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ABUNDANCE, DIVERSITY AND DISTRIBUTION OF THE GROUND BEETLES (COLEOPTERA: CARABIDAE) IN A SATOYAMA VALLEY IN KANAZAWA, JAPAN, WITH SPECIAL REFERENCE TO THE BODY SIZE AND FEEDING CATEGORIES

W. M. ElSayed[1) and K. Nakamura[1,2)

1) *Graduate School of Science and Technology, Kanazawa University, Kakuma, Kanazawa, 920-1192, Japan. E-mail: wael_elsayed88@yahoo.com*

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

Satoyama, the rural landscape in Japan, consisting of mosaic of different habitats, is a key to biodiversity conservation in Japan. The ground beetles (Coleoptera: Carabidae) were captured using pitfall traps from four habitat types, including banks of paddy fields, edges of secondary oak forests, grasslands and wetland from a 'satoyama' valley within Kanazawa University's Campus, Kanazawa, Japan. In total, 1961 specimens of 55 species from 24 genera, 15 tribes and 10 subfamilies were collected in 2007–2008. The species richness, breadth of trophic levels, ubiquitous distribution, and preference to different habitats of ground beetles were investigated.

KEY WORDS: satoyama, carabid assemblage, pitfall trap, distribution, ranking, feeding guild, mandibular morphology.

В. М. Эльсаид[1)], К. Накамура[1,2)]. Плотность, разнообразие и распределение жужелиц (Coleoptera: Carabidae) в традиционной для Японии сельской долине в окрестностях Канадзавы с замечаниями по размерным характеристикам тела и группам питания // Дальневосточный энтомолог. 2010. N 205. С. 1-19.

Сатояма – традиционный сельский ландшафт, представляет собой мозаику разнообразных местообитаний и является ключевым для сохранения биоразнообразия в Японии. Жужелицы (Coleoptera: Carabidae) отлавливались с помощью почвенных ловушек в четырех биотопах (включая рисовые чеки, опушки вторичных дубняков, луга и увлажненные местообитания) в долине с традиционным для Японии сельским ландшафтом в окрестностях студенческого городка университета Канадзава. Всего в 2007–2008 гг. было собрано 1961 экз. жуков 55 видов из 24 родов, 15 триб и 10 семейств. Исследованы видовое разнообразие жужелиц, их трофические группы, общее распределение и предпочтение к определенным местообитаниям отдельных групп жужелиц.

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

"Satoyama" is the traditional rural landscape in Japan, consisting of a mosaic of habitats including paddy and millet fields, farmlands, ponds, streams and forests. In Japan, much attention has recently been paid to satoyama, because (1) it stretches between urban areas and rural areas in mountainous regions, making up 40% of the national land; (2) it provides essential services, such as food, water, and clean air, as well as exhibiting cultural and aesthetic properties (Washitani, 2001; Takeuchi *et al.*, 2003, ElSayed & Nakamura, 2008); and (3) it is a key to biodiversity conservation in Japan (Ministry…, 2002). However, the satoyama is being threatened (the satoyama problem) chiefly because maintenance has been neglected owing to changes in lifestyle and decreasing number and ageing of populations against a background of long-term decline in agriculture and forestry. Around 70% of Ishikawa prefecture (Japan: Honshu region) is satoyama, where forests are considered to be one of the most important elements.

This study aims to examined the abundance and taxonomical diversity of ground beetles (Carabidae) collected using pitfall traps from different habitats in an unmanaged satoyama area within Kanazawa University`s Kakuma Campus, Kanazawa, Japan in 2007–2008. Carabids possess relatively well-known taxonomy and ecological functions, specialized habitat requirements and high abundance and species diversity at soil surface (Niemela et al., 2000). So far several biodiversity studies of the ground beetles have been done in the present study area using pitfall traps (Nakamura *et al*., 2006).

MATERIALS AND METHODS

Study sites

Climate and topography. The study was carried out in a valley (called Kitadan) within the satoyama area (ca. 74 ha, 60-150 m altitude, 5 km southeast of central

Kanazawa city, Ishikawa prefecture) of Kanazawa University's Kakuma Campus (N 36°32' E 136°42') (Fig. 1). In Kanazawa, the average annual temperature value is 14.8^{o} C here and throughout with a monthly average range from 3.5^{o} C (January) to 26.8^{o} C (August) and annual rainfall of 2545 mm (for 30 years: 1977–2006, Japan Meteorological Agency, http://www.data.jma.go.jp).

