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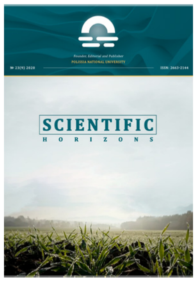

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Biodiversity and functional roles of soil organisms: An analysis of millipede populations in Southern Albania

Hajdar Kicaj*
Doctor of Sciences, Associate Professor
University Ismail Qemali
9401, Kosova Str., Vlorë, Albania
https://orcid.org/0000-0002-2611-2882
Geolind Cobaj
Master of Sciences
University Ismail Qemali
9401, Kosova Str., Vlorë, Albania
https://orcid.org/0009-0002-9738-9616

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Abstract. Soil organisms are an important component of the biodiversity of terrestrial biogeocenoses. Their considerable taxonomic and ecological variability determines a significant functional role in soil formation processes, mechanisms of sustainable development and productivity of natural ecosystems. The aim of the study is to develop a practical approach to the ecological assessment of soil organisms populations using the example of *Diplopoda* in the southern region of Albania. The study was carried out using general scientific methods of cognition: system and cluster analysis, synthesis, specification, abstraction, formalization, deduction, generalization, and the statistical method. The article systematizes and analyses statistical data on the assessment of populations of millipede species found in the study area. It considers the influence of environmental factors on the distribution of representatives of the class *Diplopoda*. It calculated the frequency of species according to the collection areas, constant values for the species of the three represented orders. Based on the data variety, composition of each zone is carried out with cluster analysis using Average Linkage. The similarity between zones is studied. The dendrogram obtained indicates the proximity of zones according to their diversity composition. Based on the results of the study, a system of tools was proposed as part of the ecological assessment of soil organisms populations, and the main approaches to its implementation were developed. The practical significance of the obtained results lies in the possibility of using them to study the dynamics of soil organism populations, including in the period of global climate change, to develop a dynamic approach to the ecological assessment of soil ecosystems and to implement an appropriate adaptation and regeneration strategy

Keywords: terrestrial ecosystem; *Diplopoda*; statistical data; geographical distribution; resistance; monitoring

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*Corresponding author

INTRODUCTION

Millipedes are a group of soil invertebrates characterized by significant species diversity in terrestrial ecosystems. As saprotrophs, millipedes perform a number of important functions, including fragmentation, transformation, and decomposition of litter in ecological systems, ensuring the recycling of carbon and nutrients, and regulating their cycle. In addition, the life cycle of millipedes affects the content of available phosphorus in the soil (Gestel *et al.*, 2021). These organisms interact with other soil organisms and can have a significant impact on the number of soil microorganisms.

Given the priority of the ecosystem approach to managing biogeocenoses, as well as the challenges of our time caused by global adverse climate change, there is a need to develop research on this topic to better understand the role of millipedes in ecosystem functioning and to develop an optimal approach to the ecological assessment of populations of these organisms. The latter can serve as a representative approach for effective ecological assessment of other soil organisms. An effective ecological assessment of soil organisms, subject to the requirements for the reliability of monitoring data, the organization of a system of practical ecological and biological research and the use of innovative scientific and technological capabilities, can solve a number of problems in the ecosystem management system.

The results of research by modern scientists led by G. Deckmyn *et al.* (2020), as well as M. Delgado-Baquerizo *et al.* (2020) and N. Eisenhauer *et al.* (2021) indicate that ecological indicators such as frequency, constant, and processing statistics show how ecological factors influence the spread of *Diplopoda*. At the same time, V. Langraf *et al.* (2021) and X. Zeng *et al.* (2023) emphasize in their works the fact that a sharp increase in the frequency of occurrence and the strength of the impact of anthropogenic factors threatens the sustainable functioning of soil ecosystems in the future. Researchers A. Potapov *et al.* (2022) in a recent publication highlighted the peculiarities of modern approaches to the ecological assessment of the population of living organisms, as well as the strategy of adaptation to climate change. Researchers C. Guerra *et al.* (2021) substantiate the expediency of using modern predictive modelling capabilities and innovative monitoring capabilities to identify significant factors of impact on ecosystems and populations of organisms, in particular.

