Article

Not peer-reviewed version

Soil Moisture and Litter Coverage Drove the Altitude Gradient Pattern of Soil Arthropods Community in a Low Elevation Mountain

Haiming Qin * , Jingwen Shang , Qin Qi , Bo Cao , Yong Kong , Yujian Li , Junfeng Chen , Xianfeng Yi *

Posted Date: 8 April 2024

doi: 10.20944/preprints202404.0480.v1

Keywords: soil fauna; community structure; elevation gradient; environmental factors

Article

Soil Moisture and Litter Coverage Drove the Altitude Gradient Pattern of Soil Arthropods Community in a Low Elevation Mountain

Haiming Qin *, Jingwen Shang, Qin Qi, Bo Cao, Yong Kong, Yujian Li, Junfeng Chen and Xianfeng Yi *

School of Life Sciences, Qufu Normal University, Qufu, 273165, PR China

* Correspondence: qinhaiming@qfnu.edu.cn (H. Qin), yixianfeng@qfnu.edu.cn (X. Yi)

Abstract: In order to investigate the vertical distribution pattern of soil fauna community in low-altitude mountain areas. On July 8th, 2022, a low hill was selected as the study area to collect soil arthropods were collected through trap. Leaf litter, vegetation type and distribution quantity were investigated at each sampling site while soil fauna were collected. Also, the soil physical and chemical parameters were measured simultaneously. The results of one-way ANOVA showed that there were significant differences (P<0.05) in soil properties, leaf litter and Plant quantities at different altitude research area. A total of 1086 soil arthropods, belonging to 5 classes and 10 orders, were collected during the study period. The dominant species of soil arthropods at different altitudes were significantly different. The dominant species at low altitude areas were *Armadillidium* sp. and *Aethus nigritus*. However, *Eupolyphaga sinensis* and *Philodromidae* were the dominant species in the high altitude areas. The results of Non-metric multidimensional scaling (NMDS) analysis showed that the soil fauna in different altitude areas were clustered into two communities: the high-altitude community and the low-altitude community. With the increase of altitude, the specie richness of soil arthropods gradually decreased, and their abundance showed a decreasing trend. The redundancy analysis (RDA) of soil arthropods and environmental factors showed that soil moisture (P<0.01), pH (P<0.01) and defoliation (P<0.05) had significant effects on the distribution of soil fauna. The results of Pearson correlation analysis indicated different environmental factors had interactive effects on the distribution of soil arthropods. The quantity and species richness of soil arthropods in different sample lines were tested by variance analysis. The results showed that there were significantly fewer quantities of soil arthropods in the sampling line closer to the trekking ladder. This result indicated that human tourism mountaineering activities had a direct impact on soil fauna. The present study can provide reference and data support for biodiversity conservation of forest park in the low mountains.

Keywords: soil fauna; community structure; elevation gradient; environmental factors

---

1. Introduction

Soil fauna are an important component of the earth biodiversity. They play a complex role in disturbing and regulating the physicochemical properties and nutrient processes of soil ecosystems[1]. Soil fauna primarily include mollusks, nematodes, annelids, tardigrades and arthropods[2]. As an important part of soil ecosystem, it plays an irreplaceable role in maintaining the balance of soil ecosystem and accelerating energy flow and material circulation[3].

Recent studies found that both seasonal changes and differences in environmental factors had a certain degree of influence on the composition and distribution of soil fauna[4,5]. Researchers have studied soil fauna in four different habitats in the Nianchu River Basin and found significant seasonal differences in the ecological niche width of soil fauna, but no significant differences in soil fauna diversity between spring and summer[6]. Furthermore, other researchers found that the diversity of soil fauna species and abundance were higher in natural forests with diverse vegetation types and complex vegetation community structures[7]. In addition to climate change and environmental factors, many scholars had also studied the composition and distribution characteristics of soil fauna at different altitudes. For example, a study on the vertical distribution pattern of soil fauna in the western Tianshan Mountain found that the density of large soil fauna in summer litter gradually decreased with increasing altitude[8]. Another study reported a clear "surface aggregation phenomenon" in the vertical distribution of soil fauna communities in the soil layers of Wuyi Mountain[9]. In recent years, researchers had explored the response of soil fauna to altitude gradients in interaction with plants and found that soil fauna diversity at different altitude gradients had a direct impact on their interaction with plants[10]. Overseas studies found that soil fauna habitats significantly influence their community structure. For example, topography, elevation and vegetation type all had significant effects on soil fauna communities[11]. At the regional scale, the change of elevation gradient was one of the main factors affecting the pattern of soil fauna diversity[12]. Currently, research on the altitudinal gradient patterns of soil fauna had mainly focused on higher altitude mountain areas[13,14]. However, under the backdrop of drastic global climate change, almost all types of soil fauna had been impacted by climate change[15]. The altitudinal distribution characteristics of soil fauna in low-altitude mountain areas under climate change remain unknown.

In the present study, the low-elevation hills (hereinafter referred to as Shimen Mountain) in Shimen Mountain National Forest Park, Qufu, Shandong Province, were selected as the research area. The characteristics of soil fauna community structure and its main influencing factors at different altitude gradients were explored. The study aimed to accumulate data for research on the altitudinal gradient distribution patterns of soil fauna. The research results will provide reference and data support for biodiversity conservation in Shimen Mountain National Forest Park.

2. Study Area and Research Methods

2.1. Plot Description

The experimental plots of this study are located in the Shimen Mountain Scenic Area, Qufu (117.09°E, 35.78°N), which is situated 25 kilometers northeast of Qufu City. The study area falls under a temperate continental monsoon climate, characterized by distinct four seasons, abundant sunlight, dry springs and autumns, rainy summers, and cold and dry winters with little snowfall[16]. The main peak of Shimen Mountain stands at an elevation of 406 meters above sea level, with acidic soil. The predominant vegetation includes cypress, small-leafed banyan, cork oak, locust trees, and maple, among others.

2.2. Research Methods

2.2.1. Sampling Plots Setting, Soil Arthropods Collection and Treatment

From July 8th to 13th, 2022, the research team conducted soil arthropods sampling at different altitudinal gradients in Shimen Mountain using pitfall traps (Figure 1-C). Starting from the foot of the mountain (150 m above sea level) to the mountaintop (400 m above sea level), one plot was set up every 50 meters, resulting in a total of 6 study plots named Plot1, Plot2, Plot3, Plot4, Plot5, and Plot6, arranged from low to high altitude. Three sampling lines were established at each altitudinal gradient (Figure 1-A). Line 1 was 5 meters away from the mountain climbing stairs, Line2 was 15 meters away, and Line 3 was 25 meters away. Three sampling traps were set up along each transect, resulting in 9 sampling repetitions for each altitude (Figure 1-B).