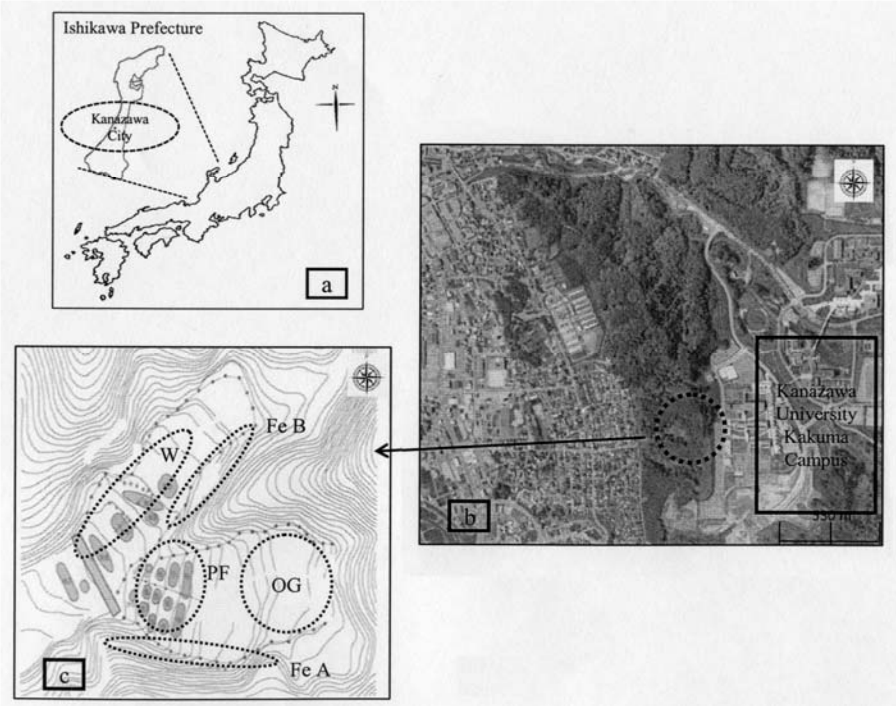

Fig. 1. Map of the study location: (a) Ishikawa Prefecture and Kanazawa City, Japan; (b) aerial photograph showing Kitadan Valley (dotted circle); and (c) the five main sampling sites in Kitadan Valley with their codes. PF – paddy fields, FeA – forest edge A, FeB – forest edge B, OG – open grassland, and W – wetland.

Sampling site. Kakuma forests consist mainly of deciduous broad leaved trees predominated by two oak species, *Quercus serrata* and *Q. variabilis*, patches of plantations of Japanese cedar, *Cryptomeria japonica*, and moso bamboo, *Phyllostachys* sp. When local people owned the forests in Kakuma, they managed them as satoyama forests. The forests have been abandoned since the land was sold to Kanazawa University 30 years ago. The forests in the campus have become taller and denser with shrubs and undergrowth, and the cedar plantations and bamboo have been left unmanaged. The bamboo patches have expanded quickly, killing trees and other plants that were overgrown by the bamboo. Terraced rice paddies cultivated in almost all the valleys, including Kitadan Valley, in Kakuma were also abandoned at the same time. In this study, a total of five sampling sites were established in Kitadan Valley (Fig. 1 c): on the banks of the terraced paddies (coded as PF), at the edges of oak forests (two sites, Fe A and Fe B) in wetland among artificial ponds (W) and in open grassland (OG), in an area of abandoned crop land where millet was cultivated in 2004 and 2005. Since 2002, terraced paddies in Kitadan, a small valley (ca. 0.5 ha, Fig. 1), have been restored gradually by local volunteers for nature education and for monitoring the recovery of biodiversity.

Sampling methods

At each sampling site, 15 unbaited pitfall traps were installed as trapping tools and spaced about 1 m apart along a transect running north to south through the centre of each survey site. The total number of traps in all sampling habitats was 75. Traps were installed in the soil to cover the period from early May till late November for two consecutive years (2007 and 2008). In most excursions, sampling of carabids was performed during the days in the middle of the month especially sunny days.