The scientific community studies millipede populations mainly from the classification and description approach. Information about the representatives of *Diplopoda* in Albania is based on the results of scientific works of local and foreign researchers, in particular H. Kicaj and M. Oirjo (2023). Scientists are studying the peculiarities of the spatial distribution of millipedes, depending on the intensity of the impact of climatic factors on the population. It should be noted that current research on the ecological functions of millipedes is very narrow and limited. Given the limited functionality of scientific research on the issues considered in this study, it is necessary to expand the parameters for assessing the ecological status of populations of soil organisms, to deepen the study of their adaptive capabilities, and to carefully analyse the set of interrelations and interdependencies between elements of soil biogeocenosis. It is also advisable to implement the basic principles of sustainable development of ecosystems into the methodology of ecological assessment of soil organisms.

Currently, many issues related to the ecology of the class *Diplopoda*, especially in Albania, remain unresolved. The aim of the study was to investigate the peculiarities of the functioning of soil organism populations using the example of *Diplopoda* representatives in the southern region of Albania, as well as to develop an effective approach to the ecological assessment of such populations as representative ones.

MATERIALS AND METHODS

In the course of the research, general methods of scientific knowledge were applied. General scientific methods of cognition were used in the course of the work: system and cluster analysis, synthesis, specification, abstraction, formalization, deduction, generalization, and the statistical method. The formation of a system of regularities and features of the object of study of the influence of a set of factors on the processes occurring in populations of soil organisms was implemented using the method of generalization. The method of ascending from the abstract to the concrete was applied in the context of the transition from general knowledge about the vectors of climate change on populations of living organisms to the essence of the consequences of such impact on populations of soil organisms, in particular, specific species of *Diplopoda*. Using system analysis, the structural links between the elements of the phenomenon under study were established, and existing approaches to the ecological assessment of populations of living organisms were studied. The method of deduction was used to highlight the essence of the negative impact of anthropogenic pressure on the development and functioning of soil organisms. Also, some ecological and statistical indicators are used to assess *Diplopoda* populations.

Constant (c) expresses the ratio between the number of samples where the species are found and the total number of samples taken. It is used to determine the constant groups of soil fauna on which the study was conducted. This classification is made: for values of constant from 50-100, the group is considered "constant"; for values of constant from 25-50, the group is considered a "companion"; for values of constant from 0-25, the group is considered "casual" (Mauries *et al.*, 1997).

Frequency (f): report of the individuals expressing a kind on the total number of individuals collected. Determination of this indicator is intended to give its performance for any stage within each and between different stations. For the studying of the variety, the Sorenson indicator is used (1):

$$d = \frac{S-1}{\log N}. \quad (1)$$

This indicator helps to assess the degree of variety of species between stations or different areas defined previously. The size of samples that have been calculated is different and also the relative density of each type (2):

$$d = \frac{H}{\log 2\ N}, \quad (2)$$

where H is the Shannon index as an indicator of overall variety (3, 4):

$$H = -\Sigma\pi \log \pi\ , \quad (3)$$

$$\pi = \frac{Ni}{N}\ , \quad (4)$$

where "Ni" – the number of individuals of type "I", "N" – the total number of individuals.

The relative density of any kind of theory differs from "0" to "1". He tends to move toward "0", when almost all the effective belongs to a type, while tends to "1" when each type is represented by the same number of individuals. Based on data, variety composition of each zone is carried out with cluster analysis using the Average Linkage method. The similarity between zones is studied. The dendrogram obtained indicates the proximity of zones according to their variety composition.

RESULTS

The essence of the ecological assessment of populations of living organisms is mainly to study the development processes, viability of individuals, resilience and adaptability, and the nature of their environment (Creamer *et al.*, 2022). Strategic assessment is also seen as a necessary component, which includes elements of forecasting and the development of appropriate measures for the purpose of preventive protection, rational exploitation and regeneration of ecosystems. It is worth noting that, in general, the main ecological characteristics of a population are its range, density, number, population dynamics, as well as age, spatial and sex structures (Le Provost *et al.*, 2021).

