Far Eastern Entomologist

Дальневосточный энтомолог

Journal published by Far East Branch
of the Russian Entomological Society
and Laboratory of Entomology,
Institute of Biology and Soil Science,
Vladivostok

Number 207: 1-20 ISSN 1026-051X February 2010

ABUNDANCE AND DIVERSITY OF SOIL AND LITTER INVERTEBRATE MACROFAUNA IN SATOYAMA IN KANAZAWA, JAPAN: A HIGHER TAXONOMIC LEVEL ANALYSIS

I. Kinasih[1] and K. Nakamura[1,2]

1) Graduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa 920-1192, Ishikawa, Japan. E-mail: idakinasih@yahoo.com

2) Division of Biodiversity, Institute of Nature and Environmental Technology, Kanazawa University, Kakuma, Kanazawa 920-1192, Ishikawa, Japan. E-mail: koji@kenroku.kanazawa-u.ac.jp

The abundance and diversity of soil and litter fauna collected in a 'satoyama' area in Kanazawa University`s Kakuma Campus, Kanazawa City, Ishikawa, Japan in 2005 are discussed. Ten sampling sites were established: six of them were located in the cultivated area in a valley with terraced paddies under restoration and other four in unmanaged forested area. The samples were dealt with at higher taxonomic levels such as class and order. CCA ordination revealed a clear separation of soil and litter fauna composition among different habitat types (forested area, dwarf bamboo area, and cultivated area) and between layers (soil and litter) with specific environmental condition. The amount of litter was the strongest influence, affecting the richness and density of the soil and litter fauna like Collembola and Arachnida.

KEY WORDS : soil and litter invertebrate macrofauna, taxonomic composition, abundance, taxa richness, effects of management, satoyama, Japan.

И. Кинасих[1], К. Накамура[1,2]. Численность и разнообразие почвенных и подстилочных беспозвоночных в традиционной для Японии сельской местности в окрестностях Канадзавы: анализ на высшем таксономическом уровне // Дальневосточный энтомолог. 2010. N 207. С. 1-20.

Обсуждаются численность и разнообразие обитающих в почве и подстилке беспозвоночных животных, собранных в 2005 г. в традиционной для Японии сельской местности в окрестностях студенческого городка университета Канадзава. Изучено 10 модельных участков, из которых 7 расположены на культивируемых участках долины, занятых рисовыми чеками в процессе их рекультивации, а 4 участка – в естественных лесных экосистемах. Данные проанализированы на высшем таксономическом уровне, т.е. по классам и отрядам. Методом ординации выявлены ясные отличия фауны беспозвоночных как между разными биотопами (лесные участки, заросли бамбучника, поля), так и между почвенным и подстилочным ярусами, характеризующимися специфичными условиями обитания. Наибольше влияние на разнообразие и численность беспозвоночных, особенно коллембол и пауков, оказывает наличие или отсутствие подстилки.

1) Высшая школа естественных наук и технологии, Университет Канадзава, Канадзава, Япония.

2) Отделение биоразнообразия, Институт природы и технологий охраны окружажщей среды, Университет Канадзава, Канадзава, Япония.

INTRODUCTION

In Japan, "satoyama" is a traditional rural, composed of several habitat types, e.g. paddy fields, secondary forests, grasslands, ponds, and streams (Kato, 2001; Kobori & Primack, 2003; Takeuchi *et al*., 2003). The satoyama is supposed to be important because it provide us various kinds of "ecosystem services" such as provisioning (e.g. food, timber), regulating (e.g. climate, water), cultural (e.g. aesthetic, recreation) and supporting (e.g. nutrient cycling, soil formation). Recently, however, the management has been neglected in many satoyama areas due to decreasing and aging human population. In unmanaged satoyama, the "type 2" crisis of biodiversity (see, The National Biodiversity Strategy of Japan, 2002) may occur. Biodiversity plays a critical role in the functioning of ecosystems, including ecosystem services to human societies. In satoyama, it is important to monitor the change in biodiversity and biological interactions in relation to the changes of satoyama environments. Reliable studies of biodiversity in both well-managed and neglected satoyama have been still scanty.

The important roles of litter and soil invertebrates in the nutrient cycles in satoyama and other ecosystems have been recognized (e.g. Kazunori *et al*., 2009; Kagawa & Maeto, 2009). Satoyama is characterized by mosaic of various habitat patches in small area with different soil characteristics, due to differences in plant composition, soil management practices, etc. During the development of the soil characters, soil fauna plays important roles in decomposition, nutrient cycling, and maintaining biological, chemical and physical character of the soil ecosystem (Vohland & Schroth, 1999; Ausden *et al*., 2001). Soil invertebrates are also known as ecosystem engineers that directly or indirectly modulate the availability of resources to other species by causing physical state changes in biotic or abiotic materials (Jones *et al*., 1997). Soil invertebrates living in soil and in litter on the ground have been proved to be effective indicators in assessing environmental conditions, including various human disturbances (Paoletti & Bressan, 1996). Soil fauna also have significant effects on the structure of plant communities by creating patches of distinct vegetation (Bardgett, 2005).

This study aims to examined the abundance and taxonomical diversity of soil and litter fauna living in different habitats in an unmanaged satoyama area within Kanazawa University`s Kakuma Campus, Kanazawa, Japan in 2005. This study deals with only invertebrate macrofauna, with body length larger than 1 mm (Coleman *et al*., 2004). In this article, we analyzed the samples at higher taxonomic resolutions mainly classes and orders. These higher-taxon indicators for soil invertebrates often show a performance similar to that of species-level indicators (Paoletti & Bressan, 1996).

So far several biodiversity studies have been done in the present study area, e.g. (1) flying insects using chemical attractant traps (Kanagami *et al*., 1996; Nakamura *et al*., 2006), using water pan trap from different vertical strata in 1999-2000 (Leksono *et al*., 2005) and using window traps (Trisnawati & Nakamura, 2008), (2) various groups of insects using four IBOY-specified traps (pitfall, window, light, and malaise traps) in 2001 (Nakamura *et al*., 2006), (3) ground beetles using pitfall traps (Nakamura *et al*., 2006), and (4) pollination system (Utsunomiya & Nakamura, 2006; Putra & Nakamura, 2009).

STUDY SITES

Climates. The study was carried out in a satoyama area (74 ha, 60-150 m altitude, 5 km southeast of central Kanazawa city, Ishikawa prefecture) in Kanazawa University`s Kakuma Campus (N36°32`E136°42`) (Fig. 1A). In Kanazawa, the average values of annual temperature was 14.5°C with a range from 3.5 (January) to 26.8 °C (August) and annual rainfall 2442.9 mm (for 30 years: 1977–2006) (Japan Meteorological Agency, http://www.data.jma.go.jp). Figure 2 shows the seasonal change of monthly average air temperature and precipitation in 2005.

Vegetation. The Kakuma hills are covered with secondary forests, mainly consisting of deciduous broad leaved trees, predominated with two oak species, *Quercus serrata* and *Q. variabilis*, and patches of plantations of Japanese cedar (sugi), *Cryptomeria japonica*, and moso bamboo, *Phyllostachys* sp. When local people owned the forests in Kakuma, they managed them as satoyama forests and used Kitadan valley as terraced paddies. The forests and terraced paddies have been abandoned since the land was sold to Kanazawa University in the early-1980s. The forests in the campus have become taller and denser with shrubs and undergrowth. The sugi plantations and bamboo were also left unmanaged. The bamboo has been expanding quickly, killing other trees and plants. Terraced paddies cultivated in almost all valleys in Kakuma were also abandoned at the same time. Since 2002, terraced paddies in Kitadan, a small valley (0.5 ha), have been restored gradually by local volunteers for nature education and for monitoring the biodiversity change during the restoration.