The traps consisted of white polyethylene beakers (13.5 cm deep, Ø 9 cm). These beakers were primed with 10% ethyleneglycol and a few drops of ordinary detergent to reduce surface tension. Three wooden sticks were drilled around each trap 11 cm below the upper brim and a plastic beaker cover was mounted above each trap to prevent flooding by rainfall and to protect the traps from damage caused by falling leaves or small twigs. The disturbance caused by placing the pitfall traps was minimized and the vegetation around the traps was not cleared. The 'digging in' effect (Greenslade, 1973; Botes *et al.,* 2007) was thus considered negligible and the traps were set immediately. Traps were kept open for two consecutive days and then each trap was emptied from its content and the specimens caught were preserved in Renner's solution (40% ethanol, 30% water, 20% glycerin, 10% acetic acid; Renner, 1982) then brought back to the laboratory for identification, counting and sorting. To reduce the variability caused by sampling error, only one of the authors (W.M.E.) was responsible for making counts in this study.

Ecological traits

Abundance and species richness. The collected carabid species were classified into three classes depending on the total number of collected individuals (n): rare species (R), where $n \leq 5$ individuals; occasional species (O), where $5 < n \leq 25$; and abundant species (A), where $n > 26$.

Concerning the species richness, the expected number of species ($S_{exp.}$) was derived from the observed number of species of carabids ($S_{obs.}$) according to Colwell & Coddington (1994), using the formula derived by Chao (1984):

$S_{exp.} = S_{obs.} + a^2/2b$, where $S_{obs.}$ is the number of observed carabid species, a is the number of carabid species represented by only a single individual (i.e. number of ''singletons'') and b is the number of carabid species represented by exactly two individuals (i.e. number of ''doubletons'').

Body size. Carabid species were measured morphometrically from the tip of the labrum to the extremity of the pygidium using a basic metal Vernier® caliper micrometer (precision ± 0.10 cm) and classified into three body size groups: small (S, ≤ 5 mm), medium (M, 5 mm < body length <15 mm) and large species (L, ≥15 mm) (Table 1).

Habitat preference. The total number of sites from which each carabid species was sampled was recorded to show the habitat preference of the carabid species (Table 1). However, for simplification, forest edges A and B were treated as one habitat and referred to forest edge (A & B). In addition, the number of species shared between each pair of habitats was calculated in an attempt to deduce the flexibility of carabid species in occupying different habitats (Table 1, Fig. 4)

Feeding category. The feeding guild was predicted from mandibular morphology and compared with previous reports whenever data were available. Mandibles were lightly brushed with 80% ethanol and distilled water in an effort to remove most of the sand and debris adhered to the mouthparts. After air-drying, specimens were examined under a Stereo fluorescence microscope (Nikon® SMZ800 series) equipped with a digital camera and a TFT LCD Nikon® monitor. Illumination was provided from a double gooseneck Olympus® HLL-301 device. Photographs were taken with a Syncroscopy Auto-Montage system (Kanazawa University, Laboratory of Biodiversity).

From the structure and morphological adaptations of the mandibles, two guilds were mainly assigned: carnivores (sharp incisors and long terebral ridge) and omnivores species (blunt incisors with short terebral ridge) (Table 1).

Statistical analyses and data processing

Different habitats in Kitadan Valley in different years were clustered by their carabid species richness and abundance to elucidate the degree of similarity among habitats using SPSS V.14 (Fig. 5). Other statistical tests as specified below were conducted using PAST V. 1.92 software running on Windows® XP.

Identification and Nomenclature

Carabids were identified to species level. The nomenclature used is in accordance with the key offered by Nakane (1978). The collected carabid species were also compared with already identified museum specimens in Kanazawa University for further confirmation.

Collected specimens of carabids were deposited in a catalogued repository in Kanazawa University in special boxes containing small sachets enclosing naphthalene-coated tablets for further specimen protection against moths and other destructive pests. These sachets were checked regularly and renewed whenever needed.

Table 1

Number of individuals (I) and ecological traits (II-VI) of carabid beetles collected from different sites of Kitadan Valley combined for 2007 and 2008