When collecting soil arthropods in the field, filter the soil arthropods in the trap using a mesh. The soil arthropods samples were transferred into 200mL plastic sample bottles and fixed with 75% alcohol. In the laboratory, morphological classification, identification and counting were carried out under OLYMPUS SZX16 stereo microscope. In the present study, soil arthropods were identified to the family level. A few soil arthropods were identified to the species level. The identification of soil arthropods was mainly based on "Chinese soil Animal Retrieval Map"[17] and "Insect Classification Retrieval"[18].

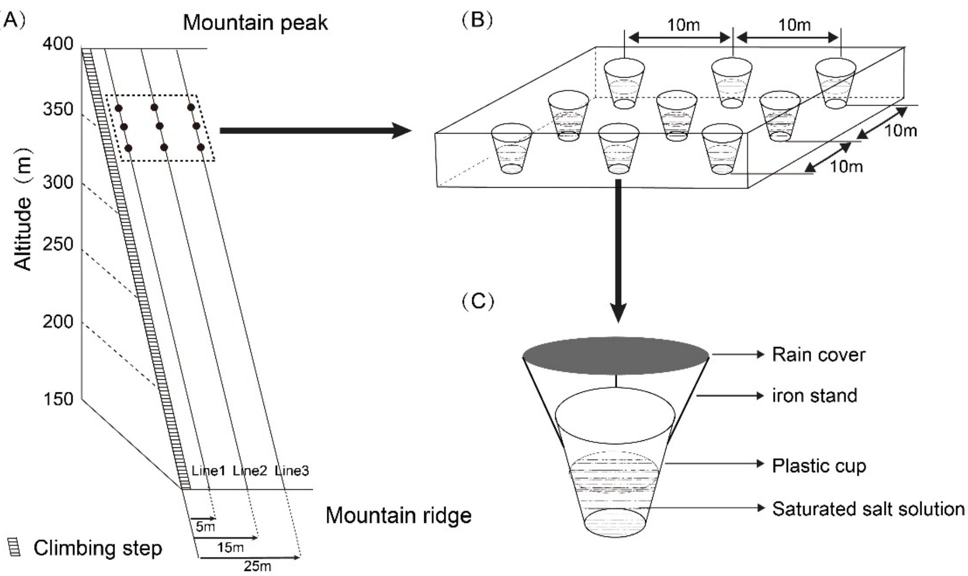


Figure 1. Schematic diagram of soil arthropods sample line setting and trap laying (A, sample line setting; B, Nine traps at each same altitude; C, The trap).

2.2.2. Environmental Factor Determination

When collecting soil fauna samples, vegetation conditions of each plot were recorded using systematic methods. Around each pitfall trap at every altitude plot, three quadrats were set up to record vegetation species and quantity. The quadrat size for arbors was 10m×10m, for shrubs was 5m×5m, and for herbaceous plants was 1m×1m. The species and quantity of arbors, shrubs, and herbaceous plants were recorded separately. Leaf litter weight per unit area (1m^2) was collected and weighed in the laboratory (accurate to 0.01 kg). Three traps were selected at each altitude plot, and soil samples were collected from around them. In the laboratory, soil pH was determined using deionized water as the extraction solution, and soil moisture content was determined using the oven-drying method.

2.2.3. Data Analysis

Statistical analysis of soil fauna species, quantities, etc., at different altitudinal gradients was conducted using commonly used community ecology software including Statistica 7.0, Primer 5.0, and Canoco for Windows 4.5. Statistical analyses included community clustering and canonical correspondence analysis. Differences in soil fauna at different altitudes were tested using one-way analysis of variance (ANOVA) and post-hoc multiple comparisons using the LSD method. Differences in soil fauna in different lines was tested by one-way analysis of variance (ANOVA).

3. Results

3.1. The Environmental Factors

The results of variance analysis showed that there were significant differences in environmental factors in different altitude gradient sampling areas (Figure 2). With the elevation gradient increasing, the soil moisture content in Plot1 (150 m above sea level) decreased significantly, which was significantly higher than that in other plots (P<0.05) (Figure 2-A). The soil acidity of Plot3 (250m above sea level) was significantly higher than that of other plots (P<0.05) (Figure 2-B). The density of arbors in the sample plot decreased with the elevation gradient, and the density of arbors in low altitude area was significantly higher than that in high altitude area (P<0.05) (Figure 2-C). The shrub density of Plot1 (150m above sea level) and Plot4 (300m above sea level) was significantly lower than that of the other four plots (P<0.05) (Figure 2-D). This result indicated that the growth of shrubs could limited by some environmental factors, such as soil moisture, nutrients or light. With the elevation gradient increasing, the herbaceous plant density in the sample plot showed a downward trend, and there was a significant difference (P<0.05) (Figure 2-E). The defoliation per unit area of Plot1 (150 m above sea level) and Plot6 (400 m above sea level) was significantly higher than that of other plots (P<0.05) (Figure 2-F).