An effective environmental assessment is impossible without the use of monitoring tools that provide a complete information base on changes in the main parameters of the population, the nature, and intensity of the impact of external factors and anthropogenic pressure. The main parameters for effective monitoring of populations are the number of individuals, the population area, reproduction and population structure parameters, and the level of anthropogenic pressure (Burton *et al.*, 2022). Population studies should be aimed at recording the total number of individuals and the dynamics of the indicator in the time aspect. Studying changes in the population's range allows the identification of fragmentation features. In general, the main task of a population monitoring system is to record the result of the interaction between the natural environment and anthropogenic load in terms of the impact on the population of specific organisms, taking into account the factors of dynamics and natural regeneration (Potapov *et al.*, 2022). At the same time, the range of monitoring parameters can be significantly expanded and adapted to the population under study, in this case, to the characteristics of millipedes as representative organisms of the soil environment.

One of the important structural elements of the ecological assessment of populations of soil organisms is the formation of prognostic parameters of population functioning (Guerra *et al.*, 2021). In this case, the forecasting should be based on the results of analytical processing of observations of long-term dynamics of the structure and characteristics of the population. Thus, it can be argued that an effective ecological assessment of soil organism populations should be based on arrays of monitoring information on the structural and functional organization of the population, the peculiarities of relationships within the ecosystem, and trends in the dynamics of environmental parameters. Particular attention should be paid to the study of microevolutionary processes occurring in populations under conditions of anthropogenic pressure on the environment and global climate change.

The class *Diplopoda* includes terrestrial organisms, phytophages. Their distribution is influenced by numerous factors, among which the most decisive are temperature, humidity, altitude, soil type, phytocoenosis and the size of decomposing plants. The study compared territories according to various parameters as part of an ecological assessment of the population of soil organisms, using the example of *Diplopoda* in the southern region of Albania. The statistical data were collected over several years in the basic areas of the study. In addition, in order to expand the information base of the current work, the results of researches by H. Kicaj (2023) and H. Kicaj & M. Qirjo (2014) were used, which provided a detailed analysis of the effect of temperature and humidity on the distribution of representatives of the family Glomeridae belonging to the class *Diplopoda*. The researcher notes that the smallest number of *Diplopoda* was isolated from the natural environment in July and August, as this period of the year is the driest in Albania. In addition, the researchers analysed the distribution of *Diplopoda* populations in the soil profile. Most of them lived in the litter and at a depth of up to 10 cm, and only 18% of millipedes migrated to a depth of 10-20 cm.

This study presented the data for the number of individuals for any of the species collected. The analysis of these data constitutes the basis of calculating the ecological indicators: constant, frequency, Shanon indicators (H), and relative density of any kind (ē). In the Table 1 are given the defined types of the *Diplopoda* class, the value of the constant, and the group to which these types belong.

Table 1. *The constant value for three represented orders*

No.	Species	Constant, %	The relevant group
	Order *Julida*		
1	*Anoploiulus pusillus* (Leach 1814)	100.00	Constant
2	*Megaphyllum karschi* (Verhoeff 1901)	62.50	Constant
3	*Pachyiulus cattarensis* (Latz 1884)	50.00	Constant
4	*Pachyiulus dentiger* (Verhoeff 1901*)*	37.50	Companion
5	*Pachyiulus varius* (Fabricius 1781)	37.50	Companion
6	*Ommatoiulus sabulosus* (Line 1758)	37.50	Companion
7	*Cylindroiulus boleti* (C.L. Koch,1847)	37.50	Companion
8	*Leptoiulus trilineatus* (C.L. Koch,1847)	25.00	Companion
9	*Pachyiulus hungaricus* (Karsch,1881)	25.00	Companion
10	*Pachyiulus valonensis* (Verhoeff 1901)	25.00	Companion
11	*Anoploiulus apfelbecki* (Verhoeff 1898)	12.50	Casual
12	*Leptoiulus macedonicus* (Atems,1927)	12.50	Casual
13	*Typhloiulus albanichus* (Atems 1929)	12.50	Casual
14	*Nopoiulus kochii* (Gervais 1847)	12.50	Casual
	Order *Polydesmida*		
15	*Polydesmus complanatus* (Verhoeff 1901)	12.50	Casual
16	*S. stigmatosum balcanicum* (Schubart, 1937)	25.00	Casual
	Order *Glomerida*		
17	*Glomeris pulchra* (C.L.Koch. 1847)	87.50	Constant
18	*Glomeris bureschi* (Verhoeff 1926)	33.15	Companion
19	*Glomeris hexastica* (Brandt,1833)	12.50	Casual
20	*Glomeris balcanica* (Verhoeff, 1906)	12.50	Casual
21	*Glomeris pustullata* (Latrielle 1804)	12.50	Casual
22	*Glomeris latermarginata* (Villers 1789)	12.50	Casual

