THE IMPACT OF DROUGHT AND ANTHROPOGENIC ACTIVITIES ON EDAPHIC MESOFAUNA COMMUNITIES IN CERTAIN NATURA 2000 STEPPE GRASSLAND HABITATS

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Abstract

The mites from the orders Parasitiformes, Trombidiformes, and Sarcoptiformes, as well as microarthropods from the Entognatha class (Collembola), insects, and other groups, were analyzed. The mites which belong to suborder Oribatida were identified at the species level. The analysis was conducted both quantitatively and qualitatively in Natura 2000 steppe meadows. The vulnerability of these sites, including susceptibility to drought and the impact of grazing, influenced the structure of the microarthropod communities. The density of individuals was higher in strictly protected areas; however, there was no significant qualitative difference compared to the buffer zones. Humidity deficiency and grazing negatively affected the mesofauna, particularly species sensitive to drought. Oribatids exhibited a rich diversity, indicating good habitat conservation. Continuous monitoring of the impact of natural and anthropogenic factors is necessary, especially in buffer zones.

Key words: Soil biodiversity, microarthropods, meso-xerophilous meadow, protected areas.

Natura 2000 is a network of nature protection areas in the territory of the European Union. It is designed to ensure the long-term survival of Europe's most valuable and threatened species and habitats. Mârzeşti Forest and Meadows (ROSCI0171) and Bârca Meadows (ROSCI0077) were declared sites of community importance by the Order of the Ministry of Environment and Sustainable Development No. 1964 of December 13, 2007 regarding the establishment of the regime of protected natural areas of sites of community importance, as an integral part of the European ecological network Natura 2000 in Romania. These areas were designated as SCI with the aim of protecting biodiversity and maintaining a favorable conservation status of the wild flora and fauna, as well as the natural habitats of community interest within the protected area.

The vulnerability of the site Mârzeşti Forest and Meadows is caused by inappropriate anthropogenic activities (sporadic plowing perpendicular to the contour lines, which favors landslides; grazing, flock transit, penning, etc.), as well as the presence of active landslides. For Bârca Meadows site, the vulnerability lies in the danger of being converted into agricultural land. Observations and field activities carried out during sample collection confirmed the presence of the aforementioned anthropogenic activities in both sites, which are likely to create a real impact on the strictly protected areas.

In both natural and anthropic ecosystems, soil mesofauna, in interrelation with soil microorganisms, actively participates in the processes of degrading necromass and, thus, in nutrient cycling. The density of microarthropods and the relationships between systematic and trophic groups decisively determine the speed and direction of decomposition, the dynamic balance of mineralization-humification, a balance that ensures soil fertility (Brussaard *et al*, 1997, Jeffery *et al*, 2010, Menta, 2012, Wardle *et al,* 2004). Considering all these factors, as well as the fact that the degree of anthropization of an ecosystem fundamentally influences the components of the biocenosis, it is particularly important to know the quantitative and qualitative characteristics of the soil microarthropod fauna.

MATERIAL AND METHOD

Field observations and sample collection were carried out in mid-June 2023 from the two natural reserves - Mârzeşti Forest and Meadows and Bârca Meadows, which are located in the Northeastern part of Romania, in Iaşi County (*table 1*).

Soil samples were gathered from habitats characterized by Ponto-Sarmatic steppes (62C0),

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which prevail across both reserves. The collection included areas under strict protection as well as buffer zones in each location. The extraction of microarthropods was carried out using the Tullgren - Berlese method, improved by Balogh. The faunistic material was studied microscopically, with the abundance of each group recorded for each sample

Table 1

Characteristics of the investigated sites

Natura 2000 Site	Location	Area (ha)	Altitude			Biogeographic region	Protected plant species
			min.	max.	med.		
Mârzeşti Forest and Meadows	N 47º 14' 24" E 27º 29' 55"	232	67	179	125	Continental	*Echium russicum, Crambe tatarica, Pulsatilla grandis*
Bârca Meadows	N 47º 4' 48" E 27º 29' 35"	159	66	129	88		*Iris aphylla ssp. hungarica, P. grandis*

The primary data thus obtained were processed using analytical and synthetic ecological estimators:

- average abundance in individuals/100 cm² or per m², calculated for both species ($\bar{a}$) and groups ($\bar{A}$);

- standard deviation (σ), a statistical measure that indicates how much individual values in a data set deviate from the mean (average value) of that data set; it quantifies the dispersion or variability of the data;

- Pearson's coefficient of variation (cv%), a statistical measure used to express the relative variability of a data series compared to its mean;

For oribatids, a representative group with bioindicator value, species-level identification was performed, and an additional use of the following indicators:

- number of taxa, respectively species (S), genera (G) and families (F);

- frequency (C), expressed in classes: IV-euconstant species (C > 75%), III-constant (C between 50.1-75%), II-accessory (C between 25.1-50%), I-accidental (C < 25%);

- relative density (D.r.), expressed in classes: V-eudominant species (D.r. > 10%), IV-dominant (D.r. between 5.1-10%), III-subdominant (D.r. between 2.1-5%), II-recedent (D.r. between 1.1-2%), I-subrecedent (D.r. < 1%);

- ecological significance (W) (Dziuba, 1968), expressed in classes: V, IV-edifying species (W > 5%), III-influential species (W between 1.1-5%), II, I-accompanying species (W < 1%);

- specific diversity (H(s)max, H(s), H.r.), estimated based on the Shannon-Wiener equation.

In addition, the adult/pre-adult ratio was also calculated, which provides information about the demographic structure of the community and its likely evolution.

The nomenclature of species and their world distribution follows Subías L.S., 2004, updated version 2024. Ecological peculiarities for each oribatid species were summarized according to (Pérez-Iñigo C.,1993, Pérez-Iñigo C.,1997; Subías L.S. and Arillo A., 2001; Weigmann G., 2006; Vasiliu N. *et al*, 1993).

RESULTS AND DISCUSSIONS

The assessment of soil microarthropod biodiversity in the analyzed reserves was conducted through inventory and analysis of mites from the suborders Parasitiformes (order Mesostigmata) and Acariformes (orders Trombidiformes and Sarcoptiformes - suborder Oribatida and cohort Astigmatina), microarthropods from the class Entognatha (Collembola), and overall insects and other groups belonging to the soil mesofauna (*table 2*). The average density of soil microarthropods ranges between 163.6 individuals/100 cm² and 274.6 individuals/100 cm², with the highest value observed in the strictly protected area of Mârzeşti Forest and Meadows Reserve and the lowest in the buffer zone of Bârca Meadows Reserve. However, in both these Natura 2000 sites, it was observed that microarthropod abundance is greater in the strictly protected area compared to the buffer zone. A comparison with the findings from Valea lui David nature reserve (ROSCI 0265), another site of community importance in northeastern Romania, reveals that the density of mesofauna at Bârca is only slightly lower, while at Mârzeşti it is slightly higher (Călugăr A., 2006). This suggests a good conservation status for both reserves at this stage. However, the calculation of the standard deviation revealed high values, indicating significant variability in the distribution of mesofauna. This variability could be caused by various ecological factors such as soil conditions, resource availability, human interference, or other environmental factors. This may have important ecological implications, as it could indicate greater natural variability in mesofauna communities or suggest that certain conditions are more unpredictable or fluctuating in those locations (*table 2*).

The Pearson variation coefficient also showed high values, indicating a moderate positive correlation between two measured variables regarding soil mesofauna.

Table 2

Global average density (individuals/100 cm²) of soil microarthropods

Taxa		sites	Mârzeşti meadows		Bârca meadows	
			1	2	1	2
Mesostigmata		Ā	13.6	6.9	10.2	33.7
		δ	10.7	6.4	6.0	15.4
		cv%	78.7	93.7	59.0	45.5
Trombidiformes		Ā	68.3	99.6	99.2	52.6
		δ	41.6	79.1	60.7	18.8
		cv%	60.9	79.4	61.2	35.8
Sarcoptiformes	Oribatida (O)	Ā	88.0	92.9	22.2	78.0
		δ	55.6	68.8	12.0	49.9
		cv%	63.2	74.1	54.0	64.0
	Astigmatina (A)	Ā	2.1	4.0	1.6	1.4
		δ	3.4	5.0	2.7	1.4
		cv%	158.6	124.6	170.5	98.0
Total Acari		Ā	172.0	203.3	136.2	165.7
		δ	87.1	104.6	78.0	68.7
		cv%	50.6	51.4	57.3	41.4
Entognatha (Collembola - C)		Ā	2.6	3.1	4.0	8.1
		δ	3.3	1.5	2.5	5.2
		cv%	126.2	46.4	63.3	64.1
Insecta		Ā	14.0	67.3	23.2	29.1
		δ	12.2	52.9	23.1	34.0
		cv%	87.4	78.6	99.5	116.7
Other groups		Ā	0.3	0.9	0.2	6.4
		δ	0.7	1.4	0.4	10.9
		cv%	20.0	158.1	200.0	170.0
Total		Ā	188.9	274.6	163.6	209.4
		δ	93.5	113.7	84.2	82.4
		cv%	49.5	41.4	51.5	39.4
O/C			34.2	29.6	5.6	9.6
O/A			41.1	23.2	13.9	54.6

Legend: 1- buffer zone; 2- strictly protected area; O/C - numerical ratio between Oribatida and Collembola; O/A - numerical ratio between Oribatida and Astigmatina; Ā - average abundance/density; δ - standard deviation; cv% - Pearson coefficient of variation

For example, it might suggest that an increase in a particular soil characteristic or factor (such as organic matter content or pH modification due to grazing) tends to be associated with a moderate increase in soil mesofauna diversity or density.