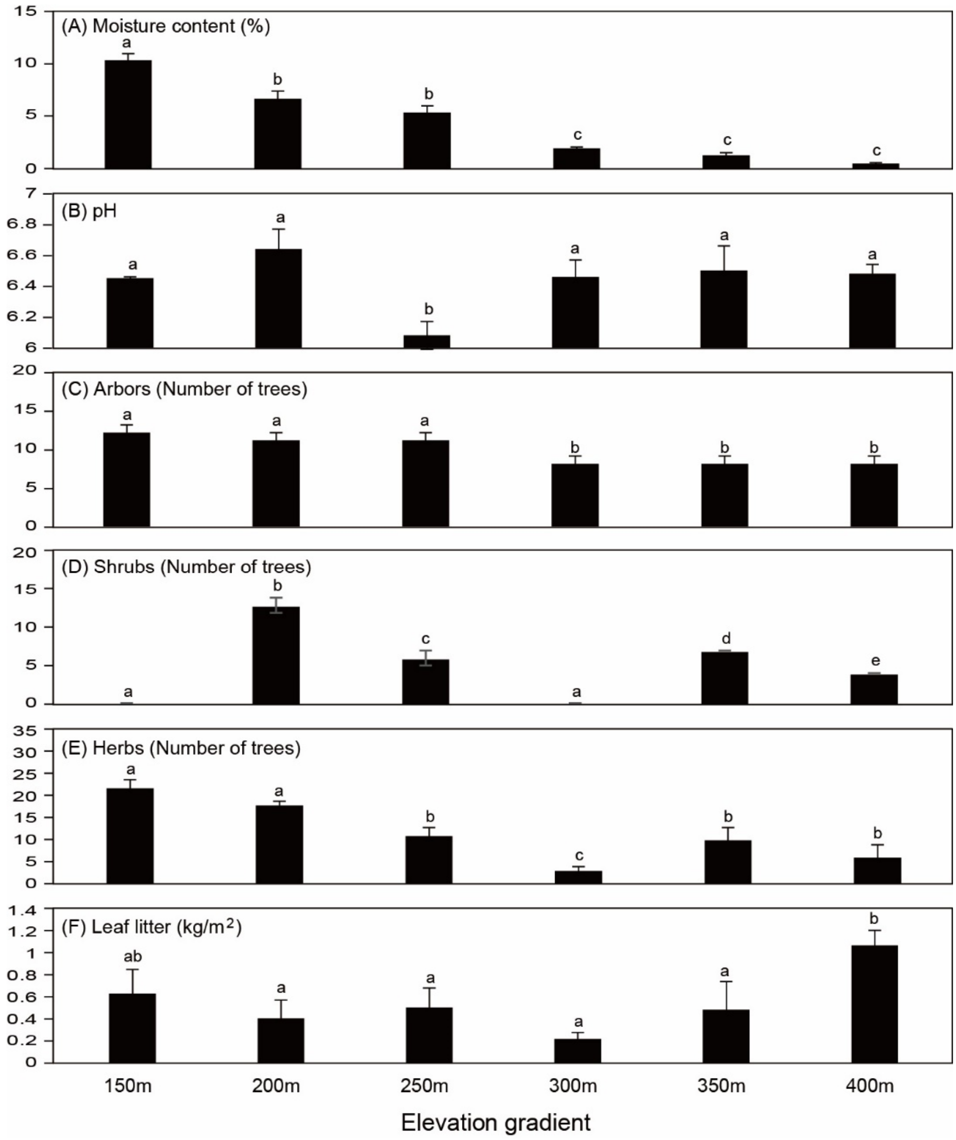


Figure 2. Environmental factors of different altitude sampling areas.

3.2. Species Composition of Soil Arthropods

A total of 1086 soil fauna were collected in this study, belonging to 10 orders within 5 classes (Figure 3). Among them, 697 were *Armadillidium* sp., accounting for 64.18% of the total. There were 99 *Eupolyphaga sinensis*, accounting for 9.12%. There were 91 *Aethus nigritus*, accounting for 8.38%. And there were 23 *Philodromidae*, accounting for 2.12% (Figure 3). Comparative analysis using dominance index revealed that the dominant species in the low-altitude areas (Plot1 and Plot2) were Crustacea and Insecta, with the most abundant being *Armadillidium* sp. of Isopoda and *Aethus nigritus* of Coleoptera. In contrast, the dominant species in the high-altitude areas (Plot3, Plot4, Plot5, and Plot6) were *Eupolyphaga sinensis* of Insecta and spiders of Philodromidae.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 8 April 2024 doi:10.20944/preprints202404.0480.v1

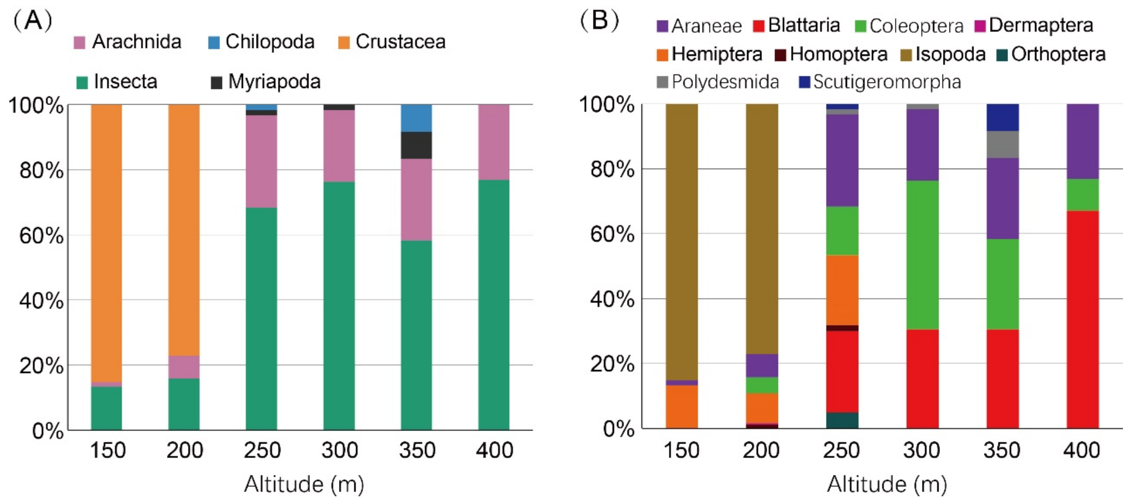
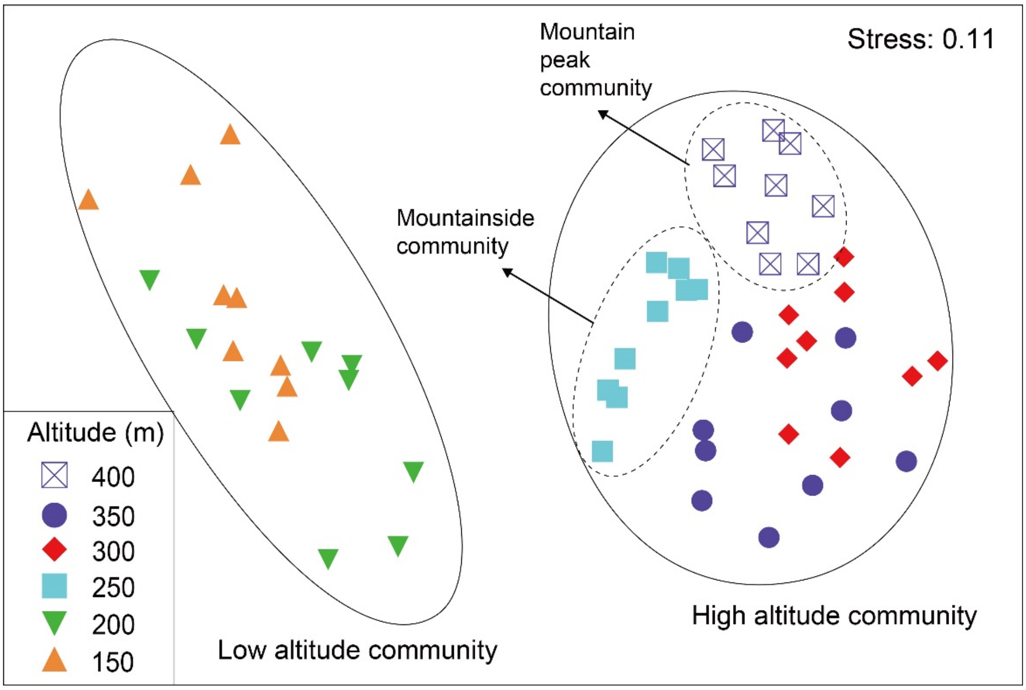