Source: *compiled by the authors*

Based on the method of material collection and the representation of the stations within each area, can see that the constant value according to the area is more representative. According to the represented orders, the following results are noticed: *Anoploiulus pusillus*, *Megaphyllum karschi*, *Glomeris pulchra*, which result in widespread in the study area. The species encountered for the first time in Albania have been noticed to have a constant value: *Polydesmus complanatus*, *Strongylosoma stigmatosum balcanicum*, *Glomeris latermarginata*, and consequently considered casual. The represented individuals of the order *Polydesmida* are considered random species. The number of species is the least represented in the area of study. Species with a constant value over 50% are evaluated as constant species*:* *Pachyiulus cattarensis*. Frequency per zones. The frequency of species for each collection station was calculated (Table 2).

Table 2. *Frequency of species according to the collection areas*

Species/Zone	Vlora	Shashica	Llogara	Shushica	Borsh	Delvina	Butrint	Kardhiq
			Order: *Julidae*					
Pachyiulus cattarensis (Latz, 1884)	0.49			0.08		0.36	0.08	
Pachyiulus dentiger (Verhoeff, 1901)	0.04	0.04	0.02	0.09				
Pachyiulus varius (Fabricius, 1781)	0.04			0.21	0.46			
Pachyiulus valonensis (Verhoeff, 1901)	0.07				0.04		0.36	

Table 2, Continued

Species/Zone	Vlora	Shashica	Llogara	Shushica	Borsh	Delvina	Butrint	Kardhiq
Pachyiulus hungaricus (Karsch, 1881)			0.01					0.02
Anoploiulus apfelbecki (Verhoeff, 1898)	0.02							
Anoploiulus pusillus (Leach, 1814)	0.13	0.21	0.16	0.09	0.18	0.17	0.28	0.89
Megaphyllum karschi (Verhoeff, 1901)	0.06	0.22	0.28	0.14		0.14		
Ommatoiulus sabulosus (Line, 1758)		0.09	0.08				0.06	
Cylindroiulus boleti (Koch, 1847)		0.09		0.05				0.06
Leptoiulus trilineatus (Koch, 1847)			0.02		0.02			
Leptoiulus macedonicus (Atems, 1927*)*						0.02		
Typhloiulus albanichus (Atems, 1929)			0.03					
Nopoiulus kochii (Gervais, 1847)			0.02	0.02				
Rendi: *Polydesmida*								
Polydesmus complanatus (Verhoeff, 1901)			0.01					
S. stigmatosum balcanicum (Schubart, 1937)		0.09		0.11				
Rendi *Glomerida*								
Glomeris hexastica (Brandt, 1833)						0.13		
Glomeris pulchra (Koch, 1847)	0.15	0.08	0.26	0.06	0.12	0.17	0.22	0.03
Glomeris bureschi (Verhoeff, 1926)		0.05	0.06	0.16	0.18			
Glomeris balcanica (Verhoeff, 1906)			0.04					
Glomeris pustullata (Latrielle, 1804)		0.11						
Glomeris latermarginata (Villers, 1789)			0.01					
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: *compiled by the authors*

It is referred from the data that the frequency of species is very variable according to the area. Thus, *Anoploiulus pusillus* has a high frequency in Kardhiq (89%); *Pachyiulus cattarensis* in the Bay of Vlora (49%) and Delvina's hollow 36%; *Pachyiulius varius* with high frequency in Borsh 46%; *Pachyiulus valonensis* with high frequency 28% in Butrint (Table 3, 4). It is also observed from the table is observed that the frequency of types of Order Julida is significantly higher than that of the two others. Since the size of the samples has been different, authors have also calculated the relative density of each kind.

