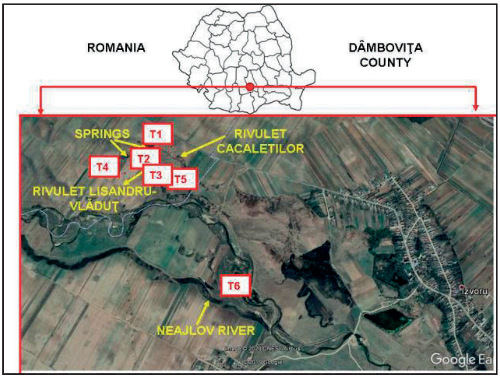

Figure 1. Geographical location of the "Springs Complex of Corbii Ciungi" Protected Area and of the investigated transects

In wooded and forest ecosystems, the dominant plant species were: *Salix fragilis L., Salix cinerea L., Alnus glutinosa (L.) Gaertn., Viburnum opulus L., Rhamnus frangula f. latifolia Dipp., Ligustrum vulgare L., Corylus avellana L., Euonymus verrucosus Scop., Cornus sanguinea L.* etc. Some species of bryophyte were identified: a) mosses *e.g. Cratoneuron commutatum (Hedw.) G. Roth* and *Brachythecium rivulare Schimp.*; and b) liverworts: *Aneura pinguis (L.)* and *Chiloscyphus polyanthus (L.).* Studies on invertebrates were made, especially on aquatic groups, but also on terrestrial ones, revealing the presence of 27 taxonomic units superior to the family (Botoşăneanu and Negrea, 1962; Ciubuc, 2007; Lotrean, 2012; The Official Monitor of Romania R.A., 2015).

Selected biological indicators

In order to monitor the conservation status and ecological diversity of the soil fauna, we selected the following biological indicators: number of taxa (Shannon diversity index), numerical abundance, dominance, evenness, equitability (Moretti et al. 2009); OM/PA index (Oribatida + Mesostigmata / Prostigmata + Astigmata) (Bedano et al., 2011); and Acari/Collembola ratio (A/C) (Perdomo et al., 2012; Yan et al., 2012; Deed, 2015). Some indexes were calculated using the statistical soft PAST (Hammer et al., 2001).

Bedano et al. (2011) found that natural areas have a higher OM / PA index value than those that are disturbed (or under stress). The A/C ratio is based on the numerical abundances of individuals from these two faunistic groups. In natural conditions this ratio has a value higher than 1. In contrast, where there is anthropogenic impact or soil degradation, this ratio changes in favour of Collembola and its value decreases (Bachelier, 1986; Visioli et al., 2013).

The soil fauna

The study was made using the transect method, following the soil moisture gradient. Six transects (T1-T6) were chosen, distributed in relation to the water source (Figure 1). The soil fauna was collected in July, 2019, using a square metal frame, with dimensions of 10X10X10 cm. In total, 30 soil probes were taken over an area of approximately 3000 s.q.m. (5 samples/ transect). The soil fauna groups were extracted using the Tullgren-Berlese method (by natural drying for 20 days) (Koehler and Melecis, 2010). Identification of soil fauna groups was performed on the Carl Zeiss stereomicroscope, and their preservation was made in ethylic alcohol pf 90^0. Taxonomic identification was done using the following keys (Dindal, 1990; Orgiazzi et al., 2016; Krantz, 2009). The statistical soft PAST was used in order to make a correspondence analysis (CA) and a canonical correspondence analisys (CCA) (Hammer et al., 2001).

The six transects investigated were positioned as follows:

- transect T1 was located near the first spring (at 5 m distance) at 44.524361 N and 25.512138 E, at an altitude of 122 metres, on a slope of 20% and with South-east exposure. The investigated habitat is scrub. The dominant plant species were: *Euonymus verrucosus Scop., Rosa canina L., Cornus sanguinea L., Ligustrum vulgare L. and Prunus spinosa L.*
- transect T2 was located at 20 metres distance from a spring, at 44.524069 N and 25.512155 E, at an altitude of 120 meters, on a slope of 5% and with South-east exposure. The investigated habitat is a meadow. The dominant plant species were: *Alopecurus pratensis L.* and *Sanguisorba officinalis L.*
- transect T3 was located at 5 metres distance from the second spring, at 44.523185 N and 25.512108 E, at an altitude of 120 metres. The investigated habitat is scrub. The dominant plant species were: *Rosa canina L., Cornus sanguinea L., Euonymus verrucosus Scop., Ligustrum vulgare L.* and *Prunus spinosa L.*
- transect T4 was located at 20 metres distance from the second spring, at 44.523663N and 25.511809 E, at an altitude of 120 metres, on a slope of 5% and with South exposure. The investigated habitat is a meadow. The dominant plant species were: *Alopecurus pratensis L.* and *Sanguisorba officinalis L.*
- transect T5 was located at 1 metre distance from the rivulet Lisandru-Vlăduţ, at 44.521888 N and 25.511166 E, at an altitude of 123 metres, on a slope of 10% and with South exposure. The investigated habitat is scrub. The dominant plant species were: *Rubus caesius L., Viburnum opulus L., Cornus sanguinea L., Aegopodium podagraria L., Corylus avellana L.* and *Rosa canina L.*
- transect T6 was located at 2 metres distance from the Neajlov river, at 44.519222 N and 25.514583 E, at an altitude of 115 metres, on a slope of 15% and with South exposure. The investigated habitat is riverine scrub. The dominant plant species were: *Lysimachia vulgaris L., Cirsium arvense L., Salix fragilis L., Amorpha fruticose L., Urtica dioica L., Lythrum salicaria L., Carex riparia L.* and *Salix purpurea L.*

Abiotic environmental factors

In total, 30 soil samples were analysed for environmental and soil chemical variables. The environmental were: litter-fermentation layer thickness (OLF); humus layer thickness (OH); soil layer thickness (OS); air temperature (T^0C), air humidity (H%); soil temperature (T^0C), soil moisture (M%); soil pH (in aqueous suspension 1:2.5; SR 7184-13: 2001; PTL 04); soil penetration resistance -SPR (PSI), measured with penetrometer STEP Systems GmbH; exposure and slope. At the same time, quantified chemical analyses were: the amount of organic carbon (humus: wet oxidation; STAS 7184/21-82; PTL 12); total N (Kjeldahl method; STAS 7184/2-85; PTL 09); PAL (extractable phosphorus) was also analysed in ammonium acetate-lactate; STAS 7184/19-82; PTL 19P); KAL (potassium extractable in ammonium acetate-lactate; STAS 7184/18-80; PTL 22) and mobile forms of Zn, Cu, Fe, Mn (using atomic absorption spectrophotometry, SR ISO 11047: 1998, PTL 32).

The biotic factor investigated was vegetation coverage (%) on each soil sample.

RESULTS AND DISCUSSIONS

Analysis of the thickness of the soil layers from the six transects showed that the humus layer was the best represented. The highest value of this parameter was recorded in T5, but the litter and fermentation layer was well represented in T1, and the soil layer in T6. The quantification of the vegetation coverage indicates a maximum value of 100%, in T4 (Table 1).

Table 1. Thickness of the soil layers (cm) and the vegetation coverage (%) from transecs (T) in "Springs Complex of Corbii Ciungi" Protected Area, 2019

T	OLF (cm)	OH (cm)	Os (cm)	Veg.cov. %
T1	5 ±1.87	4.8 ± 1.48	0.2 ± 0.44	15.4 ± 4.56
T2	2.9 ±1.24	7 ± 1.22		72 ± 37.01
T3	3 ± 1.58	7 ± 1.58		32 ± 14.76
T4	3 ± 0.70	7 ± 0.70		100 ± 22.1
T5	1.8 ±1.89	8.2 ± 1.89		2 ± 0.44
T6	0.48 ±0.32		9.52 ± 0.32	28 ± 13.33

The highest values of the air and soil temperature were recorded in T4, and the lowest in T5. Air humidity and soil moisture were highest in T5, and lowest in T4 (Table 2).

Table 2. Air temperature and humidity, soil temperature and moisture from transects (T) in "Springs Complex of Corbii Ciungi" Protected Area, 2019.

T	Tair (^{0}C)	Hair (%)	Tsoil (^{0}C)	Msoil (%)
T1	22.82 ± 0.38	72.8 ± 2.28	16.78 ± 0.71	62.4 ± 4.62
T2	25.72 ± 2.29	63.1 ± 4.92	20.62 ± 2.94	41.18 ± 5.37
T3	26.7 ± 0.46	66.8 ± 2.16	19.42 ± 2.39	55.76 ± 6.30
T4	31.24 ± 0.811	55 ± 5.78	23.44 ± 6.37	28.68 ± 9.88
T5	21.8 ± 0.59	76.2 ± 2.58	16.58 ± 0.43	69.32 ± 3.88
T6	28.24 ± 1.10	62 ± 4.58	20.02 ± 1.18	49.24 ± 4.27

