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New data on the vertical distribution of nematode communities in mountain ecosystems of Mount Zarafshan, Uzbekistan

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Abstract. *Narzullayev SB. 2022. New data on the vertical distribution of nematode communities in mountain ecosystems of Mount Zarafshan, Uzbekistan. Biodiversitas 23: 3967-3975.* New data on the vertical distribution of nematode communities in mountain ecosystems (Mount Zarafshan, Uzbekistan) is the first study on the variation of nematode species and ecological groups in Central Asia depending on altitude gradients. The study's primary purpose was to study the nematode fauna of perennial plants in the highlands and to reveal the formation of nematodes following the ecological characteristics. To achieve the study's objectives, samples were collected from perennial plants and rhizosphere soils growing in mountain ecosystems with a maximum altitude of 2590 m above sea level in 2016-2018. The sample analysis determined that the northern slope of the Zarafshan mountain range consists of 121 species belonging to 8 orders, 35 families and 58 genera. The study area is divided into four vertical altitude zones (upper, middle, lower, and foothills), which differ in climate, relief, vegetation cover and density to understand the formation of mountain nematode fauna. Sixty-four species of nematodes were identified in the upper zone, 93 in the middle zone, 104 in the lower zone, and 79 in the foothills. The nematodes in the fauna were divided into ecological groups such as plant feeders, mycophages, bacteriotrophs, predators and omnivores. The obtained results showed that the species and ecological composition of the nematode community depended on changes in vegetation cover density, soil organic composition and water regime in the height gradients.

Keywords: Mountain, nematodes, parasites, plants, vertical

INTRODUCTION

According to general biological laws, as the altitude gradients (zones) change, so does the diversity of living organisms. This pattern has been proven in many studies on flora and macrofauna (Heaney et al. 2001; Jacquemyn et al. 2005; Hodkinson 2005). However, research in this area on micro and mesofauna does not provide sufficient studies. In particular, information on the species composition of nematodes, which play an essential role in soil fauna (Ingham et al. 1985), depending on altitudinal gradients, is very scarce and specific to certain climatic zones (Dong et al. 2017; Shahid et al. 2021). Nematodes are the most abundant multicellular animals (Bongers and Ferris 1999) and very likely the second most diverse phylum with about 27,000 recently described species after arthropods (Huggot et al. 2001). They are essential for Earth's metabolism and energy exchange (Ferris and Bongers 1999). Nematodes can support increased soil fertility or become pests for plants (Suyadi et al. 2021). Assessment of biodiversity in future biocenosis due to a large number of species and individuals of nematodes, the assessment of their variation along the height gradients due to their significant role in the food chain (Ritz and Trudgill 1999), opens up the possibility of using it as an indicator of changes in soil composition (Pen-Mouratov et al. 2012; Salamun 2012). Researchers have described nematodes as the most suitable natural experiments for observing the ecological reactions of ecosystems due to changes in altitude gradients (Körner 2007).

Most all studies have shown that the composition of the nematode community changes in proportion to the height gradients (Traunspurgera et al. 2017; Kitagami et al. 2022). In some studies of the evolution of nematodes in mountain ecosystems according to altitude zones, the organic composition of the soil has been studied as a critical factor (Háněl 1996; Háněl et al. 2010; Peneva et al. 2011; Zhang et al. 2012;). Recent studies have also studied the effects of heavy metals on the biodiversity of nematodes (Dong et al. 2017; Martinez 2018; Shahid 2021).

In general, questions remain as to what are the main factors for the differentiation of nematode fauna in the highlands of the mountains, whether high altitude zones were the basis for the formation of mountain nematode fauna, or whether nematode species rose above the lower zones under the influence of geological factors not fully resolved (Dong et al. 2017). The study of the nematode fauna of mountain ecosystems by altitude zones can provide a positive solution to these problems. Central Asia, including Uzbekistan, has a harsh continental climate. No studies on the distribution of nematodes along altitude gradients have been conducted in this region. Based on this, the purpose of the research was to study the distribution and ecological composition of the nematode community along the height gradients in the Western Zarafshan mountain. The obtained results supplement the previous data on the formation of the diversity of the nematode community.