Taxa	Ind.	Ecological trait				
	I	II	III	IV	V	VI
Subfamily Bembidiinae						
Tribe Bembidiini						
Bembidion koikei (Habu et Baba)	3	R	FE, W	2	S	Omn.
Bembidion pseudolucillum (Netolitzky)	2	R	FE, W	2	S	Omn.
Tribe Tachyini						
Tachyura exarata (Bates)	3	R	OG, PF, W	3	S	Omn.
Tachyura fuscicauda (Bates)	2	R	OG, W	2	S	Omn.
Tachyura nana (Gyllenhal)	3	R	OG, W	2	S	Omn.
Tachyura tosta (Andrewes)	2	R	FE, OG	2	S	Omn.
Subfamily Brachininae						
Tribe Brachinini						
Pheropsophus jessoensis (Morawitz)	3	R	OG	1	L	Omn.
Subfamily Carabinae						
Tribe Carabini						
Carabus dehaanii punctatostriatus (Bates)	130	A	FE, OG	2	L	Car.
Carabus maiyasanus maiyasanus (Bates)	154	A	FE, OG	2	L	Car.
Leptocarabus procerulus (Chaudoir)	122	A	FE, G	2	L	Car.
Subfamily Cicindelinae						
Tribe Cicindelini						
Cicindela japana (Motschulsky)	67	A	PF, OG, W	3	M	Car.
Cicindela ovipennis (Bates)	10	O	PF, OG, W	3	M	Car.
Subfamily Harpalinae						
Tribe Harpalini						
Harpalus eous (Tschitscherine)	1	R	OG, PF, W	3	M	Omn.
Harpalus jureceki (Jedlicka)	2	R	OG, W	2	M	Omn.
Harpalus sinicus (Hope)	8	O	FE	1	M	Omn.
Oxycentrus argutoroides (Bates)	3	R	FE	1	S	Car.
Trichotichnus longitarsis (Morawitz)	2	R	FE, OG	2	M	Car.
Tribe Stenolophini						
Stenolophus congrius (Morawitz)	2	R	FE, OG	2	S	Omn.
Tribe Anisodactylini						
Anisodactylus punctatipennis (Morawitz)	109	A	FE, OG	2	M	Omn.
Anisodactylus sadoensis (Schauberger)	107	A	FE, OG	2	M	Omn.
Tribe Zabrini						
Amara congrua (Morawitz)	58	A	FE, OG, W	3	S	Omn.
Amara macros (Bates)	50	A	OG, W	2	S	Omn.
Subfamily Licininae						
Tribe Licinini						
Badister bipustulatus (Fabricius)	4	R	FE	1	L	Car.

Continue of Table 1

Taxa	I	II	III	IV	V	VI
Subfamily Pterostichinae						
Tribe Platynini						
Parabroscus crassipalpis (Bates)	4	R	FE	1	M	Omn
Platynus hasegawai (Habu)	1	R	FE, OG	2	M	Car
Platynus takabai (Habu)	2	R	FE, OG	2	M	Car
Platynus thoreyii nipponicus (Habu)	5	R	OG	1	M	Car
Synuchus (*Synuchus*) *arcuaticollis* (Motschulsky)	3	R	FE	1	M	Car
Synuchus (*Synuchus*) *crocatus* (Bates)	200	A	E, OG, PF	3	M	Car
Synuchus (*Synuchus*) *cycloderus* (Bates)	105	A	FE, OG	2	M	Car
Synuchus (*Synuchus*) *difficilis* (Hope)	9	O	FE, OG	2	S	Car
Synuchus (*Synuchus*) *dulcigradus* (Bates)	64	A	FE, OG	2	M	Car
Synuchus (*Synuchus*) *melantho* (Bates)	72	A	FE, OG	2	M	Car
Synuchus (*Crepidactyla*) *nitidus* (Motschulsky)	13	O	FE, OG	2	M	Car
Tribe Pterostichini						
Lestichus magnus (Motschulsky)	4	R	FE	1	L	Car
Pterostichus haptoroides japonensis (Lutshnik)	4	R	FE, OG	2	M	Car
Pterostichus microcephalus (Motschulsky)	3	R	OG, W	2	S	Car
Pterostichus noguchii (Bates)	2	R	OG, W	2	S	Car
Pterostichus polygenus (Bates)	128	A	FE, OG, W	3	L	Car
Pterostichus sulcitarsis (Morawitz)	12	O	FE, OG	2	M	Car
Pterostichus yoritomus (Bates)	144	A	FE, OG, P	3	M	Car
Trigonognatha auresence (Bates)	4	R	FE, OG	2	L	Omn
Trigonognatha cuprescens (Motschulsky)	5	R	FE	1	L	Omn
Subfamily Scaritinae						
Tribe Scaritini						
Scarites (*Paralleblomorphus*) *terricola* (Bates)	5	R	FE	1	L	Car
Subfamily Trechinae						
Tribe Trechini						
Lasiotrechus discuss (Fabricius)	2	R	FE	1	M	Omn
Subfamily Zabrinae						
Tribe Callistini						
Haplochlaenius costiger (Chaudoir)	107	A	FE	1	L	Car
Hemichlaenius noguchii (Bates)	1	R	FE	1	M	Car
Chlaenius bioculatus (Chaudoir)	3	R	FE, OG	2	M	Car
Chlaenius circumdatus (Brulle)	5	R	FE, OG, W	3	M	Car
Chlaenius costiger (Chaudoir,)	15	O	FE, OG	2	L	Car
Chlaenius ocreatus (Bates)	11	O	FE	1	M	Car
Chlaenius pallipes (Gebler)	173	A	FE	1	M	Car
Chlaenius posticalis (Motschulsky)	3	R	FE	1	M	Car
Chlaenius tetragonoderus (Chaudoir)	2	R	FE	1	M	Car
Chlaenius virgulifer (Chaudoir)	3	R	FE, OG	2	M	Car

