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Faunal Composition, Density and Biomass of Soil Animals in the Grasslands of Inner Mongolia

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Synopsis

To understand and conserve the grassland ecosystem in Inner Mongolia, composition, density and biomass of soil macro- and mesofauna, the important elements in a terrestrial ecosystem, were investigated in the conservated grassland area at Beiinxile, Inner Mongolia. The study was carried out from 24, July to 4, August in 1987. Mean density and biomass of macrofauna in pastures were $48-240/m^2$ and $2.8-6.1 g/m^2$, respectively, and were larger than those in meadows. The values of biomass of macrofauna in sand dune and *Populus* forest were relatively small. Rhyzophagous Scarabaeids and Tenebrionids were found at large rate in biomass in pastures. Family composition in Coleoptera of meadows was most diversified the among the study areas. It became clear that minimum appropriate quadrat size and quadrat number for macro soil animals in the grasslands in Inner Mongolia were 50cm-square and three or four quadrats per one study site, respectively. Density of Nematoda was largest among mesofauna, ranged from $4.40 \times 10^3/m^2$ to $6.02 \times 10^4/m^2$. Main members of mesofauna in usuall terrestrial ecosystems, mite and collembola, were found at a considerably few density. Considering the results of soil animals in this study, it was suggested that the grasslands in Inner Mongolia were affected significantly by the human impacts caused by stock-farming.

Key words: soil animals, macrofauna, mesofauna, faunal composition, density, biomass, grassland in Inner Mongolia.

Introduction

Soil animals do not occupy a major part in terms of biomass in terrestrial ecosystems. However, it is recognized by many investigators that they play significant part for flowing matters through terrestrial ecosystems. In the region of cool-dried steppe, there are few study of soil animals especially from a qualitative standpoint.

To understand biological production and conservation of the grassland ecosystem in Inner Mongolia, it might be necessary to clarify the fundamental knowledge concerning to soilfauna as an important element of grassland ecosystem. The aims of our present study were firstly to estimate preliminary faunal composition, density and biomass and secondly to investigate sampling size and number. From these results, the effects of the desertification of grsssland in Inner Mongolia would be revealed to some extent.

Study area

Study area was situated within the reserved grasslands of livestock farm of Biinxile, 60km south-east from Xilinhot city in Inner Mongolia. The study plots for the soil animals were set up on almost same area as where vegetation, plant productivity and soil properties were studied. The study plots were classified into four different land types. They were (a) grasslands used as pasture, (b) grasslands used as hay meadow, (c) sand dune and (d) *Populus* forest which was preserved by bars. On the grassland of pastures, we took three study sites where the degree of grazing were different. They were at Ihoura, an experimental grassland of overgrazing and Hairiudo plateau, in order of less-grazing degree. On the grasslands of meadow, three study sites were selected as followings; a slope of Gason-ura mountain, *Stipa baicalensis* dominant meadow and Wulango meadow. The study was carried out from 24, July to 4, August in 1987.

Sampling methods of the soil fauna

In this study three sampling methods were conducted according to differences in body size and nature of soil animal's habitats.

The sampling of soil macrofauna which exceded 2mm in body length was made by hand sorting method as shown in Fig. 1. Two quadrat sizes were adopted as of $25 \times 25cm^2$ and of $50 \times 50cm^2$. Quadrat number per one study point was various because of limited surveying time and man power. Macrofauna was taken from three soil layers, of liter layer, 0–5cm and 5–15cm deep above the ground. Collected macro soil animals were preserved in 80% alchohol solution and were sorted out with animal groups in labolatory. Individual number was counted and wet weight was obtained immedietely on an analytical balance using the unit of mg.

For the mesofauna of which body length ranged between 0.2 to 2mm, two extracting apparatuses were used according to the nature of the animals. For micro-arthlopoda

Fig. 1. The procedure of hand sorting method for sampling of soil macrofauna. Upper; A quadrat of 50 × 50cm^2 was set. Bottom; The dug soils were examined with naked eyes and soil animals were sampled.

which composed mainly of collembola and mite living in relatively in dried soils, Tullgren funnel was used as shown in Fig. 2. Soil samples were taken by core of 100cm^3(20cm in basal area and 5cm in depth) and taken from three soil layers, until to 15cm depth by every 5cm. Soil micro-arthlopods were extracted by lighting with 40W electric bulbs for 48 hours. All extracted animals were preserved in 80%-alchohol solution and counted in individual numbers every soil animal group. Extraction of another mesofauna of micro hygrophilous animals, mainly composed of Nematoda and Enchytraeidae, was made by Bearmann apparatus for 48 hours (Fig. 3). The volume of the soil core was 25cm^3 and three soil cores were taken to a depth of 15cm as micro-arthlopoda. Extracted micro-hygrophilous animals were immediately counted in water.