The Entognatha representatives, specifically collembolans, are represented by a much smaller number of individuals compared to those of the class Acari, both in the buffer zones and in the strictly protected areas of Mârzeşti and Bârca (*table 2*). Thus, the abundance of collembolans is over 60 times lower at Mârzeşti and over 20 times lower at Bârca compared to that of mites. This situation may be attributed to the drought period preceding sample collection. Grazing animals can compact the soil, which also negatively affects soil mesofauna, particularly groups sensitive to dryness, especially during prolonged drought conditions. Organisms from the class Collembola are generally sensitive to this phenomenon and try to protect themselves in dry environments by seeking shelter under organic material or in deeper soil layers when moisture conditions become unfavorable. Additionally, they feed on bacteria, algae, and decomposing organic material in the soil, and a lack of precipitation can affect the availability of these food resources, leading to a reduction in collembolan populations. Indeed, the calculation of the Pearson variation coefficient indicates high values, reflecting an uneven distribution of these organisms due to insufficient resources.

Among mites, Trombidiformes represent a group with a varied diet and are well-represented, especially in meadows, while Oribatida, which are detritivorous and microphytophagous, have the highest abundance in forest ecosystems (Krantz G. W., Walter D. E., 2009). The study found that Oribatida is the most numerous group but only in the buffer zone of Mârzeşti (51%) and in the strictly protected reserve area of Bârca (73%, respectively 47% of the total mites) (*table 2*). At Mârzeşti, in the strictly protected area, Trombidiformes mites are slightly more numerous than those from the suborder Oribatida (49% and 46% of the total mites, respectively), while at Bârca - the buffer zone, they represent the majority

(74%). With a reduced share, the suborder Mesostigmata, which includes zoophagous mites, occupies the third position, with the highest percentages in the strictly protected area of Bârca (20%) and the lowest in Mârzeşti (3%). The least represented among mite populations, with percentages of only 1-2%, are the acarid mites (cohort Astigmatina), known to be microphytophagous (Krantz G. W., Walter D. E., 2009), and are stimulated by moist, anaerobic environments rich in nitrogenous substances (Călugăr M. *et al*, 1989; Huţu *et al*, 1992; Călugăr A., 2005). Therefore, grazing should have been a stimulating factor for this group of mites by increasing the organic matter input from animal droppings. However, the deficient precipitation, as experienced during the period preceding soil sample collection, had a negative effect on acarid populations, as drought can influence their food availability by making organic matter less accessible or harder to decompose.

In this study, a bioindicator of the humification stage of an organic substrate was assessed, specifically the numerical ratio between oribatid mites and collembolans/astigmatid mites (Huţu *et al*, 1992). The results showed high to very high values for this ratio, with collembolans and astigmatid mites appearing sporadically and in much lower densities compared to oribatids across all analyzed samples. These findings suggest a trend towards advanced humification in both buffer zones and strictly protected areas within the Natura 2000 sites under study.

The fauna collected from the two Natura 2000 sites totaled 1411 specimens of adult oribatid mites, to which 512 juveniles were added. The study of this rich material led to identification of 51 species, classified into 43 genera and 28 families of the suborder Oribatida Dugès, 1834. The weight of the major groups in the whole fauna is as follows: "lower" oribatids (Macropyplina) - 19.6%, "superior" oribatids (Brachypylina), picnonotic – 45.1% and poronotic – 35.3%. Such a representation of the two groups of Brachypylina proves to be a characteristic of silvosteppe meadows, it being known that, in grassland ecosystems, poronotic oribatid mites are dominant, and in forest ones, picnonotic oribatids (Ivan O., 2007, Ivan O., 2010). In this study was identified and recorded for the first time in the fauna of Romania *Berniniella inornata* (Mihelčič, 1957), a species with Mediterranean distribution. In addition, some rare species, such as *Jacotella neonominata* Subias, 2004, *Birsteinius clavatus* Krivolutsky, 1965 or *Liacarus (Dorycranosus) zachvatkini* Kulijev, 1962 were found. The families Oppiidae (9 genera, 10 species), Brachychthoniidae (3 genera, 4 species) and Liacaridae (2 genera, 4 species) are the best represented in terms of number of taxa, and the species of the families Oppiidae, Ceratozetidae and Phenopelopidae have the widest distribution in the investigated sites.