MATERIALS AND METHODS

Study site

This research was conducted in the West Zarafshan Mountains. It is a part of the Pamir-Alay mountain range. The western part of the Zerafshan ridge, with its adjacent plains within Uzbekistan, lies between the valleys of the Zerafshan and Kashkadarya rivers. Its geographic coordinates are 39°20′N 69°40′E. The massif can be conditionally divided into four vertical high-altitude zones. The highest zone covers a height of 1800-2500 m, the middle zone - 1250-1800 m and the lower - 750-1250 m (Alibekov 1982).

Despite the mild heat and light conditions in mountainous areas, the natural humidity is moderate. At medium and high altitudes, it is 850-860 mm, sometimes 1000 mm. However, the moisture does not last long. The soil is brown, with humus-rich brown and carbonate brown in some areas. These soils include roughly 3-8% of humus, depending on the height of the zones. Nitrogen content is around 0.3-1.2%. pH is 6.6-7.4. In general, in the highlands of the mountain, different soils change with each other due to climate and vegetation changes (Kholikulov et al. 2011).

Perennials are the most common among the plants distributed in the region, defining the basic appearance of phytocenosis. Representatives of the genus such as *Eremurus* M.B., *Alhagi* Adans., *Cousinia* Cass., *Phlomis* L., *Hordeum* L., and *Poa* L. are common plants. For the study, seven species of perennial wild plants are common in all altitude zones of the mountain - *Cousinia integrifolia* F., *Rumex crispus* L., *Alhagi kirghisorum* Sch., *Acroptilon repens* L., *Phlomis salicifolia* Rg., *Hordeum bulbosum* T. and *Poa bulbosa* L. were selected.

In order to study the nematodes of perennial grasses distributed in the mountain ecosystem, samples from the plants mentioned above and the soil around their roots were collected in the spring and summer. For this, plants were dug up together with their roots. Soil samples took from around the roots. Five separate samples spaced 100 m apart in a line at each elevational level has taken. In this way, ten samples of 0-10 cm and 10-20 cm layers of the soil around the roots of the seven types of plants we took from the four altitude zones of the mountain. Thus, we collected a total of 1120 samples from each of the seven types of plants selected as the object of research, 160 samples (including 40 roots and above-ground vegetative parts, 15-20 grams of soil from the 0-10 cm and 10-20 cm layers around the root) in the zonal section.

Flotation or shaking (Kiryanova and Krall 1969) and modified Baerman (Southey 1986) methods were used in the laboratory to isolate nematodes from plant and soil samples. Nematodes were isolated from soil samples by the flotation method. For this purpose, we took several 300-500 ml containers, and 10-15 (20) grams of soil from one sample were dissolved in the water and shaken. The liquid part of the shaken solution is poured into the next container. This process is repeated 5-6 times. Nematodes are lighter than the soil, so they come to the solution's surface. This method is beneficial for isolating more significant nematodes (*Mononchus, Xiphinema, Criconemoides*) (Coolen 1977). To separate nematodes from the vegetative organs of the plant in the field, the plant organs are finely chopped, and the plant parts are left in a glass of water for 12-14 hours. The solution is then passed through a 0.8 mm sieve.

The nematode solution, purified from plant debris, is allowed to stand for 20-30 minutes. During this time, the nematodes sink to the bottom of the water, and the excess water above is carefully drained. In the laboratory, the Baerman funnel method was widely used in phytohelminthology (Kiryanova and Krall 1969). This method involves placing a rubber hose on a thin-walled glass funnel on one side, each mounted on a multi-seat wooden stand, and the funnel hose is clamped with a steel clamp, half of which is filled with clean tap water, and each funnel is labelled. After that, the vegetative parts of the plant are cut into individual pieces (1-1.5 cm). The vegetative organs of the crushing plant are taken from 10-15 grams, placed on a napkin cut from gauze 15x15 cm, and placed in a water funnel.

Samples taken from the rhizosphere soil of the plant are placed in the same way on a gauze napkin of 5-10 grams and immersed in an aqueous funnel, except that a wire net is placed in the funnel before placing the rhizosphere soil samples in the aqueous funnel. The purpose is to ensure that the earthenware napkin does not cover the bottom of the funnel.

Samples are left, in this case, in water funnels for 12-15 hours. During this time, the vegetative organs of the plant in the water funnels, or the nematodes in the rhizosphere soil, are released into the water and accumulate at the tube's bent point at the bottom funnel. In order to do this, 40% formalin is poured into 1/10 of the volume of the solution, and then the tube of the nematode funnel is slowly opened into this solution, leaving 4-5% of the water in the tube due to mixing with 40% formalin. We can store this fixed sample at any time and use it to prepare micro preparations.