I – number of individuals; II – abundance code (R – rare, O – occasional, A – abundant); III – habitat preference (FE – forest edge; OG – open grassland, PF – paddy fields, W – wetland); IV – number of preferred habitats; V – body size (S – small, M – medium, L – large); VI – feeding category (Car – carnivorous, Omn – omnivorous).

RESULTS

1. Abundance

1.1. Entire study area. In total, 1961 individuals were collected during the two years (1068 and 893 in 2007 and 2008, respectively) from the entire study area. No difference was found in thr total number of individuals between the two years (Kruskal-Wallis test, $p > 0.05$) (Table 1, Fig. 2)

1.2. Each study site. The highest number of individuals was for the open grassland (310 and 248 individuals during 2007 and 2008, respectively), followed by forest edge A (258 and 294 individuals during 2007 and 2008, respectively). Meanwhile, the lowest was for the wetland (102 and 144 individuals during 2007 and 2008, respectively) (Fig. 2).

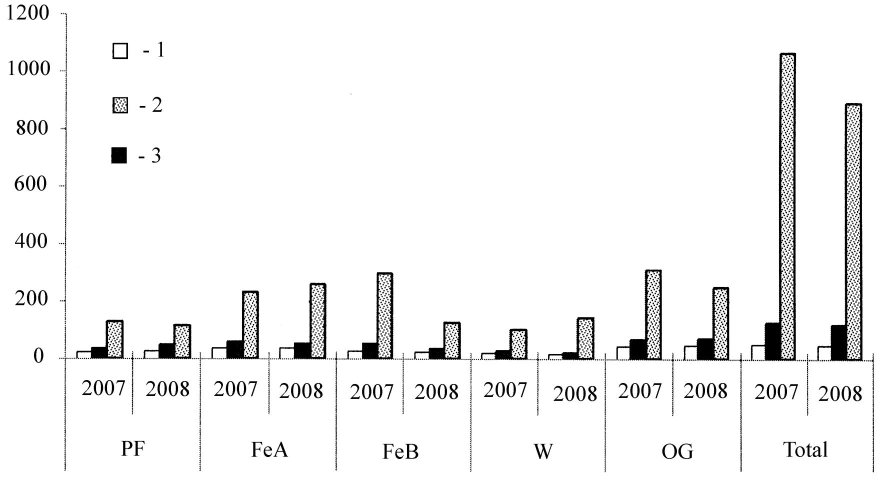

Fig. 2. Total number of species (1) and that of individuals (2) of carabids sampled from different sites in Kitadan for two consecutive years, 2007 and 2008. (3) – number of expected species derived by Chao (1984). Sampling site codes are the same as in Fig. 1. See the text for the details.

2. Taxonomic composition

2.1. **Entire study area**. For all five study sites pooled, a total of 55 species (52 and 46 in 2007 and 2008, respectively), representing 24 genera, 10 subfamilies and 15 tribes (Table 1) were recorded during the two study years. There was a decline in the number of species as well as that of individuals mentioned above, from 2007 to 2008.

2.2. **Each study site**. High variation in species richness among habitats was observed. The greatest number of carabid species was recorded in the open grassland (43 and 46 species in 2007 and 2008, respectively), while the lowest number was for the wetland habitat (21 and 17 in 2007 and 2008, respectively). Forest edges A and B exhibited 38 and 27 species in 2007 and 37 and 25 in 2008, and paddy fields 24 and 27 in 2007 and 2008, respectively (Fig. 2).