SAMPLING METHODS

Sampling site. In July of 2005, a total of ten sampling sites with different vegetations and land use were established. Six were located in Kitadan valley (Fig. 1C): (1) site SA1, SA2 and SA3 were in the dwarf bamboo, *Sasa* sp. fields, located in the edges between forest and cultivated area, (2) site PF1 and PF2 on the bank between paddy fields, (3) site ME in a Japanese millet plantation, established in May 2004. During the study period, agricultural practices, e.g. mowing, weeding and water ditch construction, were frequent. Ploughing and mowing were conducted in rice paddies from June to September. Site ME was the driest area in Kitadan and the millet was cultivated from May until September. Other four sites were located in Kakuma forest (Fig. 1B) : (1) site BM was located in an unmanaged moso bamboo grove, (2) site KO in *Q. serrata* (Konara in Japanese language) stand, (3) site KA in *Q. variabilis* (Abemaki) stand, and (4) site CD in an unmanaged *C. japonica* (Japanese cedar) plantation. Below the Kitadan valley and Kakuma forest are reffered as "Kitadan valley" and "forested area". Furthermore, four sites in the forests (BA, KO, KA and CD) and three sites, located in margin of Kitadan (SA1, SA2 and SA3) are referred to as "unmanaged sites", meanwhile cultivated areas in Kitadan (ME, PF1 and PF2) are referred to as "managed sites".

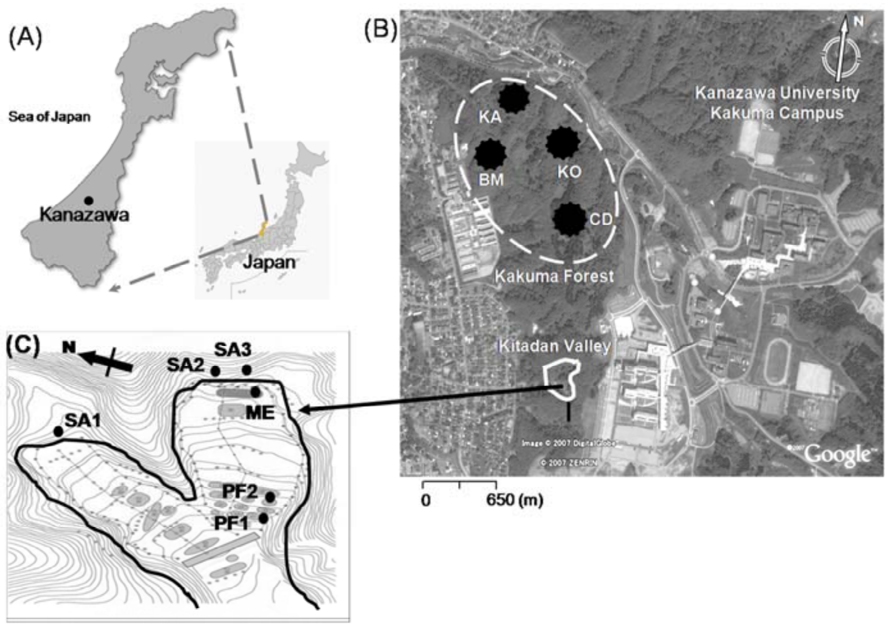

Fig. 1. Maps showing the location of Kanazawa city (A) and the forested area and Kitadan valley (B) in Kakuma Campus of Kanazawa University. Four and six sampling sites, established in the forested area and Kitadan valley, are indicated within dashed and solid lines, respectively. See the text and Table 1 for explanations of sampling site codes.

Table 1

Environmental characteristics of the ten sampling sites in the study area

Site code	Vegetation	Dominant plant species	Manage-ment in 2005	Month	Litter		Soil	
					Thick-ness, mm	**Fresh weight, g**	**Tempe-rapture, °C**	**Mois-ture, %**
KO	Secondary broad-leaved forest	*Quercus serrata*	None	July	16,7	140,7	20,2	13,3
				Sept	42,0	127,2	19,4	20,0
				Nov	42,0	276,5	12,5	78,3
				Mean	33,6	181,5	17,4	37,2
KA		*Quercus serrata, Q. variabilis*	None	July	15,7	255,4	21,5	30,0
				Sept	40,0	152,9	19,1	10,0
				Nov	40,0	229,7	9,9	46,7
				Mean	31,9	212,7	16,9	28,9
CD	Japanese cedar plantation	*Crypto-meria japonica*	None	July	11,7	334,3	22,6	50,0
				Sept	63,0	256,1	19,5	38,3
				Nov	63,0	328,6	19,5	38,3
				Mean	45,9	306,4	20,5	42,2
BM	Moso bamboo thicket	*Phyllosta-chys* sp.	None	July	30,0	503,0	20,7	30,0
				Sept	62,0	235,9	19,8	25,0
				Nov	62,0	556,1	9,1	63,3
				Mean	51,3	431,6	16,5	39,4
SA1	Dwarf bamboo field	*Sasa* sp.	Mowing (early Apr)	July	5,7	288,1	22,6	90,0
				Sept	12,0	262,7	20,9	25,0
				Nov	12,0	415,8	13,1	33,3
				Mean	9,9	322,2	18,9	49,4
SA2			None	July	14,3	349,5	22,2	41,7
				Sept	12,0	298,1	20,8	46,7
				Nov	12,0	407,3	9,6	38,3
				Mean	12,8	351,6	17,5	42,2
SA3			None	July	5,3	390,9	22,2	80,0
				Sept	12,0	322,1	20,0	25,0
				Nov	12,0	335,1	9,7	66,7
				Mean	9,8	349,4	17,3	57,2
PF1	Terraced paddies under restoration	*Oryza sativa*, *Polygonum thunbergii*, *Potentilla centigrana*, *Cardamine flexuosa*	Ploughing (Apr), mowing (May-Nov), rice paddy cultivation (Apr-Sept)	July	7,3	69,1	24,1	80,0
				Sept	12,0	74,4	22,5	65,0
				Nov	12,0	73,5	10,8	43,3
				Mean	10,4	72,3	19,1	62,3
PF2				July	5,7	12,0	24,5	80,0
				Sept	11,0	54,9	21,4	20,0
				Nov	11,0	59,8	11,0	40,0
				Mean	9,2	42,3	19,0	46,7
ME	Japanese millet plantation	*Setaria italica*	Cultivation (May-Sept)	July	2,0	25,4	26,1	31,7
				Sept	2,0	20,9	23,4	63,3
				Nov	2,0	20,9	9,5	23,3
				Mean	2,0	22,4	19,7	39,4

Measurement of environmental variables. Immediately before the sampling of soil and litter in the quadrate (see below), soil temperature (^oC), soil moisture (%) and litter thickness (mm) were recorded at three points in each site, and the average of the values were used (Table 1). Soil temperature was measured using a digital soil thermometer with the accuracy 0.1 at 10 cm depth, soil moisture using soil tester with the accuracy of 0.2 at 10 – 15 cm depth below litter layer, and litter thickness on soil surface using ruler with the accuracy of 0.1 cm. Litter gathered from the quadrate were brought to the laboratory for measuring the fresh weight on the same day.

Sampling, sorting and identification of organisms from soil and litter. Soil and litter were sampled in the following manner in the first and second week of July, September, and November of 2005. At each site three sampling quadrats (25 x 25 cm) were randomly placed with 3 – 5 m apart one another. From each quadrate, all litter on the surface and soil within 10 cm depth were sampled. Each sample was separately kept in a cloth bag and transported to the laboratory. Soil and litter samples were hand sorted for organisms larger than 2 mm in size and then extracted by Berlese funnels with 3 mm wire grid mesh aided by a 40 W light bulb. The Barlese extraction was carried out for three consecutive days. All invertebrates sampled were examined under a stereomicroscope and then were separated into higher taxa using the keys of Dindal (1990), Triplehorn and Johnson (2005). The samples were identified to order with exceptions that (1) Hymenoptera were split into Formicidae and other Hymenoptera, (2) Symphyla, Diplopoda, Annelida, Mollusca to class and (3) Platyhelminthes to phyla. All invertebrates thus sorted were counted. After the sorting, the soil and litter were returned to original places to minimize site degradation.