Table 3. *Index of relative density of any kind*

Species/Zone	Vlora	Shashika	Llogara	Shushika	Borsh	Delvina	Butrint	Kardhiq
Order *Julidae*								
Pachyiulus cattarensis (Latz, 1884)	0.09			0.23		0.12	0.14	
Pachyiulus dentiger (Verhoeff, 1901)	0.18	0.30	0.43	0.22				
Pachyiulus varius (Fabricius, 1781)	0.17			0.17	0.10			
Pachyiulus valonensis (Verhoeff, 1901)	0.15				0.22		0.09	
Pachyiulus hungaricus (Karsch, 1881)			0.55					0.21

Table 3, Continued

Species/Zone	Vlora	Shashika	Llogara	Shushika	Borsh	Delvina	Butrint	Kardhiq
Anoploiulus apfelbecki (Verhoeff, 1898)	0.24							
Anoploiulus pusillus (Leach, 1814)	0.12	0.17	0.17	0.22	0.13	0.15	0.09	0.03
Megaphyllum karschi (Verhoeff, 1901)	0.15	0.16	0.14	0.19		0.16		
Ommatoiulus sabulosus (Line, 1758)		0.21	0.21				0.16	
Cylindroiulus boleti (Koch, 1847)		0.21		0.26				0.09
Leptoiulus trilineatus (Koch, 1847)			0.37		0.40			
Leptoiulus macedonicus (Atems, 1927)						0.44		
Typhloiulus albanichus (Atems, 1929)			0.31					
Nopoiulus kochii (Gervais, 1847)			0.43	0.47				
Order *Polydesmida*								
Polydesmus complanatus (Verhoeff, 1901)			0.55					
S. stigmatosum balcanicum (Schubart, 1937)		0.21		0.20				
Order *Glomerida*								
Glomeris hexastica (Brandt, 1833)						0.17		
Glomeris pulchra (Koch, 1847)	0.12	0.22	0.15	0.25	0.15	0.15	0.10	0.13
Glomeris bureschi (Verhoeff, 1926)		0.26	0.23	0.18	0.13			
Glomeris balcanica (Verhoeff, 1906)			0.26					
Glomeris pustullata (Latrielle, 1804)		0.20						
Glomeris latermarginata (Villers, 1789)			0.55					

Source: *compiled by the authors*

Table 4. *Shannon Index according to zones*

Zone	Vlora	Shashica	Llogara	Shushice	Borsh	Delvina	Butrint	Kardhiq
Shannon index (H)	0.69	0.90	0.86	0.94	0.63	0.70	0.46	0.21

Source: *compiled by the authors*

From this table appears that the variety of *Diplopoda* collected in eight areas of study varies significantly. Higher values in Llogara, Shushica, Shashica, authors think are related to vegetation, and to the amount of material in decomposition, and the microclimate created in these environments. While lower values are associated with the collection of material in open environments, in the absence of vegetation and infields. Authors have compared the species according to the areas where they are found. The data is presented in the Figure 1.