The formula recommended by De Man is used to determine the type of nematode (de Man 1921). Yeates' classification was used to ecologically divide the species into groups (Yeates 1993). The Sorensen-Chekanovsky method of similarity coefficient (S) (Sørensen 1948) have used to compare the degree of similarity of the nematode fauna complex of mountain zones. The Shannon (H′) and Simpson (D) indices were used to identify and compare the diversity of ecological groups in different altitude zones. In doing so, both indices are simultaneously compared with other ecosystems indices, and it is concluded that the diversity of ecosystems fauna with a more extensive index is relatively more remarkable (Shannon 1949; Simpson 1949). We used the Witkowski method to distinguish the species in the fauna from the most common dominant species to the rare subrecessant species (Witkowski 1966). Species richness of nematode fauna of mountain zones was calculated according to the Margalef index per 100 g of soil (Pesenko 1982).

RESULTS AND DISCUSSION

The study identified 121 species of nematodes in the mountain and foothill ecosystems of the northern slope of the Zarafshan ridge. They belonged to two classes of nematode types (Adenophorea, Secernentea), four subclasses (Enoplia, Chromadoria, Rhabditia, Diplogastria) and eight orders, 35 families, 58 genera (Chitwood 1958; De Ley 2002, 2004). In the nematode fauna, the Rhabditida (24%) and Tylenchida (47%) orders of the Chromadorea class were dominant in terms of the number of species compared to other families. In contrast, the Aphelenchoididae, Tylenchidae and Tylenchorhynchidae families were predominant regarding the number of species. The number of species in the perennial plant nematode fauna also varied. In particular, in plants with a robust root system (*R. crispus, Alh. kirghisorum*), the fauna is relatively wealthy, with up to 70 species (*Alhagi kirghisorum Sch.*), While ephemeral perennials *Hordeum bulbosum* T. and *Poa bulbosa* L. were found in 40-42 species of nematodes. When analyzing the distribution characteristics of nematodes along the mountain zones, the lowest number of species is found in the upper mountain zone (64 species), the middle zone - 93 species, the highest in the lower zone - 104 species and the foothills - 79 species became known (Table 1).

Most identified species belonged to the Rhabditida (24%) and Tylenchida (47%) orders. Aphelenchoididae, Tylenchidae, and Tylenchorhynchidae were dominant families (Figure 1).

In mountainous zones, the number of nematode species increased with the decrease in altitude due to the preservation of dominant species in the upper zone, the emergence of new species, or the replacement of species (Table 1). For example, as you descend from the top of the mountain to the bottom, *H. elongatus, A. emarginatus, Ch. symmetricus, P. rigidus, Aph. avenae, P. pseudoparietinus, A. parietinus, A. bicaudatus, A. agricola, T. davainei, D. destructor, D. dipsaci, P. pratensis, H. multicinctus, M. dubius* have been preserved, families such as Monhysteridae, Rhabditidae, Plectidae, Panagrolaimidae, Aphelenchoididae, Dorylaimidae have enriched the fauna at the expense of new species. As a result, the nematode fauna of the lower zones is more diverse than in the upper zones (Table 1).

However, representatives of families such as Tylenchorhynchidae and Rotylenchidae were mainly distributed in the upper zones of the mountain and relatively sparsely in the lower zones.

In the different altitude zones, the species richness index varied between 8.2 and 11.9. Among the altitude zones, the lower zone of the mountain had the advantage of nematode species richness compared to other zones (D_{MG}=11.9). On the contrary, the lowest species richness (D_{MG}=8.3) was recorded in the high altitude zone.

According to the trophic classification proposed by Yeates (Yeates et al. 1993), the identified nematode species are plant feeders (37 species), mycophages or fungivores (15 species), bacteriotrophs (51 species), predators (5 species), were divided into ecological groups such as omnivorous (13 species). In turn, plant-feeding nematodes are divided into subgroups of ectoparasites and migratory and sedentary endoparasites. In terms of species richness, bacteriotrophs and plant-feeding nematodes were found to be dominant over other groups (Figure 2).