Figure 3. Percentage stacking of soil fauna at different elevation gradient (A: class level，B: order level).

3.3. Soil Arthropods Community Structure

Based on the non-metric multidimensional scaling (NMDS) analysis of soil arthropods abundance, the results indicated that soil arthropods at different altitudinal gradients in Shimen Mountain cluster into two main communities: high-altitude and low-altitude communities (Figure 4). There was a significant difference in soil arthropods community structure between high-altitude and low-altitude areas (Global test: R=0.962, *P*=0.001). The species composition and abundance of soil arthropods differ significantly between low-altitude (Plot1 and Plot2) and high-altitude areas (Plot3, 4, 5, and 6). The dominant species in low-altitude areas were soil arthropods adapted to moist environments, such as *Armadillidium* sp. While the dominant species in high-altitude areas were soil arthropods adapted to dry environments, such as *Eupolyphaga sinensis*. Additionally, within the high-altitude community, soil arthropods communities at the mountain peak and mountain slope have distinct characteristics and significantly differ from soil arthropods at other altitudes (Global test: R=0.507, *P*=0.001). The number of *Eupolyphaga sinensis* at the mountain peak (Plot6) was significantly higher than at the mountain slope (Plot3). While Scarabaeidae insects were only distributed at higher altitudes between the mountain peak and mountain slope (Plot4 and Plot5). Overall, with increasing altitude, there was a gradual decrease in the number of soil arthropods species and quantities.



Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 8 April 2024 doi:10.20944/preprints202404.0480.v1

Figure 4. Non-metric multidimensional scale sorting plot based on the number of soil fauna individuals.

3.4. The Impact of Environmental Factors on Soil Arthropods

DCA analysis of six environmental factors and zooplankton density data measured in this study showed that the maximum eigenvalue length was less than 3, so redundancy analysis (RDA) was carried out respectively[19]. The results indicated that some environmental factors significantly influenced the distribution of soil arthropods (Figure 5). Monte Carlo permutation tests revealed significant correlations (P<0.05) between three environmental factors (soil moisture content, soil pH, and leaf litter quantity) and soil arthropods community structure. Among these, soil moisture content (P=0.002) and soil pH (P=0.002) had the greatest impact on soil arthropods, followed by leaf litter quantity (P=0.05). Additionally, soil arthropods community structure was also influenced by vegetation types. The results showed that the quantity of vegetation near the plots decreased gradually with the elevation increasing. Moreover, the vegetation type from herbaceous as the dominant to shrubs and arbors as the dominant transition. Vegetation coverage and soil moisture content decrease gradually, leading to a reduction in soil arthropods abundance. Furthermore, correlation analysis between leaf litter quantity and soil arthropods abundance revealed that traps with higher leaf litter quantity and coverage at the same altitude gradient tended to capture more soil arthropods.

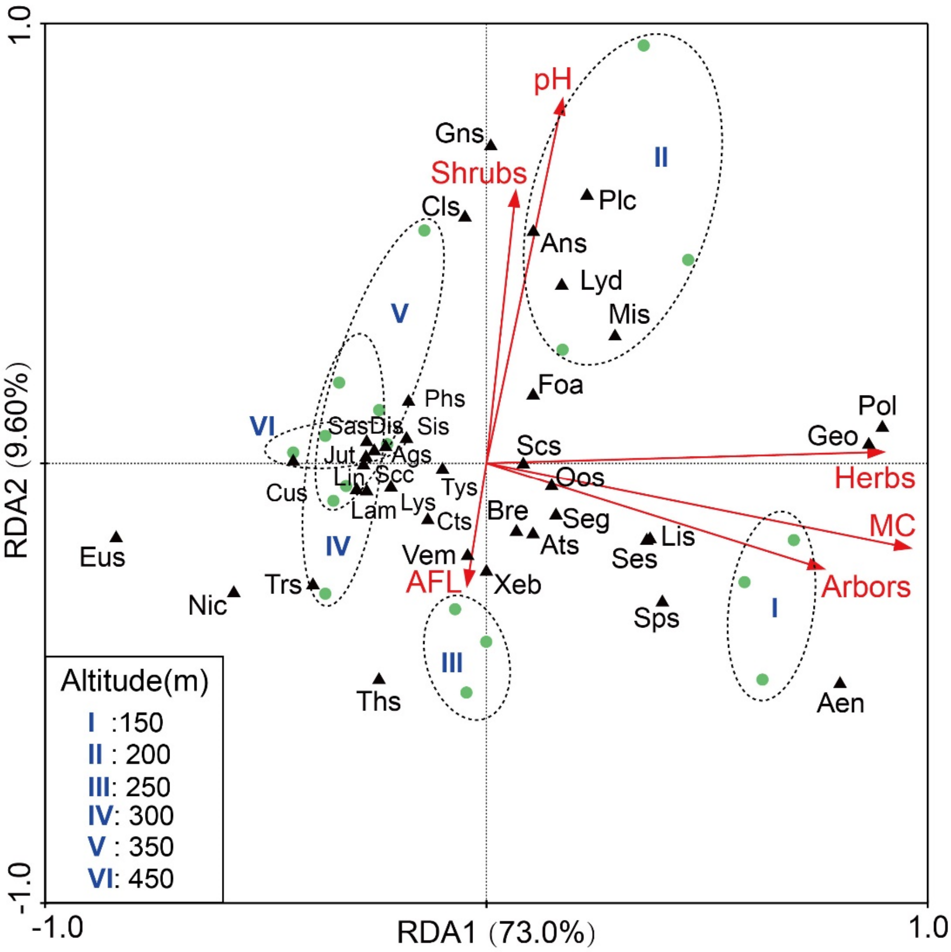


Figure 5. Results of redundant analysis based on the number of soil fauna and environmental factors.