With regard to soil penetration resistance, the most resistant soils were in T4 and T2. The most acid soil was recorded at T1 and on opposite at T5 and T6, where the quantity of nutrients was higher in comparison with T4 and T2 (Table 3). Although soil pH is a good indicator of the balance of nutrients, electrical conductivity reflects the amount of nutrients available in the soil. Only nutrients that are water-soluble are "available" for plant absorption. In strongly acidic soils, Al and Mn become highly mobile and available to plants, being toxic to them, while Ca, P and Mg are not available to plants. In strongly alkaline soils, P and most micronutrients become less mobile (Pagani et al., 2014). Electric conductivity had high values in T5 and T6, but low values in T2 and T4 (Table 3).

Table 3. Soil penetration resistance (SPR), electric conductivity (CE) and soil acidity (pH) from transects (T) in "Springs Complex of Corbii Ciungi" Protected Area, 2019

T	SRP (PSI)	CE (µS)	pH (unit pH)
T1	170 ± 0.60	96.72 ± 24.16	5.62 ± 0.42
T2	250 ± 0.16	47.72 ± 11.15	6.54 ± 0.09
T3	66 ± 0.55	154.68 ± 97.32	6.86 ± 0.32
T4	270 ± 0.49	38.52 ± 7.76	6.58 ± 0.29
T5	94 ± 0.57	282.6 ± 112.30	7.1 ±0.43
T6	110 ± 0.33	301.8 ± 207.22	7.33 ± 0.38

For soil nutrients (macro and microelements), the following results were obtained: P had the highest concentrations in T5 and T6; K in T1 and T4; Zn in T3 and T5; Cu in T2 and T4; Fe in T1 and T6; and Mn in T1 and T6. In general, the lowest values of these nutrients were found in T2 and T4 (Tables 4, 5).

Table 4. Macroelements from soil transects (T) of "Springs Complex of Corbii Ciungi" Protected Area, 2019

T	$P_{AL\ (mg/kg)}$	$K_{AL(mg/kg)}$
T1	11.76 ± 6.64	230.3 ± 40.57
T2	7.92 ± 4.16	183.65 ± 29.48
T3	21.48 ± 9.96	106.18 ± 29.86
T4	8.36 ± 4.80	195.42 ± 36.01
T5	20.56 ± 13.20	102.53 ± 20.31
T6	76.36 ± 39.96	97.66 ± 36.20

Table 5. Microelements from transects (T) of "Springs Complex of Corbii Ciungi" Protected Area, 2019.

T	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)
T1	2.18 ± 0.29	1.96 ± 0.42	260.28 ± 138.11	10.44 ± 1.64
T2	0.87 ± 0.25	2.61 ± 0.32	60.58 ± 16.36	4.42 ± 1.46
T3	4.09 ± 2.83	1.2 ± 0.47	123.54 ± 43.45	8.92 ± 6.5
T4	1.44 ± 0.40	2.11 ± 0.19	43.86 ± 15.43	5.42 ± 0.61
T5	3.55 ± 2.03	0.9 ± 0.36	87.2 ± 52.68	9.28 ± 1.60
T6	2.74 ± 1.20	1.99 ± 0.44	128.42 ± 61.23	27.72 ± 12.73

Samples from T1 and T5 were the most humus-rich (the quantity of organic carbon), whereas total nitrogen and the C/Nt ratio showed maximum values in T3 and T5 (Table 6).

The C/Nt ratio is a sensitive indicator of soil quality. It is considered an indicator of the mineralisation capacity of nitrogen. A ratio greater than 15 (C/Nt> 15) may slow the rate of decomposition of organic matter and organic nitrogen, limiting microbial activity, while a low ratio may accelerate the rate of decomposition. The presence of organic matter is a favourable factor for development of edaphic invertebrate populations (springtails, nematodes, enchytraeids, etc.), which in turn represent the food source for predator groups (such as mites) (Klarner et al., 2013).

Analysing the C/Nt ratio of the soil from this protected area, we found that a slower rate of decomposition of organic matter was recorded in T3 and T5, although this process is not very pronounced and the ratio did not greatly exceed the value of 15 (Table 6).