3. Carabid species ranking

Tables 1 and 2 show summaries of the abundance categories of the carabid species recorded during the two-year study. The abundant group was represented by 16 species comprising around 29.1% of the total number of species and 91.3% of the total number of individuals collected. Occasional species numbered 7 (12.7% of the total number of species and 4.0% of the total number of individuals collected). Rare species numbered 32 (58% of the species collected, 4.7% of the individuals collected). Figure 3 shows the abundance ranking of carabid species during different sampling years. During the two-year study, the number of abundant species ($n \geq 26$ individuals) was found to be 16. However, during 2007 only 15 species were common carabid species. Meanwhile, during 2008 the number of common carabid species was 16. The most common carabid species encountered, in terms of numbers, were *Carabus maiyasanus* and *C. dehaanii*, which comprised the majority of specimens collected in all habitat types (around 15% of the total catch of most common species). Around 51% of the two *Carabus* species were trapped in open grassland during 2007. The second most common carabid taxon was that containing the two species from the tribe Anisodactylini, *Anisodactylus punctatipennis* and *A. sadoensis* (13.9% of the total catch of common species).

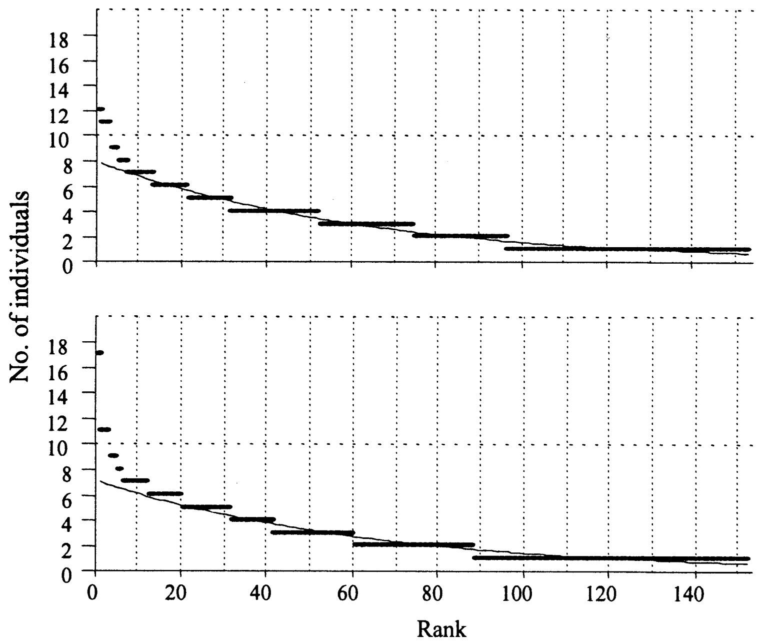

Fig. 3. Abundance ranking curve of carabid species sampled in Kitadan Valley during 2007 (top) and 2008 (bottom). All samples in Kitadan Valley were pooled.

Table 2

Number of tribes (TR), species (SP), individuals (IND) and ecological traits of the abundant, occasional and rare carabid species sampled from different sites of Kitadan Valley in 2007 and 2008 combined.

Subfamily	**Number**			**Ecological trait**								
				Habitat			**Body size**				**Feeding category**	
	TR	**SP**	**IND**	**PF**	**FE**	**OG**	**W**	**S**	**M**	**L**	**Car**	**Omn**
Common species												
Pterostichinae	2	6	713	2	6	6	1	−	5	1	6	−
Pterostichinae	2	6	713	2	6	6	1	−	5	1	6	−
Carabinae	1	3	406	−	3	3	−	−	−	3	3	−
Harpalinae	2	4	324	−	3	4	2	2	2	−	−	4
Zabrinae	1	2	280	−	2	−	−	−	1	1	2	−
Cicindelinae	1	1	67	1	−	1	1	−	1		1	−
Subtotal	7	16	1790	3	14	14	4	2	9	5	12	4
Occasional species												
Cicindelinae	1	1	10	1	−	1	1	−	1	−	1	−
Harpalinae	1	1	8	−	1	−	−	−	1	−	−	1
Pterostichinae	2	3	34	−	3	3	−	1	2	−	3	−
Zabrinae	1	2	26	−	2	1	−	−	1	1	2	−
Subtotal	5	7	78	1	6	5	1	1	5	1	6	1
Rare species												
Bembidiinae	2	6	15	1	3	4	5	6	−	−	−	6
Brachininae	1	1	3	−	−	1	−	−	−	1	−	1
Harpalinae	2	5	10	1	3	4	2	2	3	−	2	3
Licininae	1	1	4	−	1	−	−	−	−	1	1	−
Pterostichinae	2	11	37	−	9	7	2	2	6	3	8	3
Scaritinae	1	1	5	−	1	−	−	−	−	1	1	−
Trechinae	1	1	2	−	1	−	−	−	1	−	−	1
Zabrinae	1	6	17	−	6	3	1	−	6	−	6	−
Subtotal	11	32	93	2	24	19	10	10	16	6	18	14
Total	15	55	1961	6	44	38	15	13	30	12	36	19