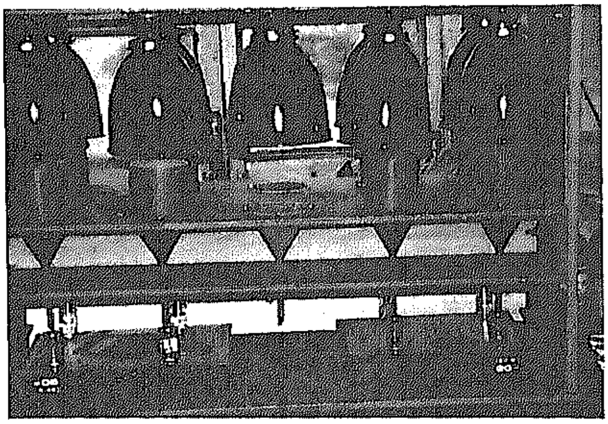

Fig. 2. Tullegren funnel apparatus for extraction of soil micro-arthlopoda, composed mainly of mite and collembola.

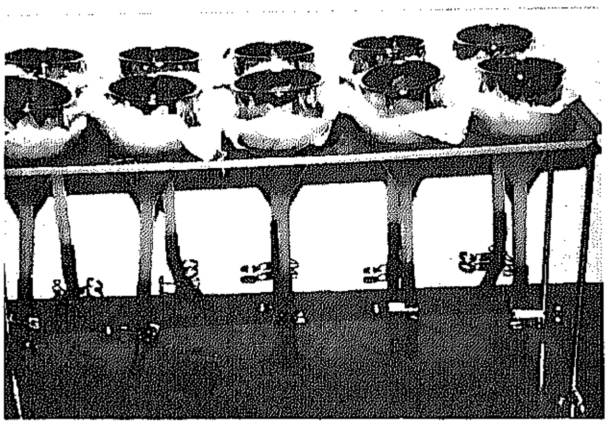

Fig. 3. Bearmann apparatus for extraction of soil hygrophilous animals, composed of mainly of Nematoda and Enchytreaidae.

Results

Macrofauna

Sampled macrofauna belonged to the following orders; Araneae, Chilopoda, and predatory Coleoptera for predators and Gastropoda, Diptera, Lepidoptera, Hemiptera and detritivorous Coleoptera for decomposers. It was characteristic in this survey that Oligocheata which was common in terrestrial ecosystems were not found and that the numbers of order of macrofauna were very poor. Order composition of both in individual number and biomass of macrofauna at four representative study sites were shown in Fig. 4. Through all the study sites the faunal composition in density and biomass showed simple patterns, however, the percentage of faunal order was somewhat different with the study sites. In the pasture of Ihoura, it was conspicuous that the percentage of detritivorous Coleoptera in biomass was very large (74.2%). As shown in Fig. 5, main family of the Coleoptera was Scarabaeidae and sampled Scarabaeids larvae seemed to belong to rhyzophagous family according to observation of its maxilla. In pastures, found family composition of Coleoptera other than Scarabaeidae were Tenebrionidae and Elateridae. On the other hand, it was known that there was a notable diversity of faunal orders in meadows and that the numbers of family in Coleoptera was very large. Families of insects found in meadows were Scarabaeidae, Staphylinidae, Elateridae, Chrysomelidae for Coleoptera and Orthoptera, Lepidoptera and Diptera mainly in the form of larva. The diversity of the insect family composition in meadows seemed to correlate the species diversity in the vegetation (Nakamura et al., 1988). Faunal composition in sand dune was the simplest in the study sites and somewhat different from other study sites. In sand dune, the greater part (80%) of density was ant, the Hymenoptera and in biomass Lepidoptera and terrestrial Gastropoda were found notably. In *Populus* forest, percentage of Araneae in density was largest in the study sites and different faunal order from grassland study sites such as of Hemiptera, Orthoptera and Scolopendromorpha were found.

