JOURNAL OF PURE AND APPLIED MICROBIOLOGY, May 2014. Vol. **8**(Spl. Edn. 1), p. 433-442

Soil Nematode Community Structure as Affected by Tourism Trampling in Wudalianchi Scenic in Northeast China

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(Received: 12 April 2014; accepted: 09 May 2014)

The effect of human trampling on soil nematode community were studied along an increasing distance from the trail of Wudalianchi World Geo-park which is located in Northeast China. It can provide valuable information about the impacts of human disturbances on ecosystem structure. Our study evaluated the abundance, the composition and the ecological indicators of soil nematode communities in three different trampling intensity (severely disturbance, moderately disturbance, slightly disturbance). Soil samples were collected from the depth of 0 cm to 20 cm in 2013. Soil nematode were separated using the Baermann's funnels method, and were identified and counted. Soil pH value, soil moisture, soil bulk density, organic matter, total nitrogen, total phosphorus, available phosphorus content, and available potassium content were measured in topsoil (0-20 cm) from each site. Sixty-one nematode genera were collected during this study. Trampling decreased the abundance of the total nematode and four tropic groups, and affected the frequency of occurrence of some species. Canonical correspondence analysis (CCA) indicated that the soil nematode trophic group distribution related to soil properties closely. Tramping increased soil bulk density, reduced soil moisture content, and decreased soil nutrient supply. Therefore, it lead to changes of soil nematode community. The severely trampling site had the lowest the abundance MI 2-5, EI and SI, and the highest BI and CI, which indicates a serious interference to the environment. Our results show human traffic can affect soil biota significantly in this ecosystem and may alter ecosystem processes. Consequently, soil nematode community analysis may provide useful information for assessing the impact of human foot traffic on soil processes.

Key words: Tourism disturbance, Nematodes, Ecological functions, Community structure.

With the development of tourism industry, activities associated with human recreation (including tourists trampling, vehicle rolling, tourist facilities placement, environmental pollution and so on) have caused soil erosion progressively, vegetation destruction, loss of biodiversity etc.[1-2]. In all kinds of recreational activities, trampling is acknowledged to be the most widespread and it becomes a problem as it represents the major disturbance affecting vegetation and soil surface horizon[3]. In tourist areas, trail is the region which is most affected by the trampling[4-5]. Therefore, it becomes a topic of considerable importance for ecological impact study.

Human trampling causes disrupting soil structure partially or totally, reducing porosity and modifying the edaphic microenvironment[6]. Soil fauna is a good indicator for human impact since it inhabits soil surface horizons mainly[7-8]. For instance, Ayres *et al*., (2008) found that human trampling reduce the abundance of soil organisms in the McMyrdi dry valleys, Antarctica[9]. Battigelli

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et al. (2004) found that soil compaction causes a change in soil fauna composition[10]. Lee *et al.* (2009) indicate a clear negative effect for trampling on the composition of soil arthropods[6]. In these soil organisms, nematode maybe the first choice because they were identifiable, small, common, and easily cultured and propagated[11-12]. Changes in soil nematode community structures reflect changes in soil microenvironments and so are increasingly used as bioindicators for disturbance of the soil environment because their numbers, taxa and trophic groups may reflect the state of soil ecological processes[13-17]. However, there have little study about tourism impact on soil nematode.

As a result of seven volcanic eruptions in the past 2.1 million years, wudalianchi World Geo-park have the most well-preserved intra-continental volcanic in China, and it was nominated as a World Heritage Property in 2010[18]. As a national scenic, Wudalianchi have precious aesthetic and scientific value, attracting a large number of domestic and foreign tourists and recuperators. According to statistic provided by the Heilongjiang Provincial Tourism Bureau, tourists increased from 230,000 to 1.25 million during recent years (2002-2012), which increased nearly 11 times. The substantial growth in tourists will lead to the changings in soil environment. It is not clear if these changes would have impact on ecosystem. We take Yaoquan mountain and South Gelaqiu mountain of Wudalianchi as study examples. The soil nematode communities at the 0-20 cm depth was investigated along an increasing distance from the trail in study sites revealing the effects of tourism trampling on the soil in 2013. We predicted that (1) The abundance of nematode would decrease with increasing distance from the trail. (2) forest soils from areas with less trampling would have more stable structure of nematode than soils with more trampling. (3) the trampling would change the composition and spatial distribution of nematode. Perhaps the knowledge of trampling impact on the nematode community will assist park managers to perfect tourism planning.

MATERIALS AND METHODS

Description of study area

The study was conducted at the temperate forest in Wudalianchi (126°00' -126°25' E, 48°30', -48°50', N) within the ecotone between the Great Hinggan Mountains, the Less Hinggan Mountains and the forest steppes of the Songnen Plain. The soil at the study site is classified as volcanic soil and the typical vegetation is the temperate mixed forest, Mongolia oak is the main plant population[18]. This area enjoys temperate continental monsoon climate, and it has long cold winters and moderately short warm summers. The annual precipitation is 476.3 mm and concentrate in June-August. The annual temperature is -0.5 °C. The annual frost-free in a year is 121 d and the average annual sunshine duration is 2726 h[19].

Field sampling

Soil samples at the 0-20 cm depth were taken from three sites along a disturbance gradient with distance at 0 (Severely disturbance, D3), 10 (Moderately disturbance, D2), and 50 (Slightly disturbance, D1) meter from the Yaoquan mountain and South Gelaqiu mountain recreational trails with six altitudes. Three replications were random chosen in each site. Each replications was composed of four 5 × 5 cm^2 samples. Samples collected from the same location were mixed thoroughly and preserved in a plastic bag. Then a part of soil fresh samples was used to measure soil moisture (MC; by the oven drying method) and soil bulk density (BD; by the cutting ring method), the other part of soil fresh samples were kept at 4°C to analyze soil nematodes, and the remaining samples were air-dried at room temperature and then sieved through a 2 mm screen to meaure soil chemical properties including soil pH (with the use of glass electrode pH meter), total nitrogen content (TN; by the semimicro Kjeldahl method), soil organic matter content (OM; by the potassium dichromate volumetric method), total phosphorus (TP; by the Mo-Sb colorimetry method), available phosphorus content (SP; by the 0.5mol/L $NaHCO_3$ extraction method), available potassium content (SK; as extracted by ammonium acetate and determined by flame photometry)[20]. The results are showed in Table 1.

Exraction and identification of soil nematodes

Soil nematodes were separated from 100 g of fresh soil using the Baermann's funnels method and preserved in 4% formaldehyde [21-22]. Collected arthropods were counted and at least 150 nematodes from each sample were indentified to genue level under a inverted compound microscope using the De Nematoden Van Nederland[23]. Abundances of nematodes were expressed as

Table 1. Soil environment parameters (mean±S.E.) of the three tourism disturbance plots

	MC (%)	pH	OM(g/kg)	TN(g/kg)	TP(g/kg)	SP(mg/kg)	SK(mg/kg)	BD (g/cm^3)
D1	35.59±2.69	6.66±0.02	87.63±3.68	5.96±0.28	2.47±0.04	37±0.02	57.10±0.09	1.26±0.04
D2	32.28±2.60	6.68±0.02	87.29±3.56	5.96±0.27	2.47±0.03	36±0.02	57.18±0.09	1.31±0.04
D3	28.86±2.60	6.47±0.02	87.06±3.56	5.88±0.27	2.26±0.03	29±0.02	56.56±0.09	1.34±0.04

Disturbance plots included: D1, slightly disturbance site; D2, moderately disturbance site; D3, severely disturbance site. Enviromment parameters included: MC, soil moisture content; OM, soil organic matter content; TN, total nitrogen content; TP, total phosphorus content; SP, available phosphorus content; SK, available potassium content; BD, soil bulk density.

individuals per 100 g (ind./100 g) of dry soil[24]. Nematodes were divided into 4 trophic groups according to the feeding habits and life history characteristics[13]: bacterivores (Ba), fungivores (Fu), omnivores-carnivores (Om) and plant parasites (Pp). And according to nematode life history characteristics, nematodes were divided into 6 colonizer-persister (cp) scale[25].

Data analysis

Several nematode community indices were calculated: (1) maturity index (MMI); (2) plant parasite maturity index (PPI); (3) soil free-living nematode maturity index (MI); (4) maturity index including cp 2-5 group (MI2-5) [25]; (5) basal index (BI); (6) channel index (CI); (7) enrichment index (EI); (8) structure index (SI) [11]; (9) nematode channel ratio (NCR) [14]; (10) fungal feeder to bacterial feeder ratio (F/B) [26]; (11) trophic diversity (TD) [27].

Soil Nematode abundances were ln(x + 1) transformed before the statistical analysis to normalize the data and make the variance constant. One-way ANOVA was used to evaluate the effects of disturbance degree on measured ecological indices. Principal component analysis was used to evaluate all soil nematode community structure parameters. Canonical correspondence analysis was used to evaluate community structure and main environmental properties under different disturbance degree. All statistical analyses were performed with SPSS and CANOCO software packages, and differences with $p < 0.05$ were considered statistically significant.

RESULTS

Composition and abundance of soil nematode communities

Sixty-one nematode genera were identified, *Cephalobus* was the dominant species (which counted more than 10 % of total), counting for 11.54 % of the total individuals. And 80.88 % of the nematode were made up of 29 common groups (which counted 1 to 10 % of total), while 31 rare groups (which counted less than 1 %) counted only 7.58 % (Table 2). The total number of genera was no significant difference in three disturbance degree sites ($p > 0.05$) (Fig. 1). And the most of genera abundance had no significant difference in three disturbance degree ($p > 0.05$). However, disturbance degree influences dramatically the abundance of some genera ($p < 0.05$) (Table 2); for example, the porportional contributions of *Teratocephalus* and *Aphelenchus* significant decreased with the increase of tourism disturbance degree, while the porportionof *Eudorylaimus* increased (Table 2). The proportional contributions of some nematode changed only slightly among three disturbance sites; for example, *Mesorhabditis* (CV = 6.22%). On the contrary, some species changed dramatically. For example, *Tenunemellus* and *Pungentus* did not get in D3, *Heterodera* and *Longidorus* did not get in D2, and *Rotylenchulus* did not get in D1. *Chrysonemoides* and *Microdorylaimus* was obtained only in the D3 and D2 respectively (Table 2). .

In this study, the average abundance of nematodes across all sites was 461 individuals per 100 gramme dry soil (ind./100 g dry soil). The total abundance of nematodes was significantly affected by the disturbance degree ($p < 0.01$) (Fig. 1). D1 had the highest individual abundance (618 ind./100 g dry soil), which was approximately two times greater than D3 (329 ind./100 g dry soil). (Fig. 2).

Functional guilds of soil nematode communities

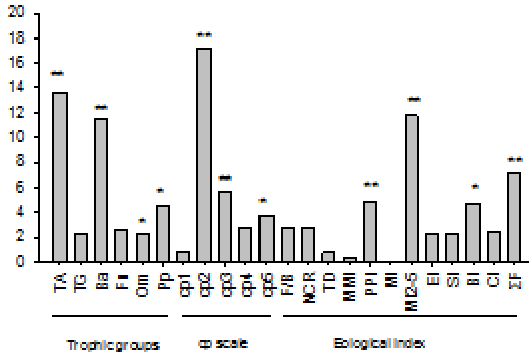
In this study, significant tourism disturbance effects were observed in the abundance of the trophic groups (Fig. 1). There

Table 2. Composition and proportional contribution (%) of soil nematode in three tourism disturbance plots

Genus	Guild	D1	D2	D3	mean	CV	*p*	Genus	Guild	D1	D2	D3	mean	CV	*p*
Mesorhabditis	Ba1	1.68	2.28	2.8	2.13	6.22	ns	*Tripyla*	Om3	0.6	0.93	0.88	0.77	16.2	ns
Panagrolaimus	Ba1	0.55	0.31	0.94	0.57	43.07	ns	*Clarkus*	Om4	0.57	0.53	0.49	0.54	39.84	ns
Pristionchus	Ba1	0.08	0.05	0.1	0.07	40	ns	*Epidorylaimus*	Om4	0.81	0.38	0.5	0.6	70.46	*
Rhabditis	Ba1	2.07	2.09	3.49	2.41	18.17	ns	*Eudorylaimus*	Om4	1.11	1.5	1.66	1.36	11.79	**
Acrobeles	Ba2	3.67	2.96	3.42	3.39	40.78	**	*Miconchus*	Om4	0.03	0.01	0.03	0.03	61.54	ns
Acrobeloides	Ba2	2.01	1.47	1.58	1.74	49.63	ns	*Microdorylaimus*	Om4	0	0.37	0	0.11	173.58	*
Anaplectus	Ba2	1.14	0.89	1.58	1.17	31.01	ns	*Mylonchulus*	Om4	0.53	0.52	0.57	0.54	30.68	ns
Cephalobus	Ba2	12.78	9.86	11.37	11.54	43.61	**	*Pungentus*	Om4	0.06	0.02	0	0.03	126.67	ns
Cervidellus	Ba2	0.03	0.1	0.08	0.07	38.71	ns	*Thonus*	Om4	1.52	2.05	1.9	1.77	20.63	*
Chronogaster	Ba2	0.77	0.9	0.97	0.86	20.5	ns	*Aporcelaimellus*	Om5	0.22	0.26	0.36	0.27	12.1	ns
Eucephalobus	Ba2	1.27	0.75	1.22	1.1	49.61	ns	*Chrysonemoides*	Om5	0	0	0.07	0.01	171.43	ns
Heterocephalobus	Ba2	2.15	1.36	2.31	1.95	44.33	*	*Discolaimus*	Om5	0.25	0.06	0.42	0.23	65.14	ns
Plectus	Ba2	6.87	12.36	6.78	8.55	39.48	**	*Longidorus*	Om5	0.08	0	0.05	0.05	108.7	ns
Wilsonema	Ba2	3.52	4.49	3.17	3.74	34.99	**	*Mesodorylaimus*	Om5	0.12	0.06	0.09	0.09	68.18	ns
Achromadora	Ba3	1.91	1.87	2.76	2.1	21.08	ns	*Paraxonchium*	Om5	0.12	0.2	0.19	0.16	17.11	ns
Bastiania	Ba3	0.76	1.51	0.84	1.01	39.41	ns	*Torumanawa*	Om5	0.12	0.09	0.04	0.09	69.05	ns
Odontolaimus	Ba3	2.44	1.66	2.5	2.21	43.13	ns	*Boleodorus*	Pp2	0.25	0.41	0.19	0.28	45.86	*
								Oxydirus	Pp5	0.14	0.03	0.08	0.09	90.7	ns
Prismatolaimus	Ba3	8.37	6.74	9.55	8.15	34.17	ns	*Cephalenchus*	Pp2	0.25	0.29	0.29	0.27	23.02	ns
								Coslenchus	Pp2	1.09	1.3	1.73	1.31	11.15	ns
Rhabdolaimus	Ba3	1.38	2.15	1.42	1.63	32.59	**	*Lelenchus*	Pp2	1.25	1.29	1.35	1.29	28.45	ns
Teratocephalus	Ba3	4.95	4.55	3.11	4.39	51.15	**	*Malenchus*	Pp2	0.04	0.09	0.04	0.05	48	ns
Alaimus	Ba4	0.5	0.3	0.62	0.46	42.86	ns	*Paratylenchus*	Pp2	2.33	0.25	0.51	1.25	132.02	*
Aphelenchoides	Fu2	7.6	5.03	6.6	6.57	49.28	**	*Psilenchus*	Pp2	2.73	1.53	1.23	2	74.55	ns
Aphelenchus	Fu2	2.48	2.04	1.65	2.15	51.74	*	*Tenunemellus*	Pp2	0.04	0.01	0	0.02	120	ns
Ditylenchus	Fu2	1.15	0.61	1.28	1.01	49.37	ns	*Tylenchus*	Pp2	1.12	2.07	0.59	1.29	60.4	ns
Filenchus	Fu2	5.36	7.37	4.43	5.76	39.04	*	*Criconemoides*	Pp3	0.25	0.29	0.6	0.35	22.09	ns
Diphtherophora	Fu3	1.98	2.03	2.66	2.16	21.01	ns	*Helicotylenchus*	Pp3	1.75	1.53	2.91	1.96	24.73	ns
Dorylaimoides	Fu4	0.27	0.21	0.21	0.24	47.75	ns	*Heterodera*	Pp3	0.03	0	0.01	0.02	150	ns
Tylencholaimus	Fu4	4.16	7.64	4.66	5.36	35.4	*	*Rotylenchulus*	Pp3	0	0.05	0.03	0.02	110	ns
								Scutylenchus	Pp3	0.44	0.16	0.52	0.37	60.92	*
								Longidorella	Pp4	0.27	0.06	0.42	0.24	68.14	ns
								Trichodorus	Pp4	0.01	0.04	0.16	0.06	85.19	ns
								the number of groups		58	58	58	61		

Disturbance plots included: D1, slightly disturbance site; D2, moderately disturbance site; D3, severely disturbance site. Guild designation is the composite of feeding habit and cp value: Ba – bacterivore; Fu – fungivore; Om - omnivores-carnivores; Pp - plant parasites. Numbers following the letters indicate the cp value of each taxon based on Bongers (1990). CV (= mean/S.D.) is the coefficient of variation. *p* indicate the effects of disturbance degree on the genera abundance. ** $p < 0.01$; * $p < 0.05$; ns – no significantly different.

were similar patterns between the abundance of trophic groups and the total nematodes. Except fungivore, which highest in D2, the abundance of three trophic groups including bacterivores, plant parasites, and omnivore was significant higher in D1 than in D2, and D3 (Fig. 2). Among three disturbance sites, bacterivores was predominant with higher relative abundance (> 50%), while omnivore-carnivores had the lowest percentage (< 8%). Tourism disturbance increased the relative abundance of bacterivores and omnivore-carnivores. The fungivores and plant parasites had the highest percentage in D2 and D1, respectively. However, no significant differences of the proportions of trophic groups were found among all disturbance sites ($p > 0.05$) (Fig. 3a).



df, degrees of freedom; * p<0.05; ** p<0.01.

Fig. 1. F-values from one-way ANOVA analysis of disturb degree ($df = 2$) on the total nematodes abundances (TA), the total nematodes groups (TG), abundances of trophic groups (Ba, bacteriophages; Fu, fungivores; Om, omnivores-carnivores; Pp, plant parasites), cp group (cp scale : colonizer-persister scale 1-5), and nematode ecological indices (F/B, ratio of fungivores to bacterivores; TD, trophic diversity index; NCR, nematode channel ratio; MMI , maturity index; PPI, plant parasite maturity index; MI, soil free-living nematode maturity index; MI 2-5, maturity index including cp 2-5 group; BI, basal index; CI, channel index; EI, enrichment index; SI, structure index; ΣF, comprehensive index).

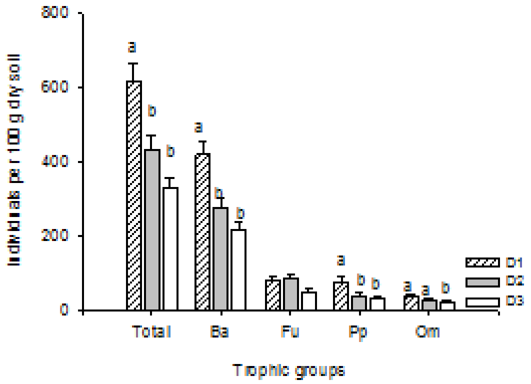


Fig. 2. Abundances (ind./100 g dry soil) of total nematodes and their trophic groups (Ba, bacterivores; Fu, fungivores; Pp, plant parastites; Om, omnivores-carnivores) in different tourism disturbance plots (D1, slightly disturbance site; D2, moderately disturbance site; D3, severely disturbance site). Different lowercase letters indicate a significant difference ($p < 0.05$).

Among three disturbance degree sites, the relative abundance of cp2 group was highest, followed by cp3 group, cp4 group, cp1 group, and cp5 group. Tourism disturbance increased the relative abundance of cp1 group and decreased that of cp2 group. The highest relative abundance of cp3 and cp5 was in D3 and lowest in D2, while that of cp4 was highest in D2 and lowest in D1. As the trophic groups, the proportions of cp groups had no significant differences among all disturbance sites ($p > 0.05$) (Fig. 3b).

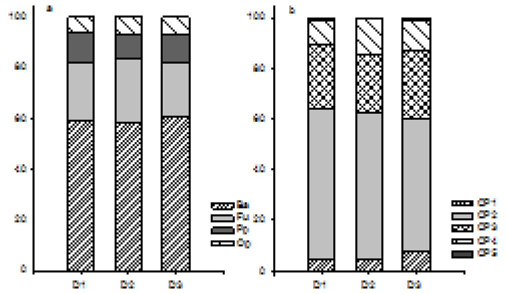


Fig. 3. Proportion of nematode tropic groups (a) and cp group (b) under different tourism disturbance plots (D1, slightly disturbance site; D2, moderately disturbance site; D3, severely disturbance site). Ba, bacterivores; Fu, fungivores; Pp, plant parastites; Om, omnivores-carnivores; cp scale : colonizer-persister scale 1-5.

Community indices of soil nematode communities

One-way ANOVA was used to analyze the community index of soil nematode. No statistically significant effects were observed in the case of MI, MMI, EI, SI, CI, F/B, NCR, and TD due to tourism pressure, while PPI, MI2-5 , and BI index were significantly different ($p < 0.05$) (Fig. 1). MI2-5 index showed the same trend as total nematodes abundance which was significantly decreaded by toursim disturbance (2.82 in D3 and 5.25 in D1) contrary to the PPI and SR index. BI index had the highest value in D3 (44.41), and lowest in D1 (26.73) (Fig. 4).

The principal component analysis of the community index indicated that the first principal component (f1) accounted for 40.86 %, the second principal component (f2) 28.59 % , and the third principal component (f3) 27.48% of variance. The three principal components accounted for most of the total variance (96.93 %) (Fig. 5). The ordination diagram (Fig. 5) based on the loading plots of PCA for soil nematode community structure parameters indicated that the total nematode abundance and

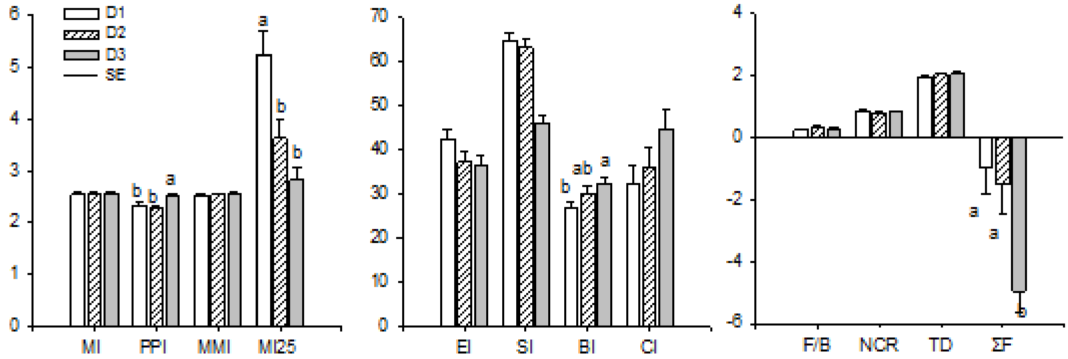


Fig. 4. Nematode community indicts under different tourism disturbance polts (D1, slightly disturbance site; D2, moderately disturbance site; D3, severely disturbance site). MI, soil free-living nematode maturity index; PPI, plant parasite maturity index; MMI , maturity index; MI 2-5, maturity index including cp 2-5 group; EI, enrichment index; SI, structure index; BI, basal index; CI, channel index; F/B, ratio of fungivores to bacterivores; NCR, nematode channel ratio; TD, trophic diversity index; £F, comprehensive index. Different lowercase letters indicate a significant difference ($p < 0.05$)

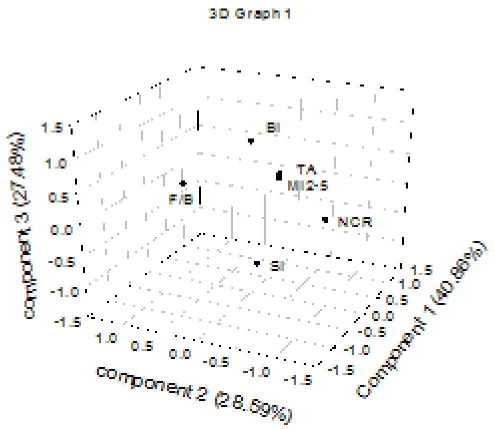


Fig. 5. The loading plots of PCA for soil nematode community structure parameters. MI 2-5, maturity index including cp 2-5 group; SI, structure index; BI, basal index; F/B, ratio of fungivores to bacterivores; NCR, nematode channel ratio; TA, the total nematodes abundances

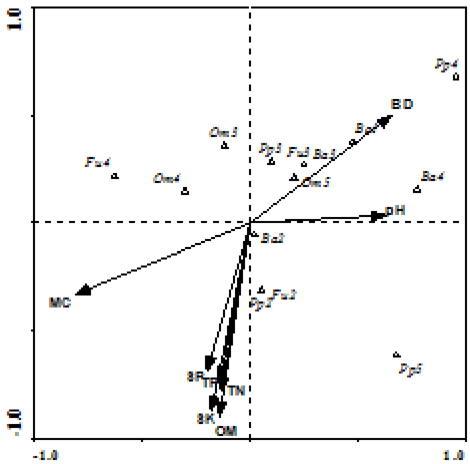


Fig. 6. Canonical correspondence analysis (CCA) between nematode trophic groups and soil environmental parameters. MC, soil moisture content; OM, soil organic matter content; TN, total nitrogen content; TP, total phosphorus content; SP, available phosphorus content; SK, available potassium content; BD, soil bulk density. Ba, bacterivores; Fu, fungivores; Pp, plant parastites; Om, omnivores-carnivores; numbers following the trophic groups indicate the cp values.

MI2-5 index had very high loading on f1, so f1 mainly explained the two factors, f2 mainly explained the F/B and NCR indexes, and f3 mainly explained the SI and BI indexes. According to the component score coefficient of the soil nematode community structure parameters (Fig. 5), ΣF index, which indicated the communities structure score comprehensively, was calculated. The ΣF index was highest in D1, followed by D2 and D3 (Fig. 4). This regular pattern was similar to that of the MI2-5 and the abundance of total nematode, as illustrated in Fig. 2 & 4. The ΣF index was significant differences among three disturbance sites (Fig. 1).

Correlations of soil nematode functional guilds and community indices with soil chemical properties

As canonical correspondence analysis (CCA) of the abundance of the functional guild and the date for environmental variables including pH, BD, OM, TN, TP, SK, SP and MC in three disturbance degree sites indicated the eigenvalues of the first axis and the second axis were 0.011 and 0.008. The first axis explained 52.4% of cumulative variance of the species data and 88.8% of the species-environment relationships. The first axis, which reflected pH of the soil, and the second axis, which reflected OM, TN, TP, SP, and SK could be illustrated by the measured environmental variables. This figure revealed the relation between the distribution of species and the environment (Fig. 6). For example, the functional guilds Ba1, Pp4 mainly appeared in areas with high bulk density, while Fu2, Pp2, and Pp5, mainly appeared in areas with high TN, OM, TP, SP, and SK.

DISCUSSION

In all kinds of recreational areas, trampling is acknowledged to be the most widespread impact[3]. Trampling caused soil compression, which led to a increased soil bulk density and reduced soil moisture centent. Recreational stress also changed nutrient supply in the soil (Table 1). These changes might exert a direct or indirect influence on nematode populations and community structure.

Responses of the abundance of nematodes

The current experiment on the impact of trampling on nematodes had revealed that trampling affected the total abundance of nematodes which declined progressively with the distance from trail. Numbers of nematodes extracted from D1 and D3 ranged from 628 to 329 ind./100 g dry soil (Fig. 2). This result is similar to those reported by Darby *et al*. (2010) [28]in desert soils and Ayres *et al*. (2008)[9] in Antarctica. Wall *et al*. (2002)[29] found the soil from areas with loose, porous and higher soil organic matter had greater nematode density. The foot traffic caused soil compression and the increment in soil bulk density which caused a reduction in the soil moisture and soil porosity. And recreational stress also reduced the amount of the nutrient supply (Table 1). All of these are well explained the decreasing abundance of nematode along the increasing distance from the trails. And the abundance of the trophic groups are similar with the total nematodes. According to Light and MacConaill (2011)[30], nematodes might not reproduce in trampled areas or they could migrate elsewhere if food choices became limited. Meanwhile, disturbance degree influences dramatacally the abundance of some genera (Table 2). Some species were not adaptable to different environments and lived only in specific heterogeneitic environments. This suggests that the limited adaptability groups of soil nematode can reflect the differences between environments and can be an important indicator to reflect variations in environments. As there are many kinds of soil nematode and their distributions are very complicated, additional long-term research should investigate to clarify their use as environmental indicators.

Responses of the community structure of nematodes

In this study, bacterivores had the highest ratio among four trophic groups (Fig. 3a) and the F/B values was low (0.22-0.34) (Fig. 4). The results mean that the organic material is mainly decomposed by the bacteria. The decomposition rate of the bacteria-based food web is rapider than fungal-based food web[11]. The result differs from previously reported studies which showed that fungivores were the dominant trophic group in Changbai mountain[31]. The differences are primarily due to the soil pH in the current study (6.47-6.68) being higher than that in Changbai mountain (4.12-5.82). Yeates (1996)[32] found a lower soil pH is favorable for fungi. Additionally, The percent of soil nematode trophic groups was no significant changed because of trampling (Fig. 3a), indicating that the tourism interference don't change the structure of soil nematode trophic groups.

We predicted that a clear effect of trampling on the percentage of soil nematode trophic groups should be found, but this has not been investigated. According to CCA sorting, the distribution of soil nematode trophic groups were apparently related to the pH and soil nutrients. Trampling did not form a dramatic change of environmental nutrient supply in this study (Table 1). It may be the reason for the result.

Responses of the ecological indices of nematodes

The cp2 group which have a tolerant of adverse conditions and wide ecologial amplitude were predominant with higher relative abundance (Fig. 3b), indicating the soil food web in Wudalianchi scenic is stressed mainly because of trampling and other artificial disturbances[11]. MI 2-5 gives a much better response to disturbances than MI and MMI in the stressed soil community [33], which are similar to our results (Fig. 1, 4). The values of MI 2-5 significantly reduced with the increasing foot traffic (Fig. 4).

In the present study, the values of EI decreased and the values of CI increased with the trampling intensity (Fig. 4). EI values reflect food web response to availability of resources and CI values indicate the predominant decomposition pathways[11] , the obtained results indicated that the trampling decreased the food resources for the food web. Higher EI and lower CI suggest more enriched condition of soil food web and greater bacterial activity in D1[34].

SI can be used to assess the response to disturbance. The values of SI decreased with the trampling intensity, lowest SI in D3 suggest the direct impact of foot traffic on the environment (Fig. 4). In D1, the value of EI was less than 50 and the value of SI was greater than 50, which suggested a undisturb environment. While in D3, the value of EI and SI were less than 50,which showed that the environment had suffered severe interference and caused degradation of the food web[11].

The value of BI significantly increased from D1 to D3 significantly. A high BI would indicate poor ecosystem health[35]. Thus, EI, BI, SI and CI appear to be most valuable as indicators for the effects of trampling on nematode suppression. However, BI and SI may be more suitable as general indicators for the health status of a soil, since CI can be high in highly disturbed agro-ecosystems as well as in undisturbed natural ecosystems. A high BI would indicate poor ecosystem health, while a high SI would indicate a well-regulated, healthy ecosystem[35].

It can be concluded from present study that foot traffic can have negative effects on soil ecosystem. The highest tramping intensity change soil properties, such as increasing soil bulk density, reducing soil moisture content, and decreasing nutrient supply. Then, it lead to disturbance and changes in the ecological functions of nematode. Recreational stress decreased the abundance of soil nematode, the values of MI 2-5, EI and SI, while it increased BI and CI, which indicates a disturbed and poor nutrient soil food web undergoing bacterial decomposition. Soil nematode community analysis may provide useful information for assessing the impact of human foot traffic on soil processes.

ACKNOWLEDGMENTS

The project was financially supported by the National Natural Science Foundation of China (41101048, 41371072), Postdoctoral Science Foundation of China (2013M541407) , Postdoctoral Science Foundation of Heilongjiang Province (LBH-Z13130) and Program for the Science and Technology Innovation Team in Universities and Colleges of Heilongjiang Province.

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