Data analysis. The number of invertebrates collected from soil and litter was compared among sites using ANOVA and Tukey HSD test. In these analyses, the data from 3 sampling points at each site were pooled and then were transformed to ln (x+1) prior to the analyses, as negative binomial distribution usually prevails in soil animal population (Huhta, 2002). These statistical analyses were conducted using Statistica software package (StatSoft Inc., Tulsa, USA). Canonical Correspondence Analysis (CCA) was used to visualize the variation in the composition of soil and litter invertebrate among the sampling sites in relation to environmental variables. CANOCO for Windows version 4.5 with the Monte Carlo test (499 permutations) was used for calculation.

RESULTS AND DISCUSSION

1. Environment conditions

Soil temperature at the open sites (ME, PF1 and PF2) in Kitadan valley was higher, especially in July and September due to the open landscape, than the shady forested areas (BM, KO, KA and CD) and sasa areas (SA1, SA2 and SA3). The lowest soil temperature was recorded at BM (16.5^oC, ranged from 9.1 to 20.7^oC), while the highest at ME in Kitadan valley (19.7^oC, ranged from 9.5 to 26.1^oC) (Table 1).

Soil moisture was significantly different ($p<0.001$) among sampling sites: low at BM (39.4%), KO (37.2), KA (28.9) in the forested area and ME (39.4) in most open place in Kitadan valley. While high at PF1 (62.3), located on the bank of paddy fields.

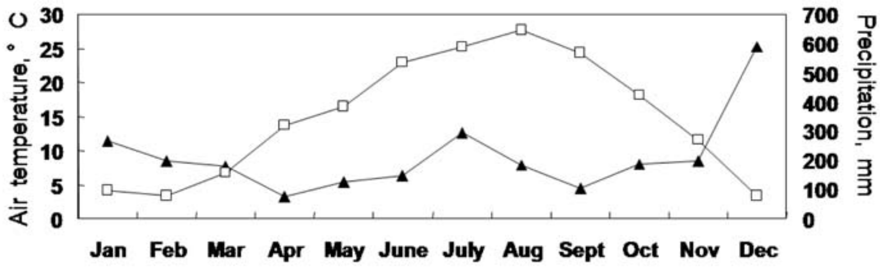

Fig. 2. Changes in the average monthly values of air temperature (□) and monthly precipitation (▲) of Kanazawa city in 2005 (obtained from Japan Meteorological Agency, http://www.data.jma.go.jp).

Litter fresh weight was significantly different ($p<0.001$) among sampling sites: the highest at BM (431.6 g), followed by SA2 (351.6), SA3 (349.4) and SA1 (322.2), while lowest at ME (22.4), followed by PF2 (42.3) and PF1 (72.3) located in Kitadan valley. Litter decomposition rate was low in the sites dominated by dense moso bamboo (BM) and sasa (SA1, SA2 and SA3), due to shading effect and low soil temperature (Ishikawa *et al*., 2006; Risch *et al*., 2007).

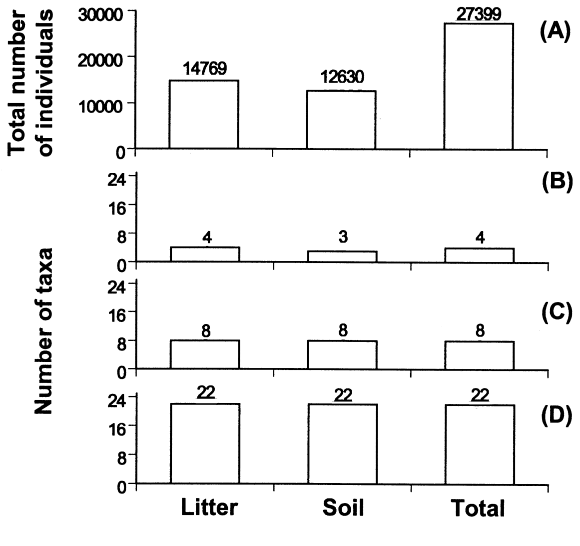

Fig. 3. Total number of individuals (A), and those of taxa at phylum (B), class (C), and order (D) levels in the samples collected from the litter and soil of the satoyama area in Kanazawa University's Kakuma Campus.

Litter layer thickness was lowest at ME among all sampling sites (2 mm) due to the agricultural practices such as mowing and litter removal, while higher at BM and CD (51.3 and 45.9 mm, respectively), where no management practice was carried out.

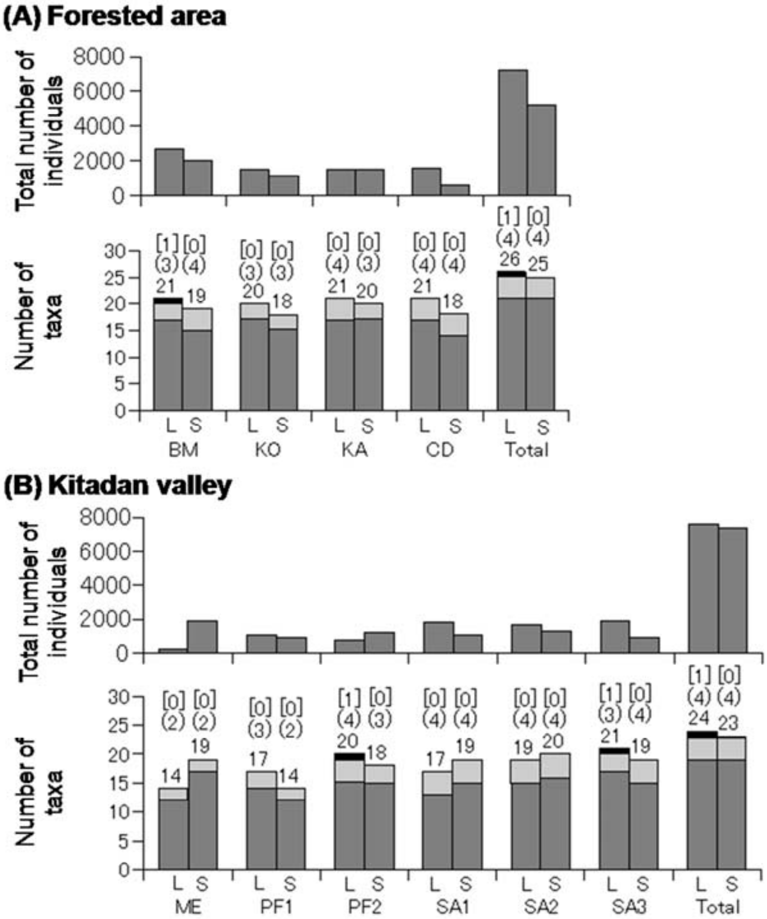

Fig. 4. Total number of individuals (top) and those of taxa (bottom) collected from litter (L) and soil (S) in each sampling site. Number on each bar: total number of taxa, including the number of phyla in square brackets and that of classes in parentheses; black – phylum; light grey – class; dark grey – order. Sampling site codes are as in Table 1.

2. Abundance

(2.1) **Whole study site**. In total, 27,399 individuals were collected (14,769 and 12,630 from litter and soil, respectively) from the whole study sites. No difference was found in total number of individuals between litter and soil (Kruskal-Wallis test, $p>0.05$) (Fig. 3).

(2.2) **Habitat groups**. Mean total number of individuals per site collected in the forested area (1805.0 (mean) ±567.7 (SD) and 1311.5±604.3 in litter and soil, respectively) was larger than in Kitadan valley (1258±685.5 and 1231±358). In both areas, total number of individuals collected from litter was higher than that from soil (7220 vs 5246 and 7549 vs 7384 in the forested area and in Kitadan valley, respectively) (Fig. 4).