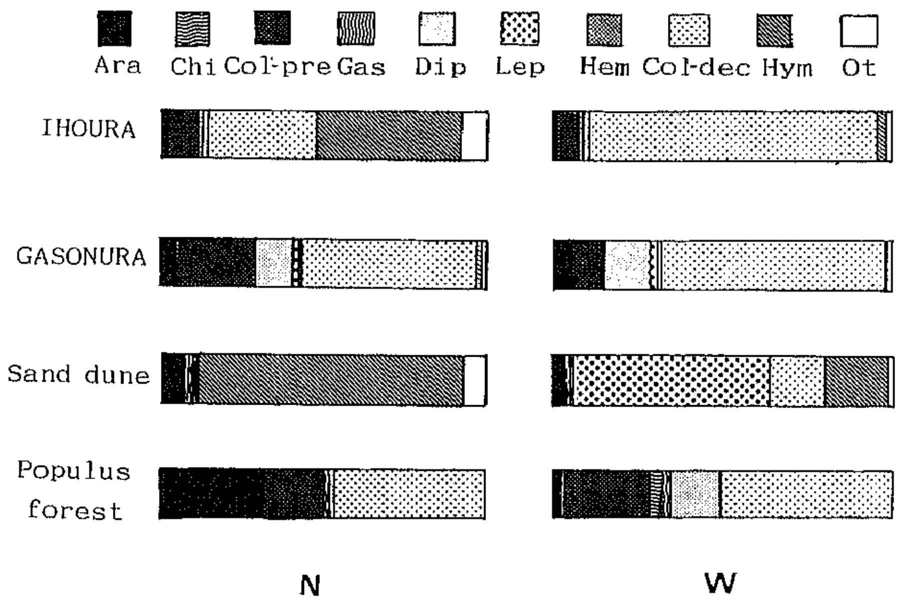

Fig. 4. The percentages of density (N) and biomass (W) of soil macrofauna at four study sites in the grasslands in Inner Mongolia. The legends are following as; Ara: Araneae, Chi: Chilopoda, Col-pre: Coleopteran predators, Gas: Gastropoda, Dip: Diptera, Lep: Lepidoptera, Hem: Hemiptera, Col-dec: Coleopteran decomposers, Hym: Hymenoptera, and Ot: Others.

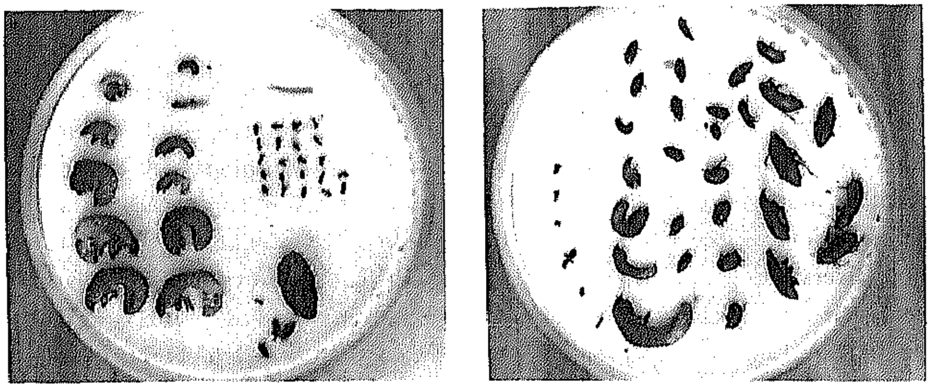

Fig. 5. Photographs of sampled macrofauna in petri dishes in the grassland of Ihoura pasture.

Mean density and biomass of macrofauna at every study area were shown in Table 1. Mean density and biomass of macrofauna were estimated in the ranges from 48 to $262.0/m^2$ and from 0.5 to 6.0 mg/m^2 (wet weight), respectively. The values of density and biomass in pastures were larger than those in meadows. It was remarkable that the pasture of Ihoura at where the largest values of density and biomass were obtained, seemed to be less grazed than other two pastures. On the other hand, pasture of Hairiud plateau seemed to be most overgrazed one at where the density was smallest. Though in the meadows length and standing crop of grasses seemed to be much, the density and biomass were not so large. The density in sand dune was largest as $262.0/m^2$, while biomass was least in this study areas. That may be due to the large percentage of ants in density, of which body size was very small. Both values in *Populus* forest were within the range of values obtained in the grasslands. The coefficient variances in biomass were larger than those in density, that was usual on the studies of soil macro-animals. It was known from this study that the values of c. v. in quadrat size of $25 \times 25 cm^2$ were smaller by about one half than those in the size of $50 \times 50 cm^2$ at many study sites.