Table 6. The content of organic carbon (Corg) and of total nitrogen (Nt) from soil transects (T) of "Springs Complex of Corbii Ciungi" Protected Area, 2019

T	Corg.(%)	Nt (%)	C/Nt
T1	5.14 ± 0.55	0.42 ± 0.05	14.24 ± 1.04
T2	1.83 ± 0.28	0.17 ± 0.01	12.26 ± 1.26
T3	11.41 ± 6.9	0.83 ± 0.42	15.53 ± 1.69
T4	1.98 ± 0.28	0.2 ± 0.02	11.56 ± 0.67
T5	8.53 ± 3.63	0.61 ± 0.21	15.92 ± 1.75
T6	1.40 ± 0.61	0.15 ± 0.08	11.82 ± 2.58

From the taxonomic point of view, the biological material revealed the presence of 34 groups. These were classified in eight taxonomic classes: Oligochaeta (ord. Haplotaxida), Nematoda, Diplopoda (ord. Iulida), Chilopoda (ord. Lithobiomorpha, Geophilomorpha), Malacostraca (ord. Isopoda), Entognatha (ord. Collembola, Diplura), Insecta (ord. Hymenoptera, Coleoptera, Diptera, Hemiptera, Psocoptera), and Arachnida (ord. Trombidiformes, Sarcoptiformes, Mesostigmata, Araneae, Pseudoscorpionida) (Table 7). The numbers of insect and mite larvae were evaluated at the same time. In total, 4180 individuals were identified, from which 350 were immature mites and 107 individuals were insect larvae. The highest numerical abundance was recorded in the following taxonomic groups: Collembola (1108 individuals), Oribatida (969 individuals), Opiidae (540 individuals) and Mesostigmata (769 individuals); in contrast Nematoda, Chrysomelidae, Erytraeidae and Belbiidae were each represented by a single individual).

Those taxonomic groups most abundant in the protected area reflect soils rich in organic matter. From a trophic point of view, these taxonomic groups participate directly in the decomposition of organic matter, and the presence of a favourable habitat leads to high populations, which in turn are a source of food for other invertebrates (such as Mesostigmata).

Examining spatial variation over the study site, the highest numbers of soil invertebrates were recorded from transects located close to the different water sources (springs or rivulet), where the soil moisture was high (e.g. T1, T3, T5, T6). Similar trends were observed in the diversity of soil invertebrate groups. The lowest values of these two parameters were obtained in T2 (17 taxonomic groups with 306 individuals) and in T4 (20 taxonomic groups with 176 individuals).

The same trend was found in the totals of insect larvae and immature stages of mites (which is an indicator of the viability of the studied ecosystems), with maximums in T3 and T5 (Tables 7 and 8).

The numerical abundances of the soil taxonomic groups were evenly distributed in T2 and T4. In a few transects some taxonomic groups were notably dominant in terms of numerical abundance (in T5 and T6) e.g. Collembola, Oribatida, Opiidae and Mesostigmata. Dominance, evenness and equitability indices showed similar trends (Table 8).

The Acari/Collembola ratio was another useful biological indicator for monitoring the quality of terrestrial habitats dependent of groundwater and surface water. The recorded values of this ratio were higher than 1 in all six investigated transects, with the highest value (12.10) in T2 (Table 8).

Turning to the OM/PA ratio, small values were recorded if the mite communities were negatively influenced by an abiotic disturbance factor. The values of the OM/PA ratio were markedly higher in T1 and T5, and lowest in meadows (T2 and T4), where the soil humidity was lower and the distance to the water sources longer (Table 8).

Table 7. Numerical abundance of taxonomic groups from transects, in “Springs Complex of Corbii Ciungi” Protected Area, 2019

Taxa	Short name	T1	T2	T3	T4	T5	T6
Phylum Annelida							
Class Clitellata							
Subclass Oligochaeta							
Order Haplotaxida							
Family Lumbricidae	Lum	1		8	2	1	1
Family Enchytreidae	Enc	3	5		1	12	
Phylum Nematoda	Nem					1	
Phylum Arthropoda							
Sub-phylum Myriapoda							
Class Diplopoda	Dip	2		1	1	1	
Ord. Julida	Iul	1	5	14	1	5	
Class Chilopoda							
Ord. Lithobiomorpha	Lit		3	1	1	12	1
Ord. Geophilomorpha	Geo					2	
Sub-phylum Crustacea							
Class Malacostraca							