(2.3) **Each study site**. In most sampling sites, total number of individuals collected from litter was higher than from soil, except ME and PF2 (Fig. 4). In soil, the highest number was recorded in BM (1958), followed ME (1913), KA (1483), and SA2 (1186), while CD was the lowest (555), followed by PF2 (1136) and PF1 (949) (Fig. 4). In litter, the highest number was recorded in BM (2653), followed by SA3 (1,935), SA1 (1,839) and SA2 (1,702), while the lowest in ME (220), followed by PF2 (754) and PF1 (1,099) (Fig. 4).

3. Taxonomic composition

3.1. General composition

(3.1.1) **Whole study areas**. ***Phyla***: Four phyla, i.e. Annelida, Arthropoda, Mollusca and Platyhelminthes, were recorded from the litter samples, while three phyla without Platyhelminthes from the soil samples (Table 2, Fig. 4).

Class: In both litter and soil samples, eight classes were recorded, consisting of six classes (Arachnida, Insecta, Malacostraca, Chilopoda, Symphyla and Diplopoda) in Arthropoda, one, in Annelida (Oligochaeta) and one, in Mollusca (Gastropoda). Oligochaeta was separated into Megadrile and Microdrile. The former is large terrestrial and semiaquatic segmented worms, commonly referred to as earthworms, while the latter is small, mostly aquatic oligochaete worms (Hendrix *et al*., 2008) (Table 2, Fig. 4).

Order: Arachnida samples consisted of five orders, Insecta 13 orders. Malacostraca two orders, and Chilopoda two orders (Table 2, Fig. 4).

Total number of taxa: In this article, the numbers of "taxa" are counted at order level, while the phylum Platyhelminthes and classes Chilopoda, Symphyla, Diplopoda and Oligochaeta are treated as one taxon, because these are not identified into lower levels. Thus, as mentioned below, a total 27 "taxa", including one phyla, four classes mentioned above and 22 orders were recorded in the whole area. Twenty seven and 26 "taxa" were recorded from litter and soil samples, respectively (Table 2).

(3.1.2) **Habitat groups**. Total number of "taxa" was slightly larger in the forested area (26 and 25 in litter and soil, respectively) than in Kitadan valley (24 and 23) (Fig. 4, Table 2). In soil, 4 classes and 21 orders were found in the forested area, meanwhile 4 classes and 19 orders in Kitadan valley. In litter, 1 phylum, 4 classes and 21 orders were recorded in the forested area, while 1 phylum, 4 classes and 20 orders in Kitadan valley. Generally, the composition of "taxa" was similar in both area, but some "taxa" such as Isoptera, Thysanoptera and Neuroptera were found only in the forested area (Table 2).

Table 2

Number of individuals (up to order level) collected from litter (L) and soil (S) at each sampling site

Taxa	Sampling Site																				Grand Total			ANOVA
	BM		KO		KA		CD		ME		PF1		PF2		SA1		SA2		SA3					
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	Total	
Arachnida																								
Acariformes	627	320	218	126	431	281	254	100	30	138	311	73	152	106	210	192	427	216	468	135	3128	1687	4815	p<0.05
Parasitiformes	509	319	296	122	283	280	244	62	16	80	123	84	112	105	305	184	275	190	317	121	2480	1547	4027	ns
Araneae	84	40	40	15	22	50	38	9	9	9	20	19	40	30	55	13	56	6	48	11	412	202	614	p<0.01
Pseudoscorpionida	1	4	1		1	1										2	2	3	3		8	10	18	ns
Opiliones			1											2					3		4	2	6	ns
Total	1221	683	556	263	737	612	536	171	55	227	454	176	304	243	570	391	760	415	839	267	6032	3448	9480	
Insecta																								
Collembola	946	725	292	222	341	530	571	97	16	77	174	77	118	219	486	270	240	203	263	186	3447	2606	6053	ns
Hymenoptera (Formicidae)	38	96	194	96	123	72	85	109	51	1321	129	417	78	299	285	131	208	273	291	214	1482	3028	4510	ns
Diptera (larvae)	17	233	139	82	41	11	137	60	32	68	18	73	62	78	60	42	44	36	84	12	634	695	1329	ns
Coleoptera	54	31	26	23	45	30	45	12	9	35	36	34	29	58	48	37	88	48	57	32	437	340	777	p<0.01
Lepidoptera (larvae)	64	5	62	4	63	6	53	8	1	5		2	4	10	22	7	37	3	74	3	380	53	433	p<0.01
Coleoptera (larvae)	13	22	7	31	7	27	15	16	7	53	9	32	12	45	10	17	16	9	6	2	102	254	356	p<0.01
Hemiptera	1		3	1	3	13	3	1	7	33	35	12	39	33	21	6	13	4	14	3	139	106	245	p<0.01
Diptera	9	16	1	18	4	5	16	13	16	5	23	11	7	11	15	13	7	8	4	7	102	107	209	ns
Isoptera			12	102			2														14	102	116	ns
Psocoptera	1	3			3	5	1			3	2	3	10	6	6	3	1	5	2	2	26	30	56	ns
Diplura		3		3	3	15	7	1		1						7		5	1	1	11	36	47	ns
Hymenoptera	5	3	2	1	3	4	2		2	4	2	2	1	3	3	2	3	2	3	2	26	23	49	ns
Blattodea	1				14	2			1	1											16	3	19	ns
Thysanoptera	2	2	2		1		5														10	2	12	p<0.01
Lepidoptera	1										1		1				1				4		4	ns
Orthoptera								1		1			1								1	2	3	ns
Neuroptera							1	1													1	1	2	ns
Total	1152	1139	740	583	651	720	943	319	142	1607	429	663	362	762	956	535	658	596	799	464	6832	7388	14220	

Continue of Table 2

Taxa	Sampling Site																				Grand Total			ANOVA
	BM		KO		KA		CD		ME		PF1		PF2		SA1		SA2		SA3					
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	Total	
Malacostraca																								
Isopoda	103	31	78	35	63	51	45	11	3	18	25	17	14	14	109	53	137	42	125	43	702	315	1017	p<0.01
Amphipoda			16	5		1			3	11	36	61	35	50				2	8	1	98	131	229	p<0.01
Total	103	31	94	40	63	52	45	11	6	29	61	78	49	64	109	53	137	44	133	44	800	446	1246	
Chilopoda																								
Geophilomorpha	49	20	16	72	6	16	11	23		10	3			1	19	27	26	78	16	23	146	270	416	p<0.01
Lithobiomorpha	48	18	14	20	23	31	19	8		9	1		1	2	13	4	27	15	38	29	184	136	320	p<0.01
Total	97	38	30	92	29	47	30	31		19	4		1	3	32	31	53	93	54	52	330	406	736	
Symphyla	43	60	6	9	17	51	8	21		25	15	26	3	59	8	14	7	19	15	7	122	291	413	ns
Diplopoda	10	7	2	6	4	1	7	2	1	6	3	6	11	5	71	17	20	19	26	31	155	100	255	p<0.01
Total	2626	1958	1428	993	1501	1483	1569	555	204	1913	966	949	730	1136	1746	1041	1635	1186	1866	865	14271	12079	26350	
Oligochaeta (Megadrile)	13	24	11	47	4	10	6	42	1		2		2	34	2	12	1	13	26	46	68	228	296	p<0.01
Oligochaeta (Microdrile)	13	46	20	45	16	22	9	14	15		131		19	34	89	49	62	61	42	36	416	307	723	p<0.01
Total	26	70	31	92	20	32	15	56	16		133		21	68	91	61	63	74	68	82	484	535	1019	
Mollusca																								
Gastropoda		3			1		2	4					2		2	2	4	3		4	11	16	27	ns
Platyhelminthes	1												1						1		3		3	ns
Grand total	**2653**	**2031**	**1459**	**1085**	**1522**	**1515**	**1586**	**615**	**220**	**1913**	**1099**	**949**	**754**	**1204**	**1839**	**1104**	**1702**	**1263**	**1935**	**951**	**14769**	**12630**	**27399**	p<0.05

Sampling site codes are as in Fig. 1.