The mode of vertical distribution of density and biomass of macrofauna was very similar among each grassland study area. So vertical distribution of density and biomass at pasture and *Populus* forest were shown in Fig. 6. In both study sites, more than 50% of total number and biomass was found in the layer of 0 to 15cm. It was shown that the distribution patterns at the two study sites were somewhat different in two points. One is that at pasture the percentage of density and biomass in litter layer is very few comparing with those at *Populus* forest, which may be due to the small amount of litter accumulation. Second point is that at *Populus* forest some portion of macrofauna is found in the soil layer below 15cm, which may be probably due to soil humidity and amount of organic matters in deep soil layer.

Table 1. Mean density and biomass of soil macrofauna at every study site in the grassland of Inner Mongolia.

Study site	Study date	Quadrat size cm^2	Quadrat namber	Mean density N/m^2	Mean biomass g/m^2
Pasture					
IHOURA	7/24−7/26	50×50	8	240.0 (0.434)	6.1 (0.773)
Grazing test pasture	7/29	25×25	4	153.6 (1.215)	2.8 (1.370)
HAIRIUDO plateau	7/30	50×50	1	48	3.8
Meadow					
GASON-URA	7/28	50×50	3	74.8 (0.401)	1.5 (0.412)
Stipa baicalensis dominant meadow	7/31	25×25	5	84.8 (1.006)	0.5 (1.313)
WULANGO	8/7	50×50	1	56	1.8
Sand dune	8/4	25×25	5	262.0 (1.072)	0.8 (1.707)
Populus forest	8/3	50×50	1	72	1.4

Values in parentheses are coefficients of variances. (c.v.)

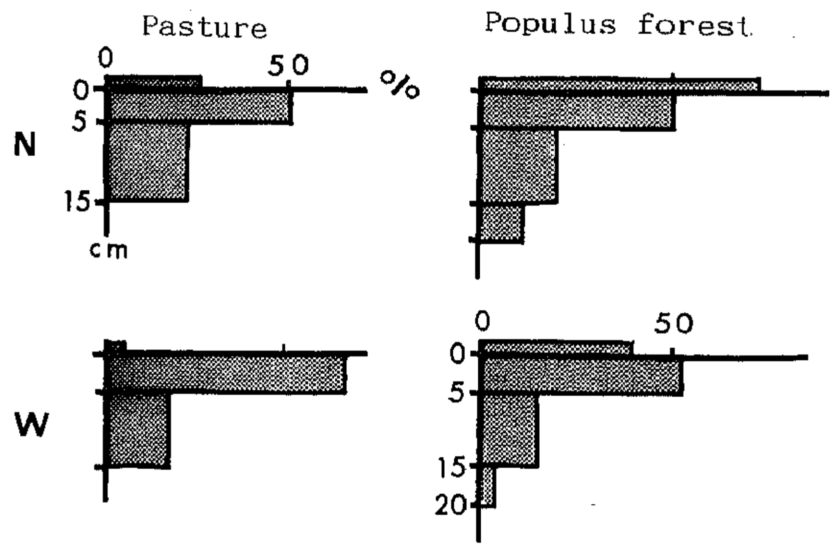

Fig. 6. Vertical distribution of dendity (N) and biomass (W) of macrofauna at pasture and *Populus* forest in Inner Mongolia.

Mesofauna

Mean densities of micro-arthlopods extracted by the Tullgren funnel at each study site were indicated in Table 2. Mites and Collembolas, which would be expected to be extracted from the soils in usual grasslands, were detected a little or not detected except in *Populus* forest. One considerable reason for a few density of micro-arthlopoda is seemed to be the way of extraction. In this study areas in Inner Mongolia, the size of soil grain is so small that a rather bulk of the sampled soil fell out through the meshes of Tullgren funnels. Then, the apparatus was improved by piling up the shiets of meshes. However, there are much rooms for further improvement for extracting methods of microarthropods in the grasslands in Inner Mongolia. Another reason is that the density of micro-arthlopoda in the grasslands in Inner Mongolia are infact very few due to the extreme dryness of soils (Takahashi et al., 1988) and to relatively small amout of litters at soil surface (Hayashi et al., 1988). The estimated mean densities of mite and Collembola in *Populus* forest were $1.8\times10^3/m^2$ and $3.5\times10^4/m^2$, respectively. These values were evaluated as rather small values comparing with the values obtained in usual forest ecosystems.