3.5. Fitting Analysis and Pearson Correlation Analysis of Soil Arthropods Quantity and Environmental Factors

The results of fitting analysis showed that soil moisture content, herbaceous plant density and defoliation per unit area were significantly positively correlated with soil arthropods (Figure 6-A, 6-E and 6-F). Pearson correlation analysis indicated that soil moisture content, arbor density, herb density and litter amount had significant (P<0.05) or extremely significant (P<0.01, Table 1) effects on

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 8 April 2024 doi:10.20944/preprints202404.0480.v1

the soil arthropods quantity. Soil moisture content has a significant impact on Arachnida (*P*=0.043). Shrub density has a significant impact on Insecta (*P*=0.018). However, soil moisture content, herbaceous plant density and defoliation had extremely significant effects on Crustacea (*Armadillidium* sp.) (*P*<0.001, *P*=0.008 and *P*=0.003).

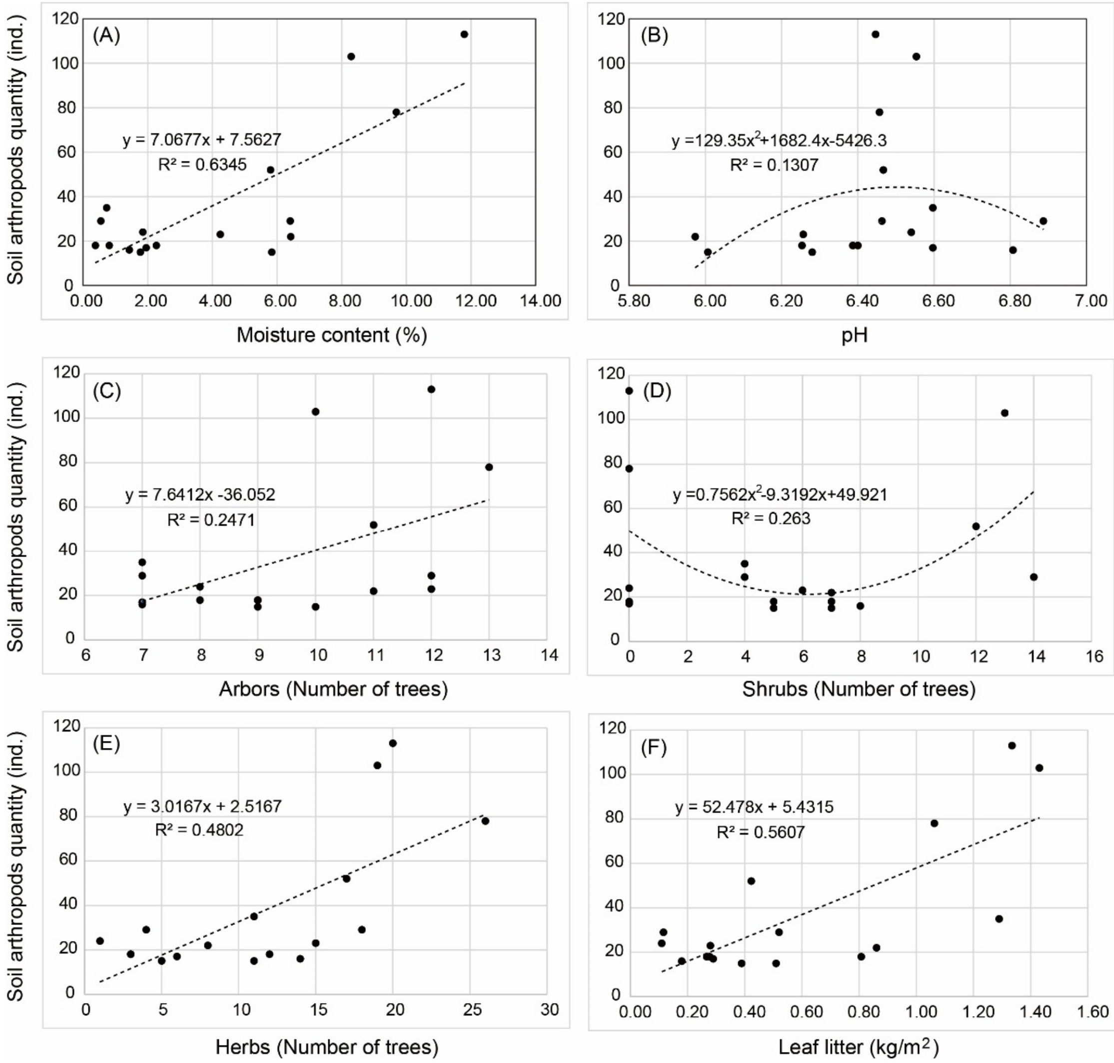


Figure 6. Fitting analysis of soil arthropods quantity and environmental factors.

Table 1. Pearson correlation analysis of soil arthropods quantity and environmental factors.

	Moisture content (%)	Soil pH	Arbors (Number of trees)	Shrubs (Number of trees)	Herbs (Number of trees)	Leaf litter (kg/m^2)
Insecta	0.324	-0.021	0.285	**-0.566***	0.304	0.403
Arachnida	**-0.495***	0.302	-0.175	0.184	-0.117	-0.424
Myriapoda	-0.250	0.030	-0.295	0.068	-0.085	-0.290
Chilopoda	-0.247	-0.166	-0.219	0.228	-0.128	-0.180
Crustacea	**0.755****	0.163	0.437	0.191	**0.622****	**-0.675****
Total quantity	**0.796****	0.173	**0.497***	0.025	**0.693****	**0.749****

Note: Bold indicates that environmental factors have significant effects on soil arthropods. One * indicates significant effect. Two * indicate extremely significant effect.

3.6. Human Tourism Mountaineering Activities Effects on Soil Arthropods

The results of one way ANOVA revealed that the species richness of soil arthropods on Line3 (5.11±0.46) was significantly higher than that on Line1 (3.44±0.26) and Line2 (3.94±0.32) ($P<0.05$, Table 2). Additionally, the abundance of soil arthropods on Line3 (30.78±10.67) was significantly higher than that on Line1 (14.67±6.25) and Line2 (19.11±7.78). Overall, soil arthropods species richness and abundance decreased as the distance to the mountain steps decreased.