Analysis of the fauna from zoogeographical point of view shows that the most numerous are the species with a wide geographical distribution, cosmopolitan and semi-cosmopolitan (33.3%), followed by the Palaearctic (27.5%), Holarctic (19.6%), and European species (17.6%). Species with a southern distribution represent 25.5% of the total, an important share, taking into account the latitude at which the investigated sites are located (Ivan O., 2018).

Table 3

Structural global parameters of oribatid communities

Sites		Ā		F/G/S	Adults/ juveniles	Specific diversity			Edifying species*
		total	adults			$H(S)_{max}$	H(S)	H. r.	
Mârzeşti meadows	I	9290	6700	20/27 /30	2.59	4.9069	3.7066	75.54	*Punctoribates punctum, Tectoribates ornatus, Oribatula pannonica, Ceratozetes minutissimus*
	II	8800	6100	25/32 /36	2.26	5.1699	4.1823	80.89	*Jacotella neonominata, Discoppia (C.) cylindrica, Sphaerochthonius splendidus*
Bârca meadows	I	7800	6128	13/19 /20	3.67	4.3219	2.7578	63.81	*Anomaloppia differens, Ceratozetes minutissimus, Oppiella nova, Poecilochthonius spiciger*
	II	2220	1720	8/10 /10	3.44	3.3219	2.7795	83.4	*Ceratozetes minutissimus, Subiasella (L.) subiasi, Discoppia (C.) cylindrica*

Legend: I – protected area; II – buffer zone; Ā - global average abundance (individuals/m^2); number of taxa: F-families, G-genera, S-species; H(S)max – maximum specific diversity; H(S) – real specific diversity; H.r. - relative diversity (%); *V and IV classes of ecological significance (W≥ 5,1%, see Material and method).

As regards the autecological particularities of species, the largest share have grassland species or species with a preference for such habitats (27.5%), followed by euryplastic elements, with wider ecological valence (19.6%), and finally preferentially forest ones (17.6%). Analyzing the preferences of the species in relation to the humidity factor, it is found that the xerophilous, meso-xerophilous and thermo-xerophilous species are more numerous than the mesophilous ones, although the weight of the two categories is close (31.4% and 29.4%, respectively).

The analysis of the global structural parameters of the oribatid communities indicates higher or close values of the global average density, the number of taxa and the specific diversity in the protected areas compared to the buffer zones (*table 3*). In the meadows at Mârzeşti, the number of taxa and, implicitly, the specific diversity, are even higher in the buffer zone than in the protected area, a fact that can be explained by the different location, which determines different stand conditions. In the case of Bârca meadows, notable differences can be observed between the protected and the buffer zone, both in terms of quantitative and qualitative parameters, with much lower values in the buffer zone. The groups of edifying species bring together typically grassland species, most of them being meso-xerophilous or thermo-xerophilous, alongside species with wider ecological plasticity. The demographic structure is balanced in all the investigated sites, illustrated by the low values of the adults/ juveniles, ratio; the good representation of the immature stages, as well as the relatively high values of the diversity indices, characterize some functional and stable communities over time and their functional integration within the ecosystem.

CONCLUSIONS

The characteristics of the reserve, including its vulnerability, were key factors influencing both the numerical and qualitative structure of soil microarthropod communities. In terms of quantity, differences were observed between the buffer zone and the strictly protected area, with a higher density of individuals in the strictly protected zone.

Concerning the qualitative aspect of the communities, no significant differences were observed between the two Natura 2000 sites or between their distinct zones – buffer and strictly protected area. For mites, it was found that oribatid mites and Trombidiformes alternated in dominance, without clear connections to specific ecosystem characteristics. Overall, mites constituted the majority of the mesofauna communities, while collembolans were present in low numbers across all sites. Two stress factors were identified in both Natura 2000 sites: grazing activities and the drought period preceding sample collection.

The drought, along with grazing present in both sites, had a negative impact on the entire mesofauna, particularly on groups sensitive to drought, such as Astigmatina and Entognatha, which were almost absent in samples from both sites.

The study of oribatid mites showed that the fauna of the two protected areas is relatively rich and diverse, characteristic for the main habitat type, Ponto-Sarmatic steppes. In the ecological spectrum of the fauna, grassland species and euryplastic ones have the largest share, notable being also the increased proportion of xerophilous and meso-xerophilous species, higher than of mesophilous ones, a fact that supports the bioindicator value of this group of edaphic microarthropods.

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