Mean densities of micro-hygrophilous animals extracted by Bearmann apparatus at every study area were shown in Table 3. The major part of animals extracted by Bearmann apparatus was Nematoda. Enchytraeidaes, which would usually extracted by that apparatus, was found so little as not to convert the density per square meter. The extracted animal groups by Bearmann appartus other than Nematoda and Enchytraeidae were Bdelloidae, Targigrada and Parameciidae. Mean densities of Nematoda in the grassland areas were estimated in the ranges from $4.40\times10^3/m^2$ to $6.02\times10^4/m^2$. Estimated density of Nematoda in *Populus* forest was largest in the study areas and

Table 2. Density of soil micro-arthlopoda extracted by Tullgren funnel at every study site in the grasslands of Inner Mongolia.

Study site	Study date	Sample number	Mite N/m^2	Collembola N/m^2
Pasture				
IHOURA	7/24–7/26	13	++	+
Grazig test pasture	7/29	10	0	+
Meadow				
GASON-URA	7/28	10	+	0
Stipa baicalensis dominant meadow	7/31	10	0	0
Populus forest	8/3	8	1.8×10^3	3.5×10^4

++ and + indicate low density less than 500/m^2 and 100/m^2, respectively.

Table 3. Mean density of Nematoda extracted by Bearmann appararus at every study site in the grasslands of Inner Mongolia.

Study site	Study date	Sample number	Mean density N/m^2	Animals other than Nematoda
Pasture				
IHOURA	7/24−7/26	13	6.02×10^4	Enchytraeidae
Grazing test pasture	7/29	10	8.47×10^3	
Meadow				
GASON-URA	7/28	10	7.60×10^3	
Stipa baicalensis dominant meadow	7/31	10	4.40×10^3	Enchytraeidae
WULANGO	8/7	5	1.48×10^4	
Sand dune	8/4	5	1.48×10^4	Bdelloidae
Populus forest	8/3	8	8.42×10^5	Enchytraeidae Bdelloidae Targigrada Parameciidae

was $8.42\times10^5/m^2$. These results of mesofauna were rather different from our preestimation according to the observation of soil features. Vertical distribution of density in density of mesofauna was shown in Fig. 7. More than 50% of mesofauna were distributed in the soil layers of 0−15cm.

Discussion

Quadrat number and quadrat size of mesofauna

On the basis of datum of density and biomass of macrofauna obtained in Ihoura grassland, necesary quadrat number of soil sample was investigated with regard to the values of cofficient of variance. Fig. 8. indicates the relation between quadrat ($50\times50cm^2$) number and mean c. v. with ranges of the standard errors. Each c. v. value was calculated by drawing every 2 to 7 datum of density and biomass randomly at seven times from eight datum in each quadrat. The figure showed that the mean c. v. and range of the standard error decreased as quadrat number increased, and held about constant at more than certain quadrat numbers. The level of c. v. of biomass was higher than that of density. Above-mentioned relationship and trend are generally found in many investigations concerning to density and biomass of soil fauna. The c. v. levels both of density and biomass in present study were roughly same or a little low in comparison with those obtained in various regions (Kitazawa, 1971). The quadrat number at which mean c. v. and the range of standard error kept constant in density and biomass were three and four, respectively. As shown in the results of Table