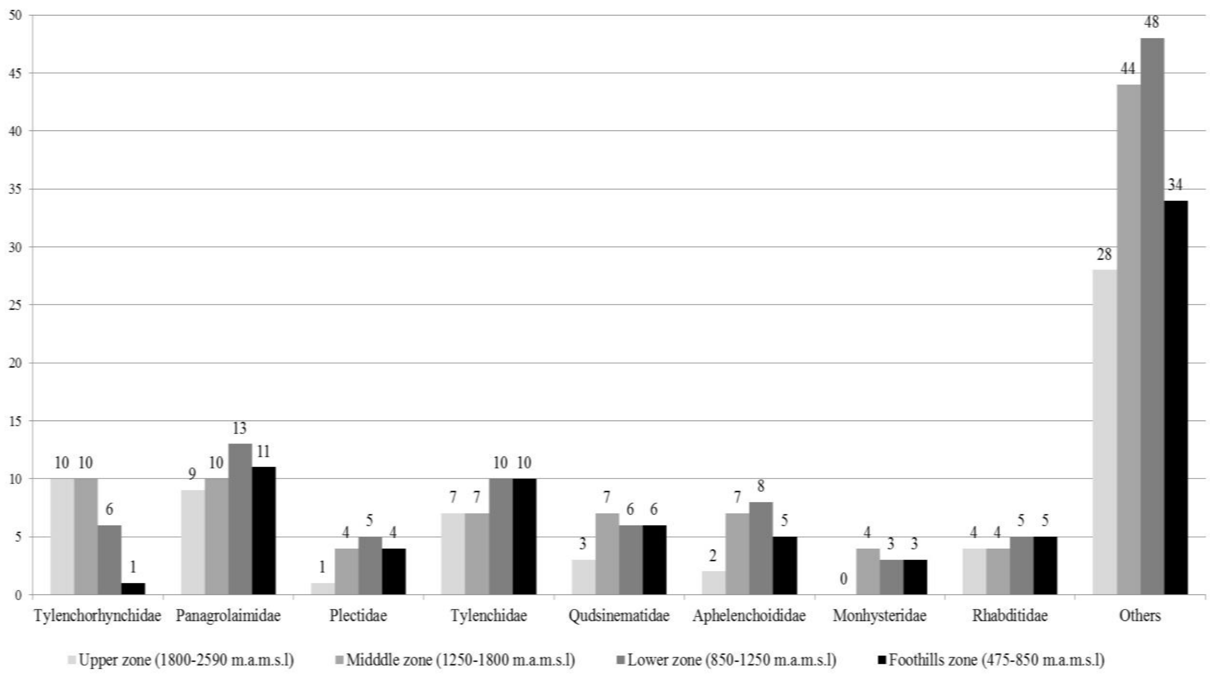

Figure 1. The distribution rate of nematode families by altitude zones (by number of species)

Table 1. Distribution and trophic features of nematode fauna of Zarafshan mountain range