(3.1.3) **Each study site**. More "taxa" were recorded in litter than in soil at each site except ME and SA1. In soil, the highest number of taxa was found in the forested area, i.e. KA and SA2 (20 "taxa"), followed by BM (19), and three sites in the Kitadan valley, ME (19), SA1 (19), and SA3 (19). The lowest number was in the Kitadan valley, i.e. PF1 (14), followed by PF2 (18) and 2 sites in the forested area, KO (18) and CD (18) (Table 2). In litter, the highest number of "taxa" were found in BM, KA, CD and SA3 (21"taxa"), followed by KO (20) and PF2 (20). All of those sites were located in the forested area except for SA3 and PF2, located in Kitadan valley. While the lowest number of "taxa" was recorded in Kitadan valley, i.e. ME (14), followed by PF1 (17) and SA1 (17).

Some "taxa" were recorded only in particular sites, e.g. Pseudoscorpionida (BM, KO, KA, SA1, SA2, SA3), Opiliones (KO, PF2, SA3), Isoptera (KO, CD), Blattodea (BM, KA, ME), Thysanoptera (BM, KO, KA, CD), Orthoptera (CD, ME, PF2) and Neuroptera (CD). Present results show that number of "taxa" was higher in the areas without management practices (the forest area) than in the areas with management (the Kitadan valley) (Table 2).

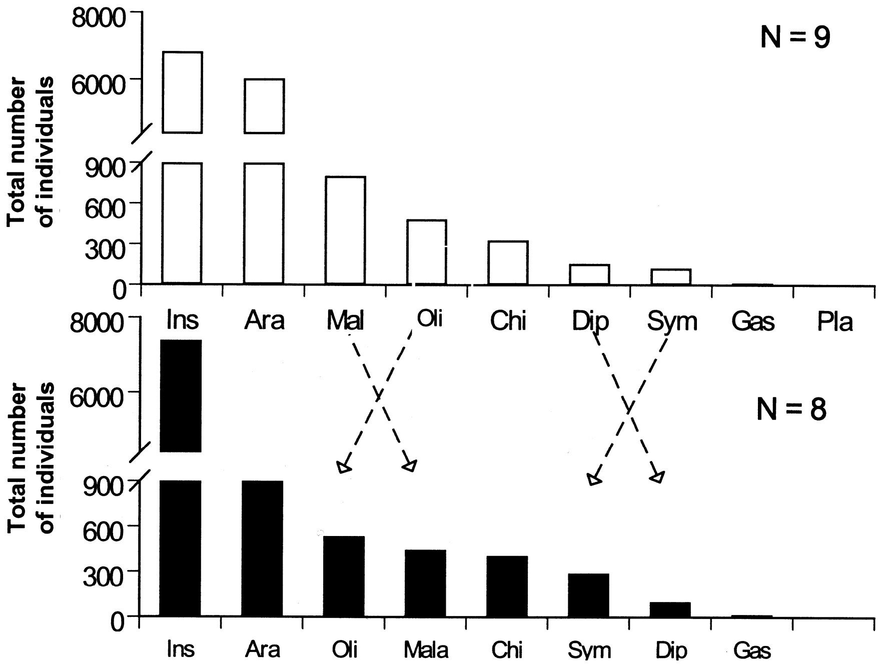

Fig. 5. Order of abundance of the macrofauna at class level for the entire study area, collected from litter (top) and soil (bottom). Sampling site codes are as in Fig. 1. Abbreviations of taxa: Ins – Insecta; Ara – Arachnida; Mal – Malacostraca; Oli – Oligochaeta; Chi – Chilopoda; Dip – Diplopoda; Sym – Symphyla; Gas – Gastropoda; and Pla – Platyhelminthes, a phylum that we did not categorize into classes.

3.2. Ranking of taxa at phyla and class levels

(3.2.1) **Whole study site**. In soil, Insecta made up 58.5% of the total number of individuals collected, followed by Arachnida (27.3%), Oligochaeta (4.2%), Malacostraca (3.5%), Chilopoda (3.2%), Symphyla (2.3%), Diplopoda (0.8%) and Gastropoda (0.1%) (Fig. 5).

In litter, the ranking of the number of individuals collected was as follows : Insecta (46.3%), Arachnida (40.8%), Malacostraca (5.4%), Oligochaeta (3.3% and 4.2%), Chilopoda (2.2%), Diplopoda (1%), Symphyla (0.8%), Gastropoda (0.1%) and Platyhelminthes (0.02%) (Fig. 5). The ranking in soil (Fig. 5, bottom) was same as in the litter (Fig. 5, top) except that ranking changed in Malacostraca (third to fourth), Oligochaeta (fourth to third), the Diplopoda (sixth to seventh) and Symphyla (seventh to sixth).

(3.2.2) **Habitat groups**. ***Forested area***: In soil, Insecta also made up 52.6% all individuals collected, followed by Arachnida (33%), Oligochaeta (4.8%), Chilopoda (4%), Symphyla (2.7%), Malacostraca (2.6%), Diplopoda (0.3%) and Gastropoda (0.1%) (Fig.6B). In litter, Insecta made up 48.3% of all individuals collected, followed by Arachnida (42.2%), Malacostraca (17.3%), Chilopoda (9.5%), Oligochaeta (5.4%), Symphyla (3.7%), Diplopoda (1.2%), Gastropoda (0.2%) and Platyhelminthes (0.04%) (Fig. 6A).

Kitadan valley: In soil, Insecta made up 62.7% of all individuals collected, followed by Arachnida (23.3%), Malacostraca (4.2%), Oligochaeta (3.9%), Chilopoda (2.7%), Symphyla (2%), Diplopoda (1.1%) and Gastropoda (0.1%) (Fig. 6B). In litter, Insecta made up 44.3% of all individuals collected, followed by Arachnida (39.5%), Malacostraca (6.6%), Oligochaeta (5.2%), Chilopoda (1.9%), Diplopoda (1.7%), Symphyla (0.6%), Gastropoda (0.1%) and Platyhelminthes (0.03%) (Fig. 6A).

It can be summarized that in both forested area and Kitadan valley, (1) both litter and soil, Insecta and Arachnida were most dominant; (2) in soil, the percentages of Insect was almost two times larger than in litter.

(3.2.3) **Each study site**. In soil of both the forested and the Kitadan areas, Insecta was the most dominant class : in the forested area, BM (56.1%), KO (53.7%), KA (47.5%) and CD (52%), followed by Arachnida; in Kitadan valley, ME (84%), PF1 (70%), PF2 (63.3%), SA1 (48.5%), SA2 (47.2%) and SA3 (49%), followed by Arachnida (Fig. 6). The following minor classes were recorded in certain sites with higher percentage: Malacostraca in KO (3.7%), KA (3.4%), PF1 (8.2%), PF2 (5.3%), SA1 (4.8%), SA2 (3.5%) and SA3 (4.6%); Chilopoda in KO (8.5%), CD (5%), SA1 (2.8%), SA2 (7.4%) and SA3 (5.5%); Symphyla in BA (3%), KA (3.4%); CD (3.4%), PF1 (2.7%) and PF2 (4.9%); Diplopoda in SA3 (3.3%); Oligochaeta in KO (8.5%), CD (9.1%), PF2 (5.7%), SA1 (5.5%), SA2 (5.9%) and SA3 (8.6%) (Fig. 6).