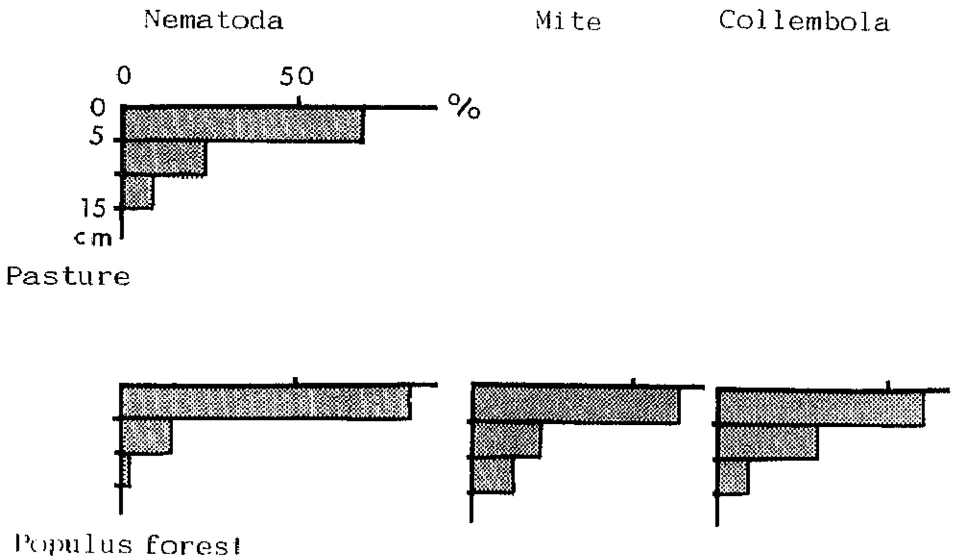

Fig. 7. Vertical distribution of density of mesofauna at pasture and *Populus* forest in Inner Mongolia.

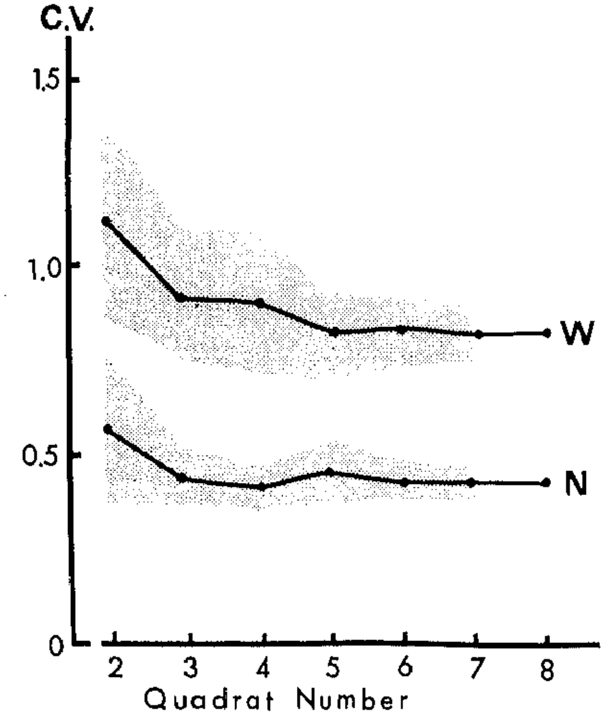

Fig. 8. The relationship between quadrat numbers and mean coefficient of variaces (c.v.) of density (N) and biomass (W) in soil macrofauna at Ihoura pasture. The shadows indicate the ranges of standard errors of c.v.

1, the values of c. v. in 50cm-quadrat were lower than those in 25cm-quadrat. This may be reflect the distribution pattern of macrofauna in this region.

From these considerations it can be said that to obtain minimum datum with small variances it is necessary to take 3 and 4 quadrats of $50 \times 50cm^2$ for density and biomass of soil fauna, respectively.

Characteristics on the soilfauna

According to the results in this study, there are some remarkable characteristics on the faunal composition. One of the characteristics is that earthwarms, which are commonly found in terrestrial ecosystems, are deficient and in place of them large number and biomass of larvae of Scarabaeids are found in the soils of the grassland especially in pastures. The second one is that micro-arthropods such as mites and collembolas, which are also abundant at high density in almost terresrial ecosystems, are found a very few in the grasslands. It can be said that the features of faunal composition are responsible for the many factors of the grassland in Inner Mongolia. The absence of earthwarm may be due to the soil physico-chemical properties, such as extreme dryness, small porosity and high alkalinity, which is pointed out by Takahashi et al. (1988) in the series of this studies. The minority of micro-arthlopods seems to be caused by small amount of litter on the surface of grasslands. Watanabe and Shidei (1963) mentioned that the density of soil animals is related with the amount of litter in forest ecosystem. Terada et al. (1981) noted that there were logarithmic linearity between the density of soil micro-arthlopoda and amount of litter and water content in subalpine forests in Japan.