Species	Ecological and trophic groups **	Foothill zone	Lower zone	Middle zone	Upper zone
Acrobeles ciliatus	B.	+	+	+	+
Acrobeles complexus	B.	-	+	+	-
Acrobeloides bütschlii	B.	+	+	-	-
Acrobeloides emarginatus	B.	+	+	+	+
Acrobeloides nanus	B.	-	+		-
Acrobeloides tricornis	B.	-		+	+
Aglenchus agricola	Ect.	+	+	+	+
Aglenchus bryophilus	Ect.	+	+	+	+
Aglenchus thornei	B.	+	+	-	-
Alaimus primitivus	B.	+	+	+	+
Anaplectus granulosus	B.	+	+	+	-
Anatonchus tridentatus	P.	-	+	+	+
Anguina sp.	End.M.	-	+	+	
Aphelenchoides bicaudatus	F	+	+	+	+
Aphelenchoides cyrtus	F	+	+	+	-
Aphelenchoides helophilus	F	-	+	-	-
Aphelenchoides kühnii	Ect.	-	+	+	-
Aphelenchoides limberi	F	-	+	-	-
Aphelenchoides parietinus	Ect.	+	+	+	+
Aphelenchoides saprophilus	F	-	-	+	-
Aphelenchoides subparietinus	F	+	+	+	-
Aphelenchoides zeravschanicus	F	+	+	-	-
Aphelenchus avanae	F	+	+	+	+
Aphelenchus cylindricaudatus	F	+	+	-	+
Bursaphelenchus talonus	F	-	-	+	-
Cephalobus persegnis	B.	+	+	+	-
Cervidellus desertus	B.	-	-	-	+
Cervidellus habibulae	B.	+	+	-	-
Cervidellus insubricus	B.	+	-	-	+
Chiloplacus bibigulae	B.	-	+	+	-
Chiloplacus lentus	B.	+	+	+	+
Chiloplacus propinguus	B.	+	+	-	-
Chiloplacus samarcandicus	B.	-	+	-	-
Chiloplacus symmetricus	B.	+	+	+	+
Clarcus parvus	P.	+	+	+	+
Criconemoides pullus	Ect.	-	-	+	+
Cylindrolaimus melancholicus	B.	+	+	+	-
Diphterophora communis	B.	-	+	-	-
Diphterophora obesus	B.	+	+	+	+
Diplogaster rivalis	B.	+	+	+	+
Diploscapter rhizophilus	B.	+	+	-	-
Ditylenchus destructor	End.M.	+	+	+	-
Ditylenchus dipsaci	End.M.	+	+	+	+
Ditylenchus intermedius	F	+	+	-	+
Dorylaimoides elegans	O.	-	-	+	+
Eucephalobus oxyuroides	B.	+	+	+	
Eucephalobus striatus	B.	+	+	+	+
Eudorylaimus dogielli	O.	+	+	+	+
Eudorylaimus kirjanovae	O.	+	+	+	+
Eudorylaimus labiatus	O.	+	+	+	-
Eudorylaimus monhystera	O.	+	+	+	+
Eudorylaimus muchabbatae	O.	+	+	+	+
Eudorylaimus sulphasae	O.	+	+	+	+
Eudorylaimus uzbekistanicus	O.	-	-	+	-
Helicotylenchus digitiformis	Ect.	+	+	+	+
Helicotylenchus multicinctus	Ect.	+	+	+	+
Heterocephalobus elongatus	B.	+	+	+	+
Heterocephalobus filiformis	B.	+	+	+	+
Heterocephalobus teres	B.	+	+	-	-
Hexatylus viviparus	F	+	+	-	-
Hoplolaimus tylenchiformis	Ect.	-	+	-	-
Laimodorus agilis	B.	+	+	+	+
Lelenchus discrepans	B.	+	+	+	+

Meloidogyne hapla	End.S.	+	+	-	-
Merlinius bogdanovii-katjakovi	Ect.	-	-	+	+
Merlinius brevidena	Ect.	-	+	+	-
Merlinius cylindricaudatus	Ect.	-	+	+	+
Merlinius dubius	Ect.	+	+	+	+
Merlinius gaudialis	Ect.	-	-	+	+
Merlinius macrurus	Ect.	-	+	+	+
Merlinius rugosus	Ect.	-	-	+	+
Mesoanguina picridis	End.M.	-	+	+	+
Mesodorylaimus bastiani	O.	+	+	+	+
Mesodorylaimus pendzschikenticus	O.	+	+	+	-
Mesorhabditis monhystera	B.	+	+	+	+
Monhystera filiformis	B.	+	+	+	-
Monhystera microphthalma	B.	+	+	+	+
Monhystera paludicola	B.	-	+	+	-
Monhystera similis	B.	+	+	-	-
Mononchus truncatus	P.	-	+	+	+
Mylonchulus sigmaturus	P.	+	+	+	+
Neotylenchus abulbosus	Ect.	-	+	+	-
Neotylenchus consobrinus	Ect.	-	+	+	-
Nothotylenchus acris	Ect.	-	-	-	+
Nygolaimus brachyuris	P.	+	+	+	+
Panagrolaimus rigidus	B.	+	+	+	+
Panagrolaimus subelongatus	B.	+	+	+	-
Paraphelenchus pseudoparietinus	F	+	+	+	+
Paraphelenchus tritici	F	+	+	-	-
Paratylenchus macrophallus	Ect.	+	+	+	-
Paratylenchus tenuicaudatus	Ect.	-	+	+	-
Pelodèra cylindrica	B.	+	+	+	-
Plectus cirratus	B.	-	+	+	+
Plectus parietinus	B.	+	+	-	-
Pratylenchus pratensis	End.M.	+	+	+	+
Pratylenchus thornei	End.M.	+	+	-	-
Pratylenchus tumidiceps	End.M.	-	+	+	-
Prismatolaimus dolichurus	B.	+	+	-	-
Proteroplectus assimilis	B.	+	+	+	-
Proteroplectus rhizophilus	B.	+	+	+	-
Rhabditis brevispina	B.	+	+	+	+
Rhabditis filiformis	B.	+	+	+	+
Rhabditis intermedius	B.	+	+	+	+
Rhabdolaimus aquaticus	B.	+	+	+	-
Rotylenchus goodeyi	Ect.	-	+	+	+
Rotylenchus robustus	Ect.	-	+	+	+
Seinura demani	O.	+	+	-	-
Seinura oxura	O.	+	+	+	-
Seinura tenuicaudata	O.	+	+	-	-
Tetylenchus clavicaudatus	Ect.	-	+	+	-
Tylencholaimus minimus	F.	+	+	+	-
Tylenchorhynchus bucharica	Ect.	-	-	+	+
Tylenchorhynchus graminicola	Ect.	-	+	+	+
Tylenchorhynchus maximus	Ect.	-	+	+	+
Tylenchus davainei	Ect.	+	+	+	+
Tylenchus filiformis	B.	-	-	+	+
Tylenchus kirjanovae	B.	+	+	-	-
Tylenchus leptosoma	B.	+	+	+	+
Xiphinema americanum	Ect.	-	-	+	-
Xiphinema elongatum	Ect.	-	-	+	+
Zeldia punctata	B.	+	-	+	+