Codes for habitat, body size and feeding category are the same as in Table 1.

Concerning species stability in abundance level during the two-year study, many carabid species were able to maintain their ranking position (especially those of occasional abundance). However, the degree of overlapping was pronounced for both abundant and rare species (Fig. 3). *Pterostichus yoritomus*, for instance, surged in terms of position in relation to other species from the six most common carabid species during 2007 to the third most common carabid species. However, over the two-year study, *P. yoritomus* remained the fourth most common carabid species. Another example is *Synuchus dulcigradus*. This species changed places with *S. melantho* in terms of abundance over the two years of the study.

Generally speaking, there was a trend of greater dominance during 2008 compared with 2007. This in turn reflects greater heterogeneity during 2008. The numbers of singletons were 24 and 29 in 2007 and 2008, respectively. The number of singletons was observed to be lowest in the wetland (8 and 4 in 2007 and 2008, respectively) and highest in open grassland (17 and 21 in 2007 and 2008, respectively).

4. Ecological traits

4.1. Habitat preference. Among the 55 carabid species in different sampling sites in Kitadan Valley, the majority of carabid species (44 species) were sampled from both forest edges (A & B) and open grassland (38 species) (Table 1). Only a few species (6 species) were sampled from paddy fields and only 15 carabid species exhibited wetland preference.

The abundant carabid species showed the same trend of forest edge and open grassland preferences (14 species in each habitat) (Table 2).

For the carabid species with occasional abundance, the dominant trend was toward forest edge preference, followed by open grassland preference. Indeed, among the 32 rare species, the highest number (24 species) was observed in forest edges (A & B), indicating forest edge preference (Table 2).

4.2. Carabid body size. Table 1 shows that carabid species are diverse in terms of body size. There is a large difference between the number of carabid species with medium-sized bodies and those of other sizes. The majority of carabid species had a medium-sized body (30 out of 55 species). Large and small-sized species were rare (12 and 13, respectively).

On the habitat level, open grassland in Kitadan Valley showed a predominance of species with a medium body size (21 species). On the other hand, wetland and paddy fields in Kitadan Valley were likely to be occupied by carabids with a small body size. Forest edges A and B harbored a large number of large species (11 species) compared with the other sampling sites in Kitadan Valley (Table 1).

Among the 16 most abundant carabid species, the majority (more than 50%) had a medium-sized body (Table 2). The carabid species with occasional abundance (Table 2) almost exclusively had a medium-sized body. Among rare carabid species, on the other hand, 50% had a medium-sized body (16 species).

4.3. Feeding category. Out of 55 recorded species sampled over the two-year study, 36 species (65.5%) were carnivorous species while only 19 species (34.5%) were omnivorous (Table 1). Most of the carnivorous were sampled from forest edges (11 species) or open grassland (9 species), whereas only a few species were recorded from wetland (6 species) or paddy fields (4 species), as indicated in Table 1. Typical carnivorous species were characterized by forward-projecting mandibles, sharp incisors used to pierce and capture prey and a long terebral ridge used to kill and slice prey into pieces. Omnivorous species, on the other hand, had a wide molar region for crushing seeds but incisors were blunt and the terebral ridge was short. Thus, omnivorous species have features that are advantageous for seed feeding but reduce the efficiency of feeding on prey.

The majority of common carabid species (75%) were carnivorous (Table 2). Only four species (25%) belonged to the omnivorous category. The carabid species with occasional abundance (Table 2) were almost all carnivorous species (six out of seven species). Among the rare species (32 species), most were carnivorous (Table 2). However, a number of omnivorous species (14 out of 32 species) could be detected among them.