Ord. Isopoda	Iso		6		1		
Sub-phylum Hexapoda							
Class Entognatha							
Ord. Collembola	Col	103	20	146	28	621	190
Ord. Diplura	Dip				4		
Class Insecta							
Ord. Hymenoptera							
Family Formicidae	For	10	5	2	4	7	2
Ord. Coleoptera	Cole			4		3	
Family Staphylinidae	Sta	1	2	1		3	2
Family Chrysomelidae	Chr						1
Ord. Diptera	Dip			1		1	1
Ord. Hemiptera							
Superfamily Aphidoidea	Aph					20	
Ord. Psocoptera	Pso				2	2	26
Insect larvae	Ins l	12	18	12	7	28	30
Sub-phylum Chelicerata							
Class Arachnida							
Superorder Acariformes							
Ord. Trombidiformes							
Subord. Prostigmata							
Family Trombidiidae	Tro	1		1		3	
Family Bdellidae	Bde		2		1	1	6
Family Cunaxidae	Cun		17	4	8		
Family Johnstoninidae	Joh	2	3	5			2
Family Labidostommidae	Lab	4		2			
Family Tetranychidae	Tet	2					
Family Erythraeidae	Ery	1					
Ord. Sarcoptiformes							
Subord. Oribatida	Ori	105	35	212	33	545	39
Family Opiidae	Opi	102	92	18	12	219	07
Family Bellbiidae	Bel		1				
Subord. Astigmata							
Family Acaridae	Aca	2	5	37	6	6	2
Family Scutacaridae	Scu			2		3	2
Ord. Mesostigmata	Mes	67	19	222	42	371	48
Mites immatures	Mi im	32	68	95	20	118	17
Ord. Pseudoscorpionida	Pse	2		4	1		
Taxa	Short name	T1	T2	T3	T4	T5	T6
Ord. Araneae	Ara	1			1		
Numerical abundance (ind.)		454	306	792	176	1985	476
Number of taxa		20	17	21	20	23	17

Table 8. Soil biological indicators from "Springs Complex of Corbii Ciungi" Protected Area, 2019.

Soil fauna indicators	T1	T2	T3	T4	T5	T6	Total
No. of taxonomical groups	20	17	21	20	23	17	34
Numerical abundance	454	306	792	176	1985	467	4180
Dominance	0.18	0.17	0.20	0.14	0.22	0.24	
Shannon	1.94	2.14	1.89	2.27	1.74	1.82	
Evenness	0.35	0.50	0.31	0.48	0.25	0.36	
Equitability	0.65	0.76	0.62	0.76	0.55	0.64	
A/C	3.09	12.10	4.04	4.21	2.04	1.07	
OM/PA	22.83	5.65	8.86	5.80	87.31	15.33	

In order to explore how the invertebrate fauna is grouped according to the proximity of the analysed transects to water sources, we performed a correspondence analysis (CA), from which we obtained a classification of several taxonomic invertebrate groups related to the three types of water source (spring, rivulet and river):

- transects T2 and T4, located in meadows, were characterised by communities of Diplopoda, Formicidae, Cunaxidae and Araneae.
- transects T1 and T6, located closed to the water sources (rivulet and Neajlov River) were characterised by Staphylinidae, Erytraeidae, Insect larva, Lythobiomorpha and Opiidae.
- transects T3 and T5 were characterised by Oribatida, Mesostigmata, Coleoptera, Lumbricidae, Acaridae, Oribatida, Pseudoscorpionida and respectively by Collembola, Diptera, Scutacaridae, Nematoda (Figure 2).

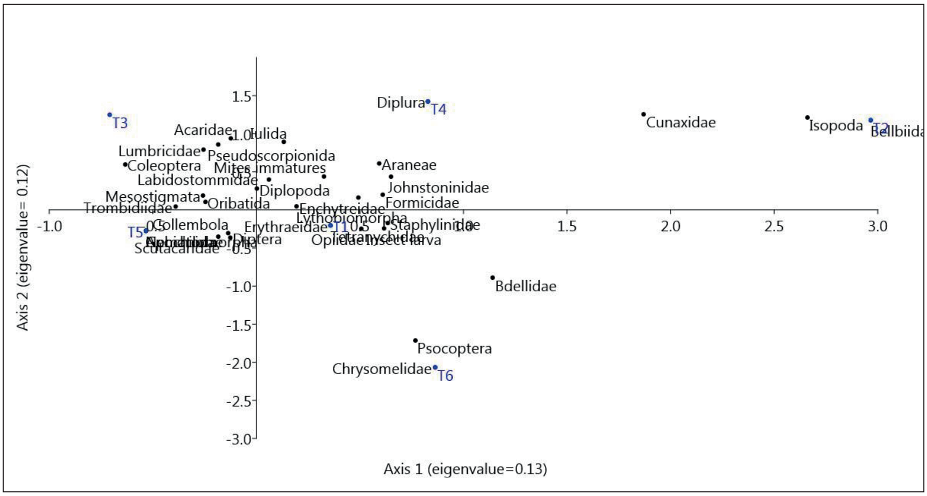

Figure 2. Correspondence analysis (CA) between identified taxonomical groups and analysed transects from "Springs Complex of Corbii Ciungi" Protected Area, 2019.