Note: ** F: fungivores; B: bacterivores; P: predators; O: omnivores; Ect: ectoparasites; End.S: sedentary endoparasites; End.M: migratory endoparasites

Table 2. Index of nematode diversity by mountain zones

	Upper zone	**Middle zone**	**Lower zone**	**Foothill zone**
Shannon H′	1.5	1.3	1.2	1.18
Simpson D	3.9	2.9	2.9	2.7

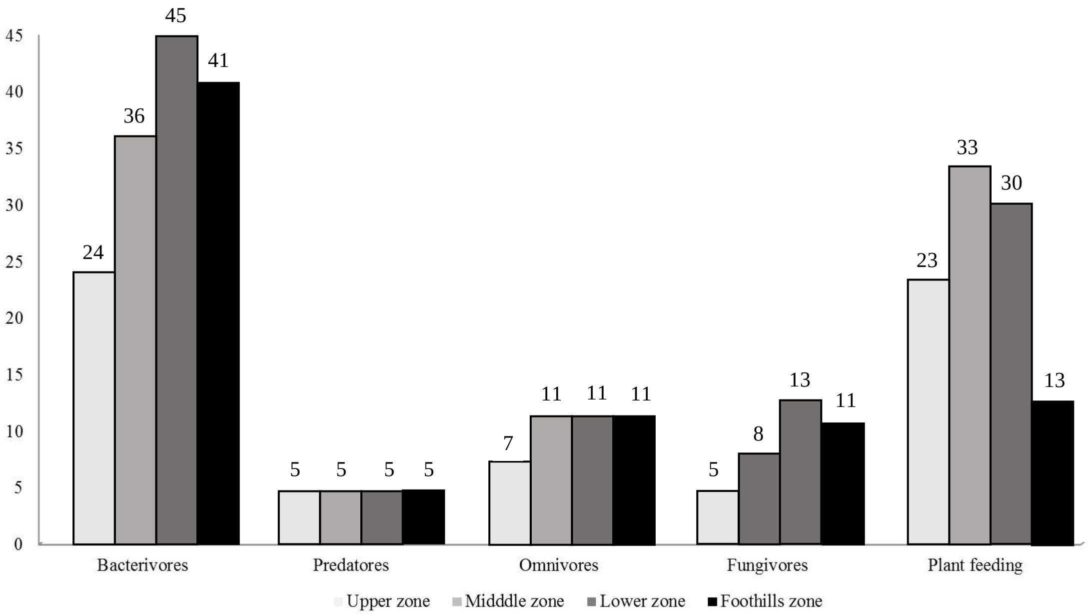

Figure 2. The occurrence rate of trophic groups of nematodes by altitude zones (by number of species)

The Shannon and Simpson indices show the diversity of nematode ecological groups in mountainous areas. In this case, the nematode fauna of the altitude zone with a more extensive index is considered relatively diverse (table 2.). It is clear from the data presented (table 2) that the most remarkable ecological diversity, although the smallest number (H′=1.5; D=3.9) of species (64 species), belongs to the upper mountain zone. The lowest diversity (H′=1.18; D=2.7) was observed in the mountainous zone. In general, the level of diversity in mountainous areas does not differ significantly.