By contrast with a few density of soil micro-arthlopoda, a certain density of Nematoda seems to be a somewhat curious result. Generally, Nematoda is apt to be found in relatively moist soils. Considering the small water content in the soils in this study areas, it can be suggested that Nematods in the grasslands inhabit inside or in vicinity of roots and rhyzomes of grasses and that the life of Nematoda is depend on the roots or rhyzomes of grasses by something. In this study, we could not distinguish the life form of Nematoda between parasitic or free living type. Hereafter, we need to confirm more detailed lifeform of the Nematoda in the grasslands in this region.

Concerning to the soil faunal composition in the region of cool-dried steppe, there are not so much studies. Alejnikova (1965) provided data on the faunal composition of meadow and pasture soils in the Middle Volga of Russia, of which latitude was approximately same as the study area. She pointed out to relatively low densities of earthwarms compared with Coleopteran Scarabaeidae and Curculionidae. Further she noted that Collembola and mite (Acari) averaged densities of 22,138 per m^2 and 32,900 per m^2, respectively. Her results showed a slightly similar tendency to our ones in regard to the macrofaunal compostion. However, there is a considerable difference from our results in the points of abundance of micro-arthlopoda. This may be due to the differences in some environmental factors between both grasslands.

It resulted in the present study that both density and biomass of macrofauna in pastures were lager than those in meadows and that both values seemed to decrease with degree of cattle's grazing. A considerable factor to the former result may be the existence of cattle's dungs as the nutrient source for soil animals especially as nitrogen resource. In pastures in Inner Mongolia, almost large bulk of cattle's dungs such as of caw or horse are removed from grasslands for the materials of fuel and only sheep's dungs, 'Yan-fun' are left. It can be thought that the 'Yan-fun' turn to be a valuable nutritional resource for soil macrofauna. The latter results may probably due to the worsening of soil condition mainly by cattle's stump pressure, which are also pointed out by Takahashi et al. (1988). To consider the difference in soil macrofauna between in pastures and meadows in the grassland, there are much left to study the soil animals from the view point of matters flow through farmed cattles.

To compare the density and biomass of soil animals obtained in Inner Mongolia with those of grasslands in Japan, Table 4 and Table 5 were shown for macrofauna and mesofauna, respectively. As the features of grasslands in Japan are considerably different from those in Inner Monglia at the points of climate, vegetation and soil properties, it is difffcult to compare the values of soil animals derectly. However, by comparing the values obtained in various grasslands, it can be expected to be revealed the factors to affect the density and biomass of soil animals. As shown in Table 4, the values obtained in Inner Mongolia are similar to those in moor and *Sasa* grasslands at Kitayatsugatake Mountains. As both glasslands are located in altidude of about 1900m in central Japan, temperature condition as mean annual temperature or Warmth Index may be close to the condition in Inner Mongolia. It is interest that the density and biomass of macrofauna are to some extent function of temperature though amount of rainfall are remarkablly different. Comparing with density of mesofauna (Table 5), density of Collembola, mite and Enchytraeidae in Inner Mongolia are too small to compare with those in Japan. Only density of Nematoda can be barely compared with those in Japan except in *Populus* forest. The order of density of Nematoda in Inner Mongolia ranges from 10^3 to 10^4 per m^2 and are smaller than those in Japan ranged from 10^5 to 10^6. This may be certainly due to the difference in soil humidity between glasslands in Japan and Inner Mongolia. It is unexpected result that the hygrophilous soil animals such as Nematoda are more abundant than collembola and mite, which can inhabit in rather dry surroundings, though water content in soils in Inner Mongolia is much low.

From global review of the biomass of whole soil animals, Ghilarov (1967) roughly compared among the cool-dried natural vegetations. He estimated biomass of soil animals (containing macrofauna and mesofauna) as follows; tundra (moss) for $3g/m^2$, steppe $25g/m^2$ and semidesert $1g/m^2$ in wet weight. Biomass of soil animals of grassland in Inner Mongolia may be estimated below $7g/m^2$ at most including macrofauna and mesofauna. This value lies in the range between the value of steppe and semide-

Table 4. Density (N) and biomass (Wt) of soil macrofauna studieds in the grassland in Japan.