From analysis of the influence of abiotic and biotic environmental factors on the soil taxonomic groups, we observed that soil moisture, the decomposition rate of organic matter (C/Nt) and soil acidity positively influenced the numerical abundance of three invertebrate groups: Lumbricidae, Collembola and Oribatida (which are hydrophilous). These taxonomic groups are considered to be the most important edaphic invertebrates, participating directly inorganic matter decomposition (Figure 3).

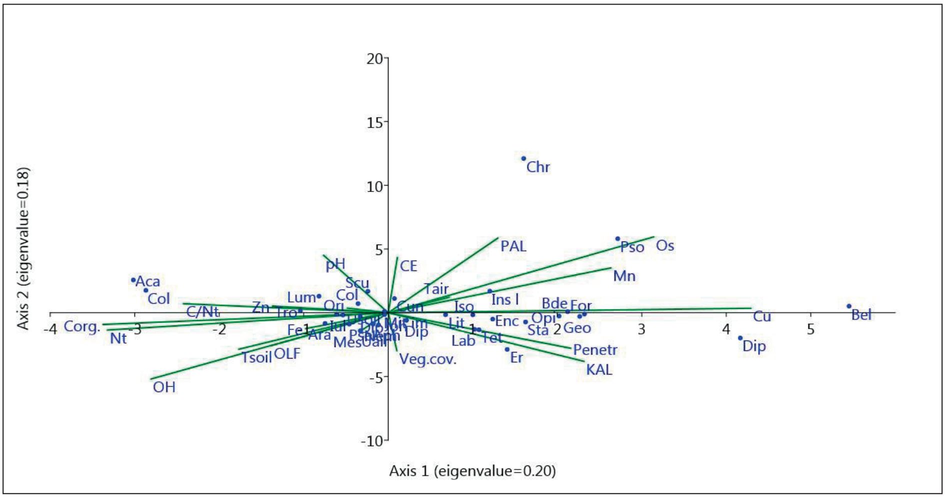

Figure 3. Canonical correspondence analysis (CCA) between identified taxonomical groups and abiotic – biotic factors, from "Springs Complex of Corbii Ciungi" Protected Area, 2019

CONCLUSIONS

Groundwater depended ecosystems are well represented in the "Springs Complex of Corbii Ciungi" Protected Area. Six transects were selected (T1-T6) on the basis of their proximity to water sources, in order to evaluate some biological indicators, that reflect the ecological status of the investigated ecosystems. Transects T2, T4 and T6 (the furthest from the water sources) were characterised by: a) their greater thickness of soil layers OLF and OH; b) higher values of air temperature and humidity, soil moisture, soil penetration resistance, electrical conductivity, content of Nt, Corg and macronutrients; and c) lower values of soil temperature and a soil pH that is slightly acid to neutral.

The Springs Complex of Corbii Ciungi" Protected Area was investigated from the biological point of view, in as well. In total 30 soil samples were analysed.

Thirty-four taxonomic groups were identified, with a total numerical abundance of 4180 individuals. The results of this study indicated that transects located closed to the water sources (T1, T3 and T5) were characterised by the more numerous and diverse invertebrate populations than in T2 and T4. The results for T6, located near the Neajlov River, departed somewhat from this pattern. Although close to a water source, the combination of very variable ground level, and hence distance from the water surface (1.5 m), and the sandy substrate, led to lower values of taxonomic diversity and numerical abundance. The same phenomenon was observed with the environmental variables recorded at the site i.e. lower soil moisture, lower amount of organic matter, etc.

There is a significant interdependence between these environmental variables, influencing the abundance and distribution of edaphic taxonomic groups in the groundwater-dependent ecosystems. Multivariate analysis indicated that certain edaphic groups (e.g. Lumbricidae, Collembola and Oribatida) are dependent on soil moisture.

The present study demonstrated that soil invertebrate groups could be used as bioindicators for monitoring the ecological status of terrestrial ecosystems, which in this protected area are connected with groundwater dependednt ecosystems (GDEs).

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