In litter of both Insecta and Arachnida were most dominant in both forested and Kitadan areas. In forested area, Arachnida was dominant in BM (46%) and KA (48.4%), while Insecta was highest in KO (50.7%) and CD (59.5%). In Kitadan valley, Arachnida was dominant in PF1 (41.3%), SA2 (44.7%) and SA3 (43.3%), while Insecta was dominant in ME (65%), PF2 (48%), SA1 (52%). The following minor classes were recorded in certain sites with higher percentage : Malacostraca in KO (6.4%), PF1 (5.6%), PF2 (6.5%), SA1 (5.9%), SA2 (8.1%) and SA3 (6.9%); Chilopoda in BA (3.7%), KO (2.1%), KA (1.9%), CD (1.9%), SA1 (1.7%), SA2 (3.11%) and SA3 (2.8%); Oligochaeta in ME (7.3%), PF1 (12.1%), SA1 (5%), SA2 (3.7%) and SA3 (3.5%); Diplopoda in SA1 (3.9%), SA2 (1.2%) and SA3 (1.3%) (Fig. 6). Some taxa showed specific habitat preference, e.g. Symphyla was collected from the sites with thick litter without human disturbance (BM) (see, Migge-Kleian *et al*., 2007), while Malacostraca (Amphipoda) from the continuously wet paddy field sites in Kitadan valley (PF1 and PF2) (see, Hassall *et al*., 1987; Vilisic *et al*., 2007).

It can be summarized that (1) in soil, Insecta was dominant in all sites, meanwhile in litter Insecta and/or Arachnida was dominated in most sites; (2) minor classes, e.g. Malacostraca, Oligochaeta and Diplopoda were more common in Kitadan valley than in forested area; meanwhile Chilopoda in the areas without management practices (the site in the forested area and sasa sites), where litter layer was thick and moist (Table 2, Fig. 6) and number of potential prey might be larger (Lawrence & Wise, 2000)

3.3. Order composition in Class Insecta

(3.3.1) **Whole study site**. In Class Insecta, a total number of orders collected was 13, 12 in soil and 13 in litter, respectively. Figure 7C shows the abundance ranking at order level in soil : Formicidae was the most abundant order, making up 24.0% of the total number of individuals collected, followed by Collembola (20.6%), Diptera (larvae and adults, 6.3%), Coleoptera (larvae and adults, 4.7%), Hemiptera (0.8%), Isoptera (0.8%), Lepidoptera (larvae and adults, 0.4%), Diplura (0.3%), Psocoptera (0.2%), Hymenoptera (0.2%), Blattodaea (0.02%), Thysanoptera (0.02%), Orthoptera (0.02%) and Neuroptera (0.01%). Meanwhile, in litter, Collembola was the most abundant order, making up 23.3% of the total number of individuals collected (Table 2), followed by Formicidae (10.0%), Diptera (larvae and adults, 5.0%), Coleoptera (larvae and adults, 3.6%), Lepidoptera (larvae and adults, 2.6%), Hemiptera (0.9%), Psocoptera, (0.2%), Isoptera (0.8%), Diplura (0.3%), Hymenoptera (0.2%), Blattodea (0.1%), Thysanoptera (0.07%), Orthoptera (0.01%) and Neuroptera (0.01%). The abundance ranking of orders in class Insecta was quite different between litter and soil, except the fact Diptera (larvae and adults) and Coleoptera (larvae and adults) showed in the same ranking (third and fourth).

(3.3.2) **Habitat groups**. ***Forested area***: In soil, Collembola was most abundant (30.0%), followed by Diptera (larvae and adults, 8.3%), Formicidae (7.1%), Coleoptera (larvae and adults, 3.7%) and Isoptera (1.9%), Lepidoptera (larvae and adults, 0.4%), Diplura (0.4%), Hemiptera (0.3%), Psocoptera (0.2%), Hymenoptera (0.2%), Blattodea (0.04%), Thysanoptera (0.04%), Orthoptera (0.02%) and Neuroptera (0.02%) (Table 2, Fig. 7A). In litter, the abundance ranking was as follows: Collembola was the most abundant, making up 29.8% of the total number of individuals collected from forested area, followed by Formicidae (6.1%), Diptera (larvae and adults, 5.0%), Lepidoptera (larvae and adults, 3.4%), Coleoptera (larvae

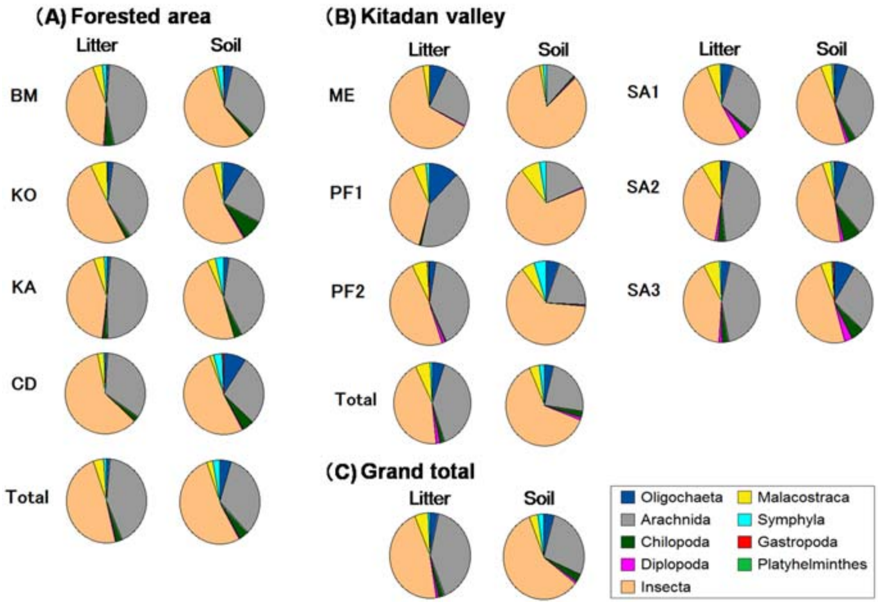

Fig. 6. Comparison of faunal composition in soil and litter at class level among the sampling sites in (A) forested area and (B) Kitadan valley. Sampling site codes are as in Table 1.

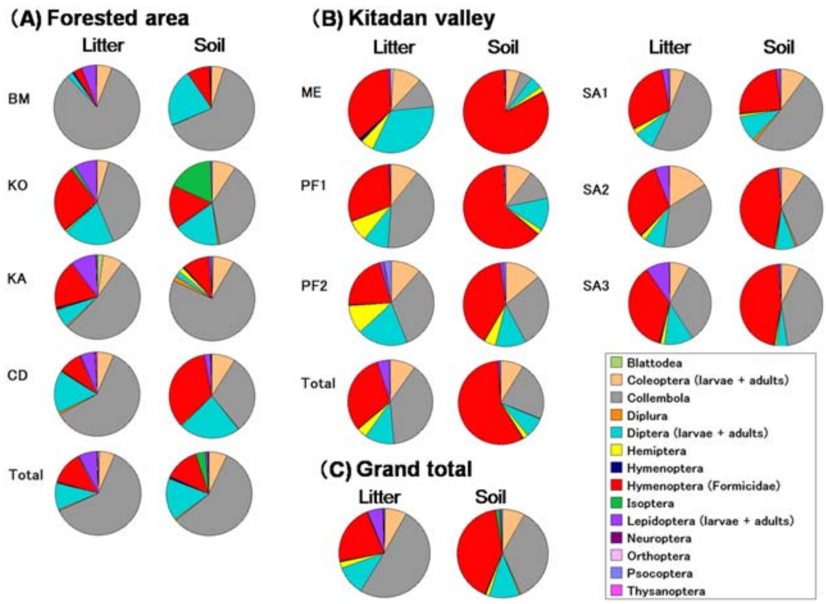

Fig. 7. Comparison of faunal composition in soil and litter at order level in the class Insecta among the sampling sites in (A) forested area and (B) Kitadan valley. Sampling site codes are as in Table 1.

and adults, 2.9%), Blattodea (0.2%), Isoptera (0.2%), Hymenoptera (0.2%), Hemiptera (0.1%), Diplura (0.1%), Thysanoptera (0.1%), Psocoptera (0.07%) and Neuroptera (0.01%). Orthoptera was not recorded in litter sample (Table 2).