Table 2. Species richness and abundance of soil fauna in different Sample lines.

Sample line	Species richness	Abundance
Line 1	3.44±0.26 [a]	14.67±6.25
Line 2	3.94±0.32 [a]	19.11±7.78
Line 3	5.11±0.46 [b]	30.78±10.67

Note: Significant differences in soil arthropods species richness exist among different transects labeled as a, b.

4. Discussion

4.1. Analysis of Soil Arthropods Community Characteristics and Influencing Factors in Different Altitude

Some studies had reported a decrease in soil arthropods abundance with increasing altitude[20,21], which was consistent with the findings of this study. The present study revealed a trend where soil arthropods species richness increased initially and then decreased with altitude at the class and order levels (Figure 4). This pattern aligns with the altitude gradient characteristics of soil arthropods communities observed by Wang et al. in Mount Lu[22]. In a study of soil arthropods in mountainous forests in eastern China. Scholars found that both the number of individuals and species initially increased and then decreased with altitude[23]. However, our study found an increasing trend in soil arthropods species with altitude, while the abundance decreased with altitude. This may be attribute to higher vegetation coverage, soil moisture, and leaf litter quantity in lower altitude areas, providing more favorable conditions for soil arthropods. Additionally, the study site chosen for this research is a low-altitude mountain with an elevation of only 400 meters. Due to the limitation of altitude, the distribution pattern of soil arthropods along altitude gradients may differ from that of higher altitude mountain areas.

Another study had reported that the difference of dominant species of soil fauna was not determined by a single environmental condition. It was pointed out that variations in soil pH significantly influence the dominant species of soil arthropods at different altitudes[24]. In our study, among the six altitudinal gradient plots established, Plot3 (250 m above sea level) exhibited significantly lower pH values compared to other sites (Figure 2). The dominant species composition of soil arthropods at this site was significantly different from other altitudinal areas. Low altitude dominant species *Aethus nigritus* and high altitude dominant species *Eupolyphaga sinensis* were both more abundant. This suggests that the unique acidic environment at this site may be an important influencing factor. This result was consistent with the findings of Luo et al., who reported a negative correlation between soil arthropods community density and taxa with pH[25].

Furthermore, it had been found that soil fauna were strongly correlated with water content[26]. Additionally, research had reported that the abundance of medium and small soil arthropods was significantly influenced by soil moisture content, with higher soil moisture content leading to higher abundance[27], which was consistent with the findings of this study. We found that soil moisture content decreases significantly with increasing altitude (Figure 2). As a result, species and abundance of soil arthropods adapted to moist environments, such as *Armadillidium* sp., gradually decrease with decreasing soil moisture content. The dominant species transition to soil arthropods more adapted to higher altitudes and drier environments, such as *Eupolyphaga sinensis*. This finding was consistent with those of Cao Lili et al., whose study indicated a significant increase in the number of isopods and their larvae in seasons with abundant rainfall, favoring humid conditions[28]. Some foreign researchers found that the amounts of leaves and nutrients in litter of different vegetation types had obvious changes[29]. Such differences had significantly effects on the diversity and community structure of soil animals[30]. The present study found that in low-altitude areas dominated by herbaceous vegetation (Plot1 and Plot2), soil arthropods abundance was highest. As altitude increased, the dominant species transition to shrubs and arbors, and the vegetation density and coverage gradually decrease. The abundance of soil arthropods decreased gradually. In addition,

 doi:10.20944/preprints202404.0480.v1

areas with more leaf litter captured more soil arthropods at the same altitude gradient (Figure 5). However, some studies had shown that soil arthropods abundance was higher in habitats dominated by arbors[31]. It was speculated that this difference might be due to the fact that the leaf litter of herbaceous vegetation was more easily decomposed into humus by small and medium-sized soil arthropods. However, arbors litter was more prone to lignification and was not easy to decompose[31]. Another study found that soil arthropods in the same altitude zone tend to aggregate near the surface, where abundant leaf litter provides food and suitable living conditions by increasing humus content through decomposition and excretion[32,33]. It can be seen that soil moisture and leaf litter drives the community construction of soil fauna.

4.2. Effects of Human Interference on Soil Fauna

Human activities also had a significant impact on the community structure of soil fauna[34], and the diversity of soil fauna in green space types with low human interference was often higher than that in green space types with frequent human interference[35]. It had been noted that tourist disturbances could affect the development of soil fauna individuals, leading to changes in soil fauna community structure[36]. Human activities could also influence the habitat environment of soil fauna, resulting in reduced soil fauna diversity[37]. In the present study, statistical analysis revealed that the plots on sampling Line1, closest to the mountain stairs, had the fewest species and individuals of soil fauna. While the plots on sampling Line3, subject to mild disturbance, had the most species and individuals (Table 2). This result may be caused by the frequent mountaineering activities affecting the distribution of soil fauna. Human mountaineering drives soil fauna to live and roost in the deeper forests far from the climbing steps. This finding is consistent with the results of Dong's study on large soil arthropod community in Sanqing Mountain. His study indicated that the density and species of large soil arthropods in severely disturbed areas were lower than that in moderately and mildly disturbed areas[38].In addition, the tourism waste generated by tourism disturbance will also affect the community composition and structure of soil arthropods. Some soil arthropods were extremely sensitive to the environment, and their species and quantity will change with the environmental changes[39]. It had been reported that the number of individuals, groups, species richness and diversity of soil arthropods in tea gardens without heavy metal pollution were significantly higher than those in contaminated tea gardens[40]. The present study did not elaborate the effects of tourism garbage on soil fauna. Whether tourism garbage in Shimen Mountain has an impact on soil fauna communities needs further study.

Based on the results of the present study, the following recommendations can be proposed for the conservation of biodiversity in Shimen Mountain National Forest Park: (1) Ensure good vegetation coverage to provide suitable habitat for soil fauna. (2) Promote environmental protection awareness to tourists, and reduce human disturbance and destruction of natural habitats. (3) Promptly restore ecological sites affected by human disturbances and damage.

Acknowledgments: This work were supported by the project of Open fund project of State Key Laboratory of Lake Science and Environment (2022SKL014) and National college students Innovation and Entrepreneurship training program of China (202110446121).