As a result of the research, four species belonging to the genus *Merlinius* (*M. brevidena, M. cylindricaudatus, M. gaudialis, and M. macrurus*) were identified as new species for the fauna of Uzbekistan.

Discussion

As a result of the research, we observed that the nematodes community is unevenly distributed along the height gradients. The fewest species were detected in the high altitude zone, while the highest was in the mountain's low altitude zone. The reason for this can be explained by the fact that in the high altitude zone, there is a sufficient amount of moisture and organic matter, but cold climatic conditions, short vegetation period of plants and high leaching of the soil layer. The main limiting factor in the high altitude zone of the mountain is that the humus content is 8, sometimes up to 9%, and the slope is not less than 10°C (Kholikulov et al. 2011). As the mountain descended, the number of nematode species increased. There are 93 species in the middle zone and 104 in the lower zone. The number of species in the foothills has decreased by 79 species. These figures can be associated with relief in the first place. Due to the steepness of the slope in the high altitude zone, constant erosion processes enabled living organisms to move downstream, enriching the fauna of the lower zones. Thus, the enrichment of the fauna as the altitude decreases is due to the preservation of the previously dominant species, the emergence of new species or the replacement of species. For example, as you descend from the top of the mountain to the bottom, *Heterocephalobus elongatus, A. emarginatus, Ch. symmetricus, P. rigidus, Aph. avenae, P. pseudoparietinus, A. parietinus, A.bicaudatus, A. agricola, T. davainei, D. destructor, D. dipsaci, P. pratensis, H. multicinctus, M. dubius* have been preserved, families such as Monhysteridae, Rhabditidae, Plectidae, Panagrolaimidae, Aphelenchoididae, Dorylaimidae have enriched the fauna at the expense of new species. This nematode fauna of the lower zones is more affluent than in the upper zones. This is consistent with the results obtained by researchers other than ours (Hostchits 2004; Dong et al. 2017). However, according to Kergunteuil et al. (2016), species richness increased with increasing altitude. Most species are marked in the upper zone.

Because the species enrich the nematode fauna of the lower zones in the upper zones, the coefficient of similarity in the communities of nematodes in the adjacent zones is high (Table 3).

In this case, the value of S′ varied from 0.19 to 0.4, and a relatively significant difference occurred when we compared the lower and upper zones of the mountain (S′ = 0.4). However, the coefficient of similarity between the middle and lower zones of the mountain was S′ = 0.19. It indicates that the fauna of these zones of the mountain is very close to each other. In the upper and middle zones of the mountain, S′ = 0.32. When calculating the coefficient of similarity of the foothills with other mountain zones, S′ = 0.4 with the upper zone, S′ = 0.31 with the middle zone and S′ = 0.17 with the lower zone. As can be seen from the figures given, the foothill zone is almost identical to the nematode fauna of the adjacent lower zone, and as it rises to the upper zones, the similarity between the nematode communities decreases and the difference increases.

Table 3. Coefficient of similarity of the nematode community in the elevation zones of the Zarafshan ridge (according to Sørensen-Chekanovsky)

Elevation zones	Upper zone		Middle zone		Lower zone	
	Total number of species	**S′**	**Total number of species**	**S′**	**Total number of species**	**S′**
Upper Zone			53	0,32		
Middle Zone	53	0.31	-	-		
Lower Zone	51	0.4	80	0.19	-	-
Foothill Zone	55	0.4	60	0.31**	77	0.17

However, some facts refute this hypothesis. The number of species decreased as the Tylenchorhynchidae family, which is widespread in the study area, descended from the upper zone (Figure 2). Theoretically, the members of this family should be composed of ectoparasite species that live mainly in the rhizosphere and be susceptible to erosion factors. Perhaps this phenomenon can be justified by the conclusion that high-altitude regions can be considered the family's centre of origin and distribution.

In most studies in this area, mycophages (fungovores) have been the dominant group (Háněl 1996; Peneva et al. 2011; Zhang et al. 2012; Dong 2017). However, in our study, nematodes feeding on fungal mycelium were not recorded in large numbers. At 1800-2590 m, their share was 7.8%, while it reached 14% in the foothills. The humus content in the foothills is not as high as in the highlands (5-8%). The increase in the weight of mycophages was not due to a significant increase in the number of species in this group but to a sharp decrease in plant-feeding nematodes (Figure 1). Although the humus content in the high-altitude zone is higher than in the low-altitude zone, it can be said that the low temperature inhibited the growth of fungi and, in turn, the proliferation of mycophages. In the low-altitude zones, adequate temperatures and moisture from spring water flowing from the high-altitude zones create favorable conditions for developing mycophagous nematodes. In general, the relatively low proportion of mycophages in the fauna compared to studies in this area can be attributed to the relatively low content of organic matter (3-8%) in the soil of mountain ranges in Central Asia. For example, the average organic matter content in the Vihorlat Mountains was 8.8% (Hanel 2010); in the Beskydy Mountains (Hanel 1996), it was 3.5-21.5%.

Changes in the rate of occurrence of herbivorous nematodes in mountainous areas can be understood as correlating with plant density. The species of nematodes of this group varied from the high mountain zone to the foothills as follows: 35:35>28<16. In the zone of low altitude (1250-1800 m), which is favourable for plant growth (humus, good moisture content), the plants are very dense under the influence of anthropogenic factors, and the growing season is complete. Accordingly, plant-feeding nematodes peaked in the mid-elevation zone (33 species). However, in the foothills, their species began to fall again (Figure 1). This can be explained by the overgrazing of livestock in the foothills zone and the rarity of plants due to the solid anthropogenic factors. In addition, the ecosystems in this zone have been degraded, mainly by annual ephemeral plants (Khujanazarov et al. 2019; Bekuzarova et al. 2020).

The distribution of bacteriotrophic nematodes in mountainous areas is almost indistinguishable. Representatives of this group dominated in all zones. However, nematode offspring of bacteriotrophs have been shown to alternate in the distribution in mountainous areas. For example, nematodes belonging to the genus *Monhystera*, *Plectus*, and *Proteroplectus* are mainly distributed in the lower zones of the mountain, and the number of species decreases as they rise to higher altitudes. In the case of *Acrobeloides* and *Merlinius*, the opposite is true (Table 1). Predatory and carnivorous nematodes did not cause significant changes in the composition of nematode fauna in mountainous areas. Representatives of these groups were observed to be relatively evenly distributed in all zones (Table 1).

Thus, when analyzing the distribution characteristics of ecological groups of nematodes in mountainous areas, it was found that bacteriotrophs form the basis of the fauna. However, the group that changes the appearance of the nematode is not the most common bacteriotrophs but a group of plant feeders.

In general, in different zones of the northern slope of the Zarafshan mountain range, it was found that the nutritional characteristics of nematodes and the ecological groups divided according to the degree of contact with plants are unevenly distributed. This feature can be associated with the amount of organic matter in different altitudes, precipitation, moisture retention, and anthropogenic factors. Although the amount of humus in the upper mountain zones is relatively high, the low soil temperature, low moisture retention, and the intensity of erosion processes can be attributed to the spread of stiletto forms in these zones, which are mainly associated with plants. More free-living species were observed in the lower part of the mountain, especially in the foothills. Based on the above, it is known that the nematode fauna also changes in proportion to the changes in the vegetation cover in mountainous areas. However, several problematic results have also emerged during the study. The first is the uniform distribution of predators and carnivores, although the climatic and soil conditions are different in different altitude zones of the mountain. First, despite the highest number of species in the lower zone, why has the number of predators and carnivores not increased? It is known that the prevalence of this group is directly related to other groups of nematodes (Hostchits 2004; Kergunteuil 2016). Second, although the living conditions for nematodes in the high altitude zone were somewhat unfavorable (low temperature, low humidity, relatively short vegetation), representatives of the ectoparasitic Tylenchorhynchidae family were found mainly in this zone and sharply decreased towards the lower zones (Figure 2). These cases cast doubt on the entire disclosure of the formation of nematodes in the highlands at the expense of ecological groups of nematodes. The answers to the above questions require extensive research on the formation of nematode fauna in the area.

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