Kitadan valley: In soil, Formicidae was the most abundant taxa (36.0%), followed by Collembola (14.0%), Coleoptera (larvae and adults, 5.4%), Diptera (larvae and adults, 4.9%), Hemiptera (1.2%), Lepidoptera (larvae and adults, 0.4%), Psocoptera (0.3%), Hymenoptera (0.2%), Diplura (0.2%), Blattodea (0.01%) and Orthoptera (0.01%) (Table 2, Fig. 7B). In litter, Collembola was most abundant taxa (17.2%), followed by Formicidae (13.8%), Diptera (larvae and adults, 4.9%), Coleoptera (larvae and adults, 4.3%), Lepidoptera (larvae and adults, 1.2%), Hemiptera (1.7%), Psocoptera (0.3%), Hymenoptera (0.2%), Diplura (0.01%), Blattodea (0.01%) and Orthoptera (0.01%).

Summarizing, (1) the abundance ranking at order levels in class Insecta was quite different between litter and soil, both in the forested area and Kitadan valley; (2) Collembola was the most dominant order in forested area (both in litter and soil) and Kitadan valley (in litter), meanwhile Formicidae was the most dominant order in soil of Kitadan valley. As mentioned bellow, a large number of ants were collected from soil of ME and PF1.

(3.3.3) **Each study site**. In soil, Collembola was the most abundant in both forested and Kitadan areas except for ME and PF1, where Formicidae was dominant (69.1% and 43.9%). Formicidae was the second abundant in KA (4.8%), CD (17.7%), PF2 (24.8%), SA1 (11.9%), SA2 (21.6%) and SA3 (22.5%). Diptera (larvae and adults) was the second dominant in BM (12.3%) and PF1 (8.9%). Meanwhile Coleoptera (larvae and adults) was the second dominant in ME (4.6%). Isoptera appeared more frequent in KO (9.4%) (Fig. 7).

In litter, Collembola was the most abundant in all sites in both forested and Kitadan areas except for ME, where Formicidae was dominant (23.2%). Formicidae was the second most abundant in KO (13.3%), KA (8.1%), PF1 (11.7%), PF2 (10.3%), SA1 (15.5%) SA2 (12.2%), and SA3 (15.0%). Diptera (larvae and adults) was the second most abundant in CD (9.6%) and ME (21.8%), while Coleoptera (larvae and adults) in BM (2.5%) (Fig. 7). Isoptera was found only in KO and CD in the forested area, where woody materials were abundant (Table 2). Distribution of Coleoptera adults ($F=2.41$, $p<0.01$), Coleoptera larvae ($F=2.83$, $p<0.01$), Lepidoptera larvae ($F=9.06$, $p<0.01$), Hemiptera ($F=3.43$, $p<0.01$), and Thysanoptera ($F=2.49$, $p<0.01$) were significantly biased among different sampling sites.

These results indicate that (1) the order composition was quite different between litter and soil both in forested and Kitadan areas; (2) the abundant orders, Collembola and Lepidoptera (larvae and adults), were more prevalent in the forested area than in Kitadan valley. Meanwhile, Formicidae, Oligochaeta, Diptera (larvae and adults) and Coleoptera (larvae and adults) were more abundant in the Kitadan valley than in the forested area.

4. Multivariate analysis

In Figure 8, CCA ordination visualizes the variation in the soil and litter faunal composition obtained from the sites in the forested area and Kitadan valley at three sampling periods (July, September and November, 2005). Although there are some exceptions, the figure shows that most litter samples (open symbols) were located in

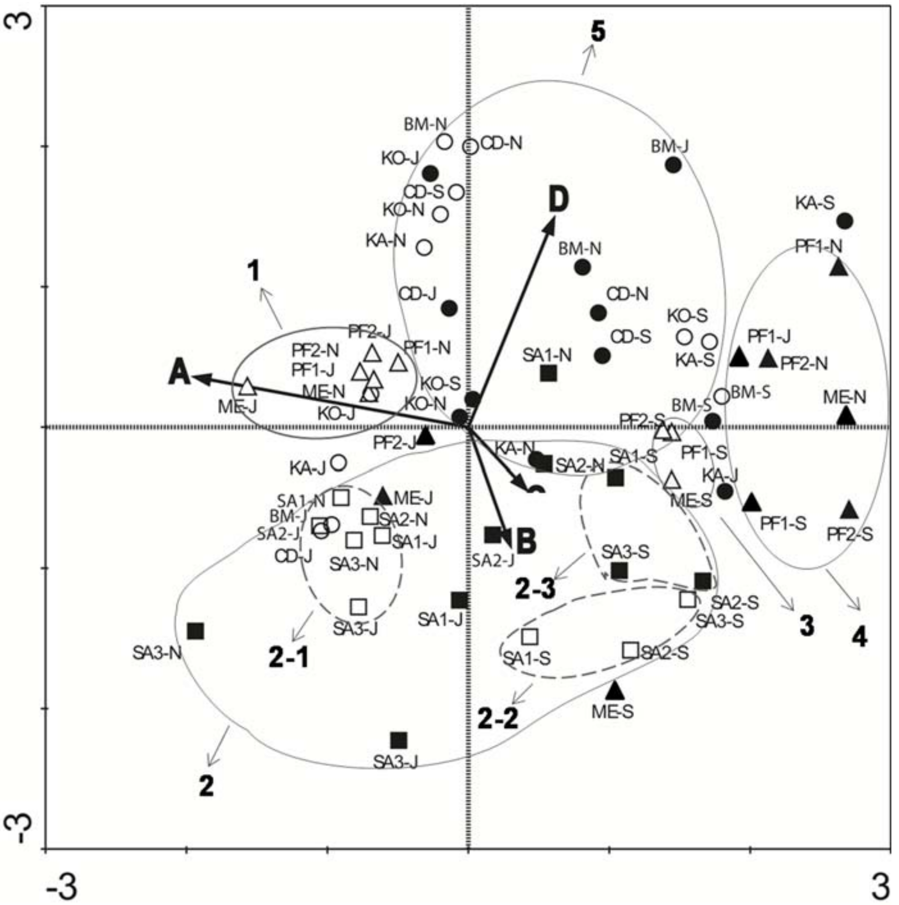

Fig. 8. CCA ordination showing the variation in faunal composition among the sampling sites (site codes are as in Table 1), sampling layers (soil and litter, denoted with closed and open symbols, respectively), and sampling periods (J, S, and N, hyphenated with the sampling site codes indicate July, September, and November of 2005, respectively). Arrows indicate the environmental parameters (A – soil temperature; B – litter biomass; C – soil moisture; and D – litter thickness). ○ – sites in forested area; □ , sasa sites; and △ , sites in Kitadan valley. Circles with numbers (1–5) indicate the groups of sampling sites. Dotted circles in circle 2 show the sasa sites, sampled during different months.

the left side of the y-axis and the soil ones (closed symbols) in the right side, indicating that soil and litter layer were rather clearly separated from each other. In more closer view, the following facts are also revealed: in PF1, PF2 and ME, the culativated sites in Kitadan, litter samples (circle 1 and 3) were distinctly different from soil samples (circle 4), as mentioned in earlier part (see, Order composition in class Insecta). The litter samples, moreover, collected in September (circle 3) is also different from those collected in July and November (circle 1). In the sasa sites (SA1, SA2 and SA3), the litter samples (open rectangles within dotted circle 2-1) were separated from the soil samples with exceptions of those collected in September (dotted circle 2-2) and SA3 in November (circle 2). With regard to seasonality in the sasa sites, the samples collected in September from both litter (dotted circle 2-2) and soil (2-3) were separated from the litter and soil samples, respectively, collected in July and November. In addition, the soil and litter samples collected from the sasa sites in September also were separated along the second axis. However, in the forested sites (circle 5) faunal composition was not separated neither among the sites and between litter and soil nor among sampling months. The possible reason why samples collected in September differed from those collected in July and November in Kitadan valley may depend on the local climate and amount of litter. In the study area, precipitation was low and temperature was high in September (Fig. 2), which affected the populations of major taxa such as Collembola.