References

1. Orgiazzi, A.; Bardgett, R.D.; Barrios, E.; Behan-Pelletier, V.; Briones, M.J.I.; Chotte, J.L.; De Deyn, G.B.; Eggleton, P.; Fierer, N.; Fraser, T.; Hedlund, K.; Jeffery, S.; Johnson, N.C.; Jones, A.; Kandeler, E.; Kaneko, N.; Lavelle, P.; Lemanceau, P.; Miko, L.; Montanarella, L.; Moreira, F.M.S.; Ramirez, K.S.; Scheu, S.; Singh, B.K.; Six, J.; van der Putten, W.H.; Wall, D.H. *Global Soil Biodiversity Atlas*. European Commission, Publications Office of the European Union, Luxembourg, **2016**.
2. Yin, W.Y. Review and Prospect of Soil Zoology [J]. *Biol. Bull.* **2001**, *8*, 1-3.
3. Sun, X.; Xie, Z.J.; Qiao, Z.H.; Gao, M.X.; Yin, R.; Chang, L.; Wu, D.H.; Liu, M.Q.; Zhu, Y.G. Research advances in trait-based approaches in soil fauna community ecology [J/OL]. *Chin. J. Appl. Ecol.* 2024, accepted. https://link.cnki.net/urlid/21.1253.Q.20240206.1058.002.
4. Yan, J.; Wu, J.H. Study Advances in Plant Diversity Effects on Soil Fauna [J]. *Soils* **2018**, *50*, 231-238. DOI: 10.13758/j.cnki.tr.2018.02.002.

5. Liu, X.J.; Wu, Q.Q.; Li, Y.Y.; Ruan, H.H.; Ding, X.N.; Cao, G.H.; Shen, C.Q. Interaction effects of stand development and seasonality on soil arthropods community in poplar plantations [J]. *J. Nanjing For. Univ. (Nat. Sci. Ed.).* **2023**, *47*, 224-230.
6. Xu, H.J.; Yu, L.Z.; Huang, X.R.; Zhu, J.J.; Yang, J.Y.; Gao, S.L.; Wang, Y.J. Biodiversity of macro ground-dwelling arthropods in secondary forests and plantation forests of montane region of eastern Liaoning Province [J]. *Chinese J. Ecol.* **2015**, *34*, 727-735. DOI: 10.13292/j.1000-4890.2015.0099.
7. Menta, C.; Conti, F.D.; Fondón, C.L.; Staffilani, F.; Remelli, S. Soil arthropods responses in agroecosystem: implications of different management and cropping systems [J]. *Agronomy* **2020**, *10*, 1-19. DOI: 10.3390/agronomy10070982.
8. Liu, S.Q. The characteristics of soil fauna communities and the division of functional groups in different altitudinal gradients of Picea schrenkiana in Western Tianshan Mountains [D]. *Yili Norm. Univ.* **2024**. DOI: 10.27808/d.cnki.gylsf.2022.000114.
9. Wang, S.J.; Ruan, H.H.; Wang, J.S.; Xu, Z.K.; Wu, Y.Y. Composition structure of soil fauna community under the typical vegetations in the Wuyi Mountains [J]. *Acta Ecol. Sin.* **2010**, *30*, 5174-5184.
10. Ding, Z.Q.; Xu, G.R.; Zhang, S.; Zhang, Y.X.; Ma, K.M. Altitudinal pattern of soil fauna plant interaction in Dongling Mountain, Beijing [J]. *Acta Ecol. Sin.* **2022**, *42*, 2741-2750. DOI: 10.5846/stxb202103290814.
11. Sanders, N.J.; Rahbek, C. The patterns and causes of elevational diversity gradients [J]. *Ecography* **2012**, *35*, 1-3. DOI: 10.1111/j.1600-0587.2011.07338.x.
12. Jiang, Y.F.; Yin, X.Q.; Wang, F.B. Composition and spatial distribution of soil mesofauna along an elevation gradient on the north slope of the Changbai Mountains, China [J]. *Pedosphere* **2015**, *25*, 811-824. DOI: 10.1016/S1002-0160(15)30062-X.
13. Wang, R.H.; Liu, Q.Y.; Wang, X.Y.; Zhao, Z.Y.; Dou, Y.J. Responses of soil mite community diversity to altitude gradients in Luya Mountain, China [J]. *J. Shanxi Univ. (Nat. Sci. Ed.).* **2022**, *45*, 1138-1150. DOI: 10.13451/j.sxu.ns.2022043.
14. Liu, D.D.; Wu, H.T.; Yu, H.X.; Sun, X.; Liu, D.; Cheng, P.; Bai, X.Y.; Dai, G.H.; Zhang, Z.S.; Wang, W.F. Distribution pattern of soil Oribatida and Collembola diversity along altitudinal gradient in the Changbai Mountains [J]. *Sci. Geog. Sin.* **2023**, *43*, 1299-1309. DOI: 10.13249/j.cnki.sgs.2023.07.017.
15. Zhang, H.; Wu, H.T. Research progresses in effects of climate warming on soil fauna community structure [J]. *Chinese J. Ecol.* **2020**, *39*, 655-664. DOI: 10.13292/j.1000-4890.202002.008.
16. Yang, C.C.; Tao, Y.; Jia, D.X. Climate Profile of Qufu City in 2020 and Its Impact Assessment [J]. *Mod. Agric. Sci. Technol.* **2021**, *17*, 185-187. DOI: 10.3969/j.Issn.1007-5739.2021.17.077.
17. Yin, W.Y. *Atlas of soil fauna in China*. Beijing: Science Press, **1998.**
18. Li, H.X.; Sui, J.Z.; Zhou, S.X. *Insect classification and Retrieval*. Beijing: Agriculture Press, **1987**.
19. Zhang, J.; Yuan, Z.; Wang, H.YY.; Cao, J.; Zheng, Z.X.; Ye, B.B. Study on the relationship between plankton community structure change and environmental factors in Dafangying Reservoir [J]. *J. Anhui Agric. Univ.* 2024, accepted. DOI: 10.13610/j.cnki.1672-352x.20240313.001.
20. Liu, D.D.; Liu, D.; Yu, H.X.; Wu, H.T. Strong variations and shifting mechanisms of altitudal diversity and abundance patterns in soil oribatid mites (Acari: Oribatida) on the Changbai Mountain, China [J]. *Appl. Soil Ecol.* **2023**, *186*. DOI: 10.1016/J.APSOIL.2023.104808.
21. Xu, Y.Y.; Cao, M.; Xu, G.R. Diversity distribution patterns of Collembola in litter layers along three typical climate zones in Yunnan Province. *Acta Ecol. Sin.* **2020**, *40*, 5008-5017. DOI: 10.5846/stxb201904290879.
22. Wang, H.Y.; Zhu, Y.H. The study of the characteristics of soil fauna community and soil humus characteristics at different elevations in Lushan [J]. *Hubei Agric. Sci.* **2022**, *7*, 25-30. DOI: 10.14088/j.cnki.issn0439-8114.2022.07.005.
23. Zang, J.C.; Huang, W.J.; Zang, Y.J.; Bin, L.; Zhang, Y.L.; Song, M.C. Community structure and diversity of soil fauna at different altitudes in Alpine grassland in northern Tibet [J]. *J. Northwest Sci-Tech Univ. Agric.For. (Nat.Sci.Ed.).* **2023**, *51*, 72-81. DOI: 10.13207/j.cnki.jnwafu.2023.05.008.
24. Liu, S. Distribution Pattern and Influencing Factors of Soil Oribatid Mites Diversity along Altitudinal Gradient in Evergreen Broad-leaved Forest of Tianmu Mountain [D]. *Harbin Norm. Univ.* **2022**. DOI: 10.27064/d.cnki.ghasu.2022.000248.
25. Luo, M.J.; Li, S.S.; Qiang, D.H.; Liu, C.H. Relationship between soil fauna community composition and soil physical and chemical properties in Nanniwan wetland [J]. *Ecol. Environ. Sci.* **2018**, *27*, 1432-1439. DOI: 10.16258/j.cnki.1674-5906.2018.08.007.
26. Sun, L.N. The characteristics of Soil Faunal in Longwan Nature Reserve forest and the division of functional groups [D]. *Northeast Norm. Univ.* **2013**.
27. Feng, J.; Qiao, Z.H.; Yan, Q.B.; Yao, H.F.; Wang, B.; Sun, X. Effects of urbanization and greenspace types on community structure and functional traits of soil Collembola [J/OL]. *Acta Ecol. Sin.* **2024**, *6*, 1-15. DOI: 10.20103/j.stxb.stxb202306261353.
28. Cao, L.L.; Ruan, H.H.; Li, Y.Y.; Ni, J.P.; Wang, G.B.; Cao, G.H.; Shen, C.Q.; Xu, Y.M. Variations of surface soil macrofauna in different aged Metasequoia glyptostroboides plantations [J]. *J. Nanjing For. Univ. (Nat. Sci. Ed.).* 2024, accepted. http://kns.cnki.net/kcms/detail/32.1161.S.20231115.1415.002.html.