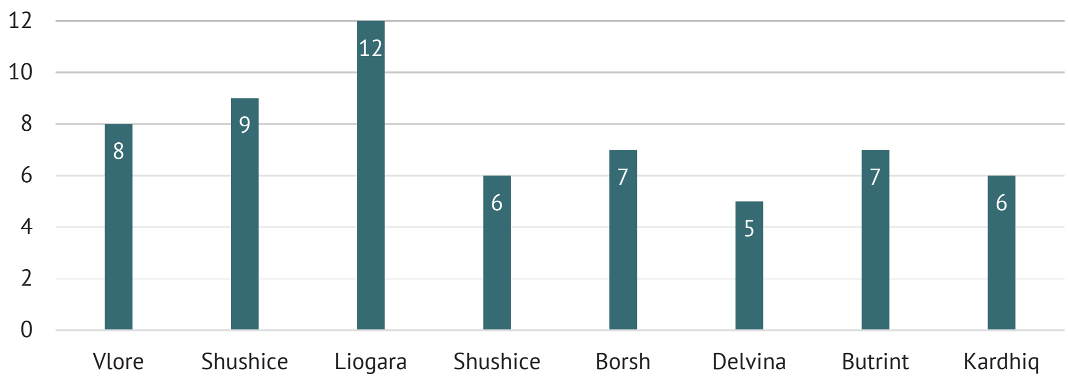

Figure 1. *The number of species in areas collected*

Among the areas taken in the study, the following areas result with greater variety: Llogara-Karaburun (12 species), Vlora city (eight species), and Shashica-Tragjas (nine species). These areas have a high percentage of humus, decomposed leaves, and good decomposition. Lands are classified according to constituent elements, an earth category V, VI, VII. Result with fewer species Delvina's station, Butrint-Stillo, Kardhiq, and Shushica's

Valley respectively with 5, 7, and 6 species defined. Collection stations in these areas are presented with low biodiversity and poor land with alimentary elements. Variety differs even within the same area, at various collection stations. These changes are evident in the values of frequencies according to zones and stations. The areas' similarity according to species. Based on the variety of species of each zone, cluster analysis is carried out using Average Linkage. The zone of Llogara is separated from other areas. The high biodiversity in this area, the height of the collection areas, and the high content of decomposed material affect the variety of this zone. In the context of this study, eight species are referred to for the first time in this area. In similarity between areas Tragjas-Shashicë and Kardhiq factor that could affect is the type of land. The data according to pedology for these collection stations represent similarities in composition and type of land.

Among other stations, a rough grouping of stations Delvine, Butrint, Vlore, and Borsh can be influenced by climatic factors, the similarity of vegetation, and height above sea level. Areas of Borsh have differences between them. The collecting places for this area have started in the valley Fterra-Borsh with rich vegetation and Mediterranean shrubs, the valley of this area presents high climate change. The functioning of ecosystems is based on the principle of energy binding, thus preserving the internal organization of the structure. If there is a significant gradient between the energy reserves of individual components of the ecosystem, an imbalance occurs, with a significant increase in entropy and a decrease in the level of orderliness (Arnolds *et al.*, 2023). In such conditions, natural ecosystems are no longer able to maintain a state of stability, energy flows are dynamically changing in vertical and horizontal dimensions, and the ecosystem becomes unable to counteract external destructive influences.

Today, it is still possible to prevent the negative effects of climate change on soil ecosystems by applying appropriate technical, economic, and management measures. Modern scientific forecasts require the development of an appropriate plan of preventive and regeneration measures and their consistent implementation. The effectiveness of the soil ecosystem management system in the face of negative climatic trends depends on the adaptive capacity of the system, which, in turn, is determined by genetic variation of traits (De Deyn & Kooistra, 2021). It is worth noting that the basis of soil ecosystems is the biotic component, which ensures adaptation to new environmental conditions and effectively counteracts the impact of destabilizing exogenous factors.

For optimal ecological assessment of populations in the context of ecosystem dynamics, it is necessary to organize monitoring, including observation of soil organisms and their habitats, as well as forecasting changes to ensure a sustainable ecosystem. A prerequisite for effective monitoring is regular comprehensive research using modern scientific achievements and innovative technological capabilities. It is advisable to select a representative network of test sites with different types of zonal features of soil ecosystems. The implementation of systematic ecological and biological research allows for a full ecological assessment of soil organism populations, as they are a sensitive indicator of the state of the environment. In addition, the management of sustainable ecosystems involves the development of an ecological network to preserve the natural environment and individual species in the face of climate change.

DISCUSSION

The results obtained in this study are in line with the findings of many researchers. Firstly, most scientists are unanimous in their belief that climatic factors play a significant role in the geographical distribution of millipedes. At the same time, scientists D. Bachvarova *et al.* (2022) note that with the onset of drought, millipedes burrowed into deeper soil layers. This may indicate a wide range of ecological tolerance of the studied species. The results of the current study are in line with the following conclusions of scientists: the distribution of *Diplopoda* populations indicates a rather high adaptive capacity of organisms. At the same time, climatic factors such as temperature and humidity affect the geographical distribution of soil organisms.