In the above ordination, the first and second CCA axes explained 5.3% and 1.3% of variation, respectively. Monte-Carlo test showed that the first axis (F = 4.432, p = 0.002) and all axes are highly significant (F = 2.085, p = 0.002) with first axis explain more than other axes. The species-environment correlation coefficients for the first and second CCA axes were 0.89 and 0.82, respectively, suggesting a strong relation between soil and litter taxa to litter thickness, litter biomass, soil moisture (second axis) and the soil temperature (first axis) (Fig. 8). Biological interpretation of CCA ordination (Fig. 8) may be related to the following facts: Collembola and Acariformes were abundant in litter of the forested and sasa sites (e.g. BA, KA, KO, SA1, SA2 and SA3) (Fig. 7) and have positive correlation with litter biomass and litter thickness, but have negative correlation with soil temperature and humidity (Fig. 8). Formicidae was abundant in agriculture area in Kitadan valley (e.g. PF1, 2 and 3 and ME), where litter was scarce.

ACKNOWLEDGEMENTS

We thank the following persons for their encouragement and assistance in the field: Mr. K. Aoki, Mr. S. Kameda, Mr. N. Kameda, and all members of the Laboratory of Ecology, Faculty of Science, Kanazawa University. We also thank to Mr. R.E Putra and C. Yanto for sorting and identification. This work was supported partly by the 21st Century COE Program of Kanazawa University (2002–2005, team leader Professor K. Hayakawa), by a Grant-in-Aid for Scientific Research (No. 18580328) to Koji Nakamura, and by a Japanese Government (Monbukagakusho) Scholarship to Ida Kinasih.

REFERENCES

Ausden, M., Sutherland, W. J. & James, R. 2001. The effects of sooding lowland wet grassland on soil macroinvertebrate prey of breeding wading birds. *Journal of Applied Ecology*, 38: 320–338.

Bardgett, R. 2005. *The biology of soil: a community and ecosystem approach*. Oxford University Press Inc., New York.

Coleman, D.C., Crossley, Jr. D.A. & Hendrix, P.F. 2004. *Fundamentals of soil ecology*. Elsevier Academic Press, USA.

Dindal, D. L. 1990. *Soil Biology Guide*. John Wiley & Sons, Inc.

Hassall, M., Turner, J.G. & Rands, M.R.W. 1987. Effects of terrestrial isopods on the decomposition on woodland leaf litter. *Oecologia*, 72: 597–604.

Huhta,V. 2002. Soil macroarthropod communities in planted birch stands in comparison with natural forests in central Finland. *Applied Soil Ecology*, 20: 199–209.

Jones, C.G., Lawton, J.H. & Shachak, M. 1997. Positive and negative effects of organisms as physical ecosystem engineers. *Ecology*, 78: 1946–1957.

Kagawa, Y. & Maeto, K. 2009. Spatial population structure of the predatory ground beetle *Carabus yaconicus* (Coleoptera: Carabidae) in the mixed farmland-woodland satoyama landscape of Japan. *European Journal Entomology*, 106: 385–391.

Kanagami, H., Nakano, T., Takada, K., Nakamura, A. & Nakamura, K. 1996. Insect fauna sampled by chemical traps on Kakuma hills in Kanazawa City. *Proceeding of the Association for Plant Protection of Hokuriku*, 44: 81–85. (In Japanese).

Kato, M. 2001. 'Satoyama' and biodiversity conservation: 'Satoyama' as important insect habitats. *Global Environment Research*, 5: 135–149.

Kazunori, T., Miyake, J., Karita, M., Okumura, H. & Wakatsuki, T. 2009. Dynamics of soil mesofauna in relation to the decomposition rate of leaf litter of *Quercus serrata*, *Chamaecyparis obtuse*, *Clethra barvinervis*, and Bamboo in Satoyama forest the Nara campus, Kinki University. *Memoirs of the Faculty of Agriculture of Kinki University*, 42: 127–144.

Kobori, H. & Primack, R. B. 2003. Conservation for Satoyama, the Traditional Landscape of Japan. *Arnoldia*, 62(4): 2–10.

Lawrence, K.L. & Wise, D.H. 2000. Spider predation on forest-floor Collembola and evidence for indirect effects on decomposition. *Pedobiologia*, 44: 33–39.

Leksono, A.S., Takada, K., Koji, S., Nakagoshi, N., Anggraeni, T. & Nakamura, K. 2005. Vertical and seasonal distribution of flying beetles in a suburban temperate deciduous forest collected by water pan trap. *Insect Science*, 12: 199–206.

Migge-Kleian, S., Woltmann, L., Anas, I., Schulz, W., Steingrebe, A. & Schaefer, M. 2007. Impact of forest disturbance and land use change on soil and litter arthropod assemblages in tropical rainforest margins. – In: Tscharntke T., Leuschner, C., Zeller, M., Guhardja, E. & Bidin, A. (Eds.). *Stability of Tropical Rainforest Margins: Linking Ecological, Economic, and Social Constraints of Land Use and Conservation*. Springer, Berlin.

Nakamura, K., Tanabe, S.I., Kimura, K., Kasagi, T., Utsunomiya, D., Ohwaki, A., Akaishi, D., Takada, K., Linawati, Putra, R.E., Koji, S., Nakamura, A., Okawara, K. & Kinoshita, E. 2006. Satoyama biodiversity and conservation in the Pan-Japan Sea Region. – In: K. Hayakawa et al. (Eds.). *Past, Present and Future Environments of Pan-Japan Sea Region*. Maruzen Co. Ltd. 510–546.

Nature Conservation Bureau, Ministry of Environment, Government of Japan. 2002. *Living with Nature: The national biodiversity strategy of Japan*. Tokyo, Japan. 23pp.

Paoletti, M.G. & Bressan, M. 1996. Soil invertebrates as bioindicators of human disturbance. *Critical Reviews in Plant Sciences*, 15: 21–62.
Risch, A.C., Jurgensen, M.F. & Frank, D.A. 2007. Effects of grazing and soil micro-climate on decomposition rates in a spatio-temporally heterogeneous grassland. *Plant and Soil*, 298: 191–201.
Putra, R.E. & Nakamura, K. 2009. Foraging ecology of local wild bees community in an abandoned Satoyama system in Kanazawa, Central Japan. *Entomological Research*, 39: 99–106.
Takeuchi, K., Brown, R.D., Washitani, I., Tsunekawa, A., Yokohari, M. (Eds.). 2003. *Satoyama: The traditional rural landscape of Japan*. Springer, Berlin.
Triplehorn, C.A. & Johnson, N.F. 2005. *Borror and Delong's Introduction to the Study of Insects. 7th Edition*. Brooks/Cole. Belmont, CA., U.S.A. 864 pp.
Trisnawati, I. & Nakamura, K. 2008. Abundance, diversity, and distribution of above-ground arthropods collected by window traps from Satoyama in Kanazawa, Japan: an order level analysis. *Far Eastern Entomologist*, 181: 1–23.
Utsunomiya, D. & Nakamura, K. 2006. Effects of anthropogenic disturbances on the flowering plant – insect pollinator system in Kanazawa Castle Park, Kanazawa, Japan. *Far Eastern Entomologist*, 162: 1-24.
Vohland, K. & Schroth, G. 1999. Distribution patterns of the litter macrofauna in agroforestry and monoculture plantation in central Amazonia as affected by plant species and management. *Applied Soil Ecology*, 13: 57–68.

© **Far Eastern entomologist (Far East. entomol.)** Journal published since October 1994.

Address: Institute of Biology and Soil Science, Far East Branch of Russian Academy of Sciences, 690022, Vladivostok-22, Russia.
E-mail: entomol@ibss.dvo.ru web-site: http://www.biosoil.ru/fee