29. Wenninger, E.J.; Inouye, R.S. Insect community response to plant diversity and productivity in a sagebrush-steppe ecosystem [J]. *J. Arid Environ.* **2008**, *72*, 24-33. DOI: 10.1016/j.jaridenv.2007.04.005.
30. Agnieszka, J.; Bartłomiej, W.; Edyta, S.; Agnieszka, K.B.; Wojciech, B.; Anna, K.I.; Marcin, C.; Marcin, P. How applied reclamation treatments and vegetation type affect on soil fauna in a novel ecosystem developed on a spoil heap of carboniferous rocks [J]. *Eur. J. Soil Biol.* **2023**, *119*. DOI; 10.1016/J.EJSOBI.2023.103571.
31. Yan, J.C.; Cui, D.; Lv, L.Q.; Jiang, Z.C.; Zhang, M.R.; Liu, J.H.; Cao, J.; Wang, Q.L. Distribution characteristics of soil fauna communities in the forest-grassland ecotone of the West Tianshan Nature Reserve. [J]. *Chinese J. Ecol.* 2024, accepted. https: //link.cnki.net/urlid/21.1148.Q.20240124.1721.008.
32. Cao, Y.; Gao, M.X.; Zhang, X.P.; Dong, C.X. Distribution characteristics of soil macro-faunal communities along a latitudinal gradient in farmland of Heilongjiang Province [J]. *Acta Ecol. Sin.* **2017**, *37*, 1677-1687. DOI: 10.5846/stxb201510142073.
33. Wu, Q.; Wu, H.T.; Sun, X.; Lin, Y.L.; Liu, D.D.; Kang, Y.J.; Liu, J.P. Community composition and surface aggregation characteristics of soil collembola in Changbai Mountain Tundra [J]. *Environ. Ecol.* **2023**, *5*, 39-46.
34. Huang, M. Research on taxonomy and diversity of soil oribatid mites in agricultural region of Heilongjiang province [D]. *Chinese Acad. Sci. (Northeast Institute of Geography and Agroecology, Chinese Acad. Sci.)*, **2023**. DOI: 10.27536/d.cnki.gccdy.50016.10001001106.
35. Tang, J.R. Relationships between soil fauna community characteristics and environmental factors in natural forests of mountain parks in the main urban area of Chongqing [D]. *Southwest Univ.* **2022**. DOI: 10.27684/d.cnki.gxndx.2022.004106.
36. Van-Klink, R.; Schrama, M.; Nolte, S.; Bakker, J.P.; WallisDeVries, M.F.; Berg, M.P. Defoliation and soil compaction jointly drive large-herbivore grazing effects on plants and soil arthropods on clay soil [J]. *Ecosystems* **2015**, *18*, 671-685. DOI: 10.1007/s10021-015-9855-z.
37. Ye, Y.; Jiang, Y.X. Changes of Community Structure and Functional Groups of Soil fauna under Tourism Disturbance--Taking Heishiding, Jiulong Lake and Northridge Mountain as an Example [J]. *J. Zhaoqing Univ.* **2017**, *38*, 52-57.
38. Dong, C.X.; Wang, B.J.; Xue, Z.; Tang, N.; Miao, Z.P. Response of soil macro-fauna communities to tourism disturbance-Taking Sanqing Mountain as an example [J]. *J. Shangrao Norm. Univ.* **2022**, *3*, 71-76. DOI: 10.3969/j.issn.1004-2237.2022.03.012.
39. Wang, Z.M.; Zhao, Y.M.; Zhong, S.G.; Chen, G. Indicative effect of soil fauna on heavy metal pollution [J]. *J. Environ. Hyg.* **2022**, *6*, 463-472. DOI: 10.13421/j.Cnki.Hjwsxzz.2022.06.012.
40. Xing, S.W.; Xu, J.M.; Huang, B.; Gao, J.T.; Han, L. Effect of heavy metal pollution on the community structure and diversity of soil fauna in tea garden located in a tungsten mining area [J]. *Ecol. Environ. Sci.* **2021**, *30*, 1903-1915. DOI: 10.16258/j.cnki.1674-5906.2021.09.015.