Recent studies by M. de Oliveira (2019), T. de Almeida (2022), and R. Bouzan *et al.* (2022) show that, in addition to climatic factors, the distribution of the organisms under study is influenced by phytocoenosis and soil composition. Scientists argue that soil with a high content of humus and nitrogen is a more favourable habitat for the *Diplopoda* class. Researchers believe that the nature of the phytocoenosis plays a minor role in the spatial distribution of *Diplopoda* populations. At the same time, soil with a high content of humus and nitrogen is a favourable factor for their functioning. However, similar data for Albania is virtually non-existent. The current study analysed the distribution of *Diplopoda* populations related to vegetation, the amount of decomposing material, and the microclimate created in these environments. Obviously, lower population figures are associated with the collection of material in open environments, in the absence of vegetation and fields. Thus, it can be argued that phytocoenosis and soil composition have a significant impact on the ecological parameters of soil organisms.

In addition, an important parameter of the ecological characteristics of millipede populations is their vertical distribution in the soil profile. Most species are able to migrate between different soil layers to adapt to unfavourable environmental factors. Such conclusions of the study coincide with the results of scientific research by Z. Tóth & E. Hornung (2020). The scientists carried out a comparative analysis of the vertical distribution of millipedes, which is synergistic with the results of research on the southern region of Albania in the current study. The researchers note that *Diplopoda* are saprophages, so they mostly live on the soil surface in the forest floor and in the forest litter. In addition, *Diplopoda* are more tolerant of low humidity. Modern researchers K. Arnolds *et al.* (2023) pay special attention to the role of an effective ecological assessment of soil organisms in the ecosystem management system. At the same time, they emphasize the need to establish effective population monitoring of species to form an information base for further assessment and development of preventive and regeneration measures. It is difficult to disagree with the conclusions of the scientists.

Scientists X. Sun *et al.* (2022) and W. So *et al.* (2022) identify priority areas of practical implementation within the monitoring system, including the allocation of population areas, study of the spatial structure and habitat changes. At the same time, G. Blume-Werry *et al.* (2023) argue that habitat analysis requires an integrated approach, i.e. it is advisable to monitor both the abiotic component of the habitat (in particular, the characteristics of the soil cover) and the biotic component (e.g. species living nearby). According to the scientists, this monitoring parameter is of paramount importance, as it demonstrates the dynamics of habitats and the causes of its occurrence (e.g., drought, anthropogenic factors, floods). The conclusions of the current study are in line with such beliefs. It should be added that habitat monitoring should be carried out both in conditions that are comfortable for populations and in unfavourable conditions. Information on the characteristics of habitats in different conditions, in terms of comparative analysis, may be of scientific and practical value in the reconstruction or reintroduction of populations.

It is worth noting that effective monitoring of soil organism populations can be carried out not only by standard methods, but also by simplified visual assessments of parameters that reflect the basic parameters of the population's state. It is undeniable that individual parameters specific to each species can play the role of markers of population status. However, for certain species, it may be preferable to use reasonable minimized integral indicators that can be used to assess the ecological status of the population (Yarwood *et al.*, 2020; Gunstone *et al.*, 2021; Asato *et al.*, 2023). Based on monitoring data, it is possible to conduct an integrated ecological assessment of population indicators for rapid diagnosis of their condition.

Taking into account the results of the current study and the results of scientific research, it can be argued that the vital activity of most *Diplopoda* species in the southern region of Albania takes place in conditions of ecological compliance with the main limiting factors, including the water regime and soil moisture level, soil salt regime and nutrient content, and temperature fluctuations. The populations of the studied organisms are quite stable and tolerant to minor changes in environmental factors. In general, the problem of studying the ecological characteristics of millipede populations in Albania was complex and multidimensional. The current study creates prerequisites for its further comprehensive study. The main directions of prognostic prospects for further scientific research include improving approaches to the ecological assessment of soil organisms populations based on the principles of individualization and sustainable development of the ecosystem.

CONCLUSIONS

As a result of the study, the peculiarities of the functioning of soil organisms populations were analysed on the example of *Diplopoda* in the southern region of Albania, and an effective approach to the ecological assessment of such populations as representative ones was developed. The paper scientifically substantiates the principles of determining the parameters of the ecological status of populations of certain species of soil organisms at the biogeocenosis level, based on the concept of ecological niche. In addition, the basics of scientific and methodological tools for assessing the spatial variation of the population within the framework of environmental assessment have been developed.

It was found that *Pachyiulus varius*, *Anoploiulus pusillus*, *Pachyiulus cattarensis*, *Glomeris pulchra*. These are species with wide spreading regional but in Albania. The zones that have a bigger number of species are Llogara and Shashica. The presence of forest environments, materials in decomposition, and microclimate elements influence the degree of high variety. Some sampling stations present similarities in terms of the species found. In the proximity between the areas affected: high above the sea level stations and collection materials, similarity in the composition and type of land, climatic factors, vegetation almost similar in most collecting areas, which dominates the growth of vegetation. Among areas of study, those with the greatest similarity of variety are Delvina – Butrinti – Vlora, and Tragjas – Kardhiq. While Llogara is estimated as the most different area. Although studies need more specific comparisons, authors think that this result is a consequence of the similarity of the areas and of other factors such as pedology, climate, and vegetation, predators.

The paper substantiates the need to improve existing approaches to effective and reliable ecological assessment of soil organism populations. In addition, the main prerequisites and factors for the effective implementation of the ecosystem management system under negative weather and climate trends, as well as taking into account the specifics of the soil habitat, are identified.

Based on the results obtained in this work, the author proposes priority vectors for further research on the topic, and substantiates the need to organize the availability and systematization of research and practical information on the methodology of ecological assessment of populations of living organisms. There is a need for further study of the problem in the regional context, with the use of modern tools for forecasting and adaptation modelling.

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CONFLICT OF INTEREST

None.

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Біорізноманіття та функціональна роль ґрунтових організмів: аналіз популяцій багатоніжок у Південній Албанії

Хаджар Кічай
Доктор наук, доцент
Університет Ісмаїла Кемалі
9401, вул. Косова, м. Вльора, Албанія
https://orcid.org/0000-0002-2611-2882

Геолінд Кобай
Магістр
Університет Ісмаїла Кемалі
9401, вул. Косова, м. Вльора, Албанія
https://orcid.org/0009-0002-9738-9616

Анотація. Ґрунтові організми являють собою важливу складову біологічного різноманіття наземних біогеоценозів. Їх значна таксономічна та екологічна варіативність зумовлює вагому функціональну роль в процесах ґрунтоутворення, механізмах сталого розвитку та продуктивності природних екосистем. Метою дослідження було розробка практичного підходу до екологічної оцінки популяцій ґрунтових організмів на прикладі *Diplopoda* у південному регіоні Албанії. Дослідження здійснювалось з використанням загальнонаукових методів пізнання: системного та кластерного аналізу, синтезу, конкретизації, абстрагування, формалізації, дедукції, узагальнення, а також статистичного методу. У статті систематизовано та проаналізовано статистичні дані щодо оцінки популяцій видів багатоніжок, виявлених на досліджуваній території. Розглянуто вплив екологічних факторів на поширення представників класу *Diplopoda*. Розраховано частоту видів відповідно до зон збору, константні значення для видів трьох представлених порядків. На основі отриманих даних проведено кластерний аналіз видового складу кожної зони з використанням методу середніх зв'язків (Average Linkage). Вивчено подібність між зонами. Отримана дендрограма вказує на близькість зон за видовим складом. За результатами дослідження було запропоновано систему інструментів в складі екологічної оцінки популяцій ґрунтових організмів, розроблено основні підходи щодо її реалізації. Практична значимість отриманих результатів полягає в можливості їх використання для дослідження динаміки розвитку популяцій ґрунтових організмів, в тому числі у період глобальних кліматичних змін, розробки динамічного підходу до екологічної оцінки ґрунтових екосистем та реалізації відповідної стратегії адаптації та регенерації

Ключові слова: наземна екосистема; *Diplopoda*; статистичні дані; географічне поширення; резистентність; моніторинг