Locality	Community	Date	Soil macrofauna		Authority	
			N	Wt g		
Ozegahara	Tall herbage	May, Aug, Oct.	512	12.34	Kitazawa, et al.	1954
Ozegahara	Sasa	Aug.	874	9.08	Kitazawa, et al.	1954
Mt.Shibutu	Alpine grassland	Aug.	106	10.40	Kitazawa, et al.	1954
Ozegahara	Osmunda community	Aug.	152	13.44	Kitazawa, et al.	1954
Mt.Shibutu	Alpine meadow	Aug.	180±72*	5.04±0.93*	Saito, et al.	1975
Tanzawa Mts. Hirogatake	Montane grassland	July	193	19.78	Kitazawa, et al.	1964
Tanzawa Mts. Hirogatake	Montane grassland	Nov.	208	17.45	Kitazawa, et al.	1964
Yatsugatake Mts. Kirigamine	Moor grassland	Sep.	526±151*	4.14±0.83*	Saito, et al.	1978
Yatsugatake Mts. Kirigamine	Moor grassland	Oct.	255±174*	4.84±1.14*	Saito, et al.	1978
Utsukusigahara	Sasa-Calamagrostis	Aug.	376~400	—	Shimuzu, et al.	1971
Mt.Fuji Nashigahara	Miscanthus	Apr.	355±69*	6.06±0.99*	Saito, et al.	1978
Mt.Fuji Nashigahara	Miscanthus	July	333±25*	9.37±2.91*	Saito, et al.	1978
Yatsugatake Mts.	Sasa	May, june, Oct.	367	5.58	Fujiyama, et al.	1981

Asterisls indocate standard errors.

Table 5. Density of mesofauna studied in the grasslands in Japan.

Animal group	Locality	Plant community	Date	Density N/m^2	Authority	
Nematoda	Mt.Shibutsu	Alpine meadow	Aug.	5.15×10^5	Saito et al.	1975
	Ozegahara	Osmunda	Aug.	2.85×10^5	〃	
	Ozegahara	Phragmites	Aug.	2.28×10^5	〃	
	Kirigamine	Moor grassland	Aug.	8.42×10^6	Kitazawa	1978
	Kirigamine	〃	Oct.	6.21×10^6	〃	
	Mt.Fuji	Miscanthus	Jul.	3.23×10^6	〃	
	Mts.kitayatsugatake	Sasa	Oct.	1.60×10^6	Terada et al.	1981
Enchytraeidae	Mt.Shibutsu	Alpine meadow	Aug.	7.52×10^4	Saito et al.	1975
	Ozegahara	Osmunda	Aug.	3.65×10^5	〃	
	Ozegahara	Phragmites	Aug.	5.47×10^5	〃	
	Kirigamine	Moor grassland	Aug.	8.55×10^5	Kitazawa	1978
	Kirigamine	〃	Oct.	7.62×10^5	〃	
	Mts.Kitayatsugatake	Sasa	Oct.	2.80×10^3	Terada et al.	1981
Mite (Acarina)	Mt.Fuji	Miscanthus	early winter	1.67×10^5	Aoki et al.	1976
	Kirigamine	Moor grassland	late autumun	2.90×10^4	〃	
	Mts.Kitayatsugatake	Sasa	Oct.	1.25×10^4	Terada et al.	1981
Collembola	Mt.Fuji	Miscanthus	Nov.	6.50×10^4	estimated from Tamura	1978
	Kirigamine	Moor grassland	Nov.	1.08×10^4	〃	
	Mts.Kitayatsugatake	Sasa	Oct.	9.60×10^3	Terada et al.	1981

sert of Ghilarov's estimation and is rather small value as in Steppe region. This diffecence is caused by environmental conditions and probably human impact.

According to the examination of faunal composition, density and biomass in this study, it can be revealed that grasslands in Inner Mongolia are affected significantly by human impacts caused by stock-farming. For instance, the result of difference in density and biomass of macrofauna between pastures and meadows shows the importance of cattle's dungs for nutrient source to soil animals. However, at present situation, large bulk of cattle's dungs is rmoved from grasslands. The result of mesofaunal composition suggests that there are a few margin of litter on which many microarthlopods depend for nutrition and space to colonization. It can be thought that there are left only a few inhabitable spaces for soil animals except in vicinity or inside roots or rhyzomes of grasses for Nematoda or rhyzophagous Scarabacid beetles. These circumstances seems to be a fairly poor and severe for soil animals to live abundantly and will be related to the desertification in the grasslands. To consider the conservation and to protect against the desertification of grassland ecosystems in Inner Mongolia, it is necesary to study the grasland ecosystems from the view point of matters flow in consideration of human factors caused by live-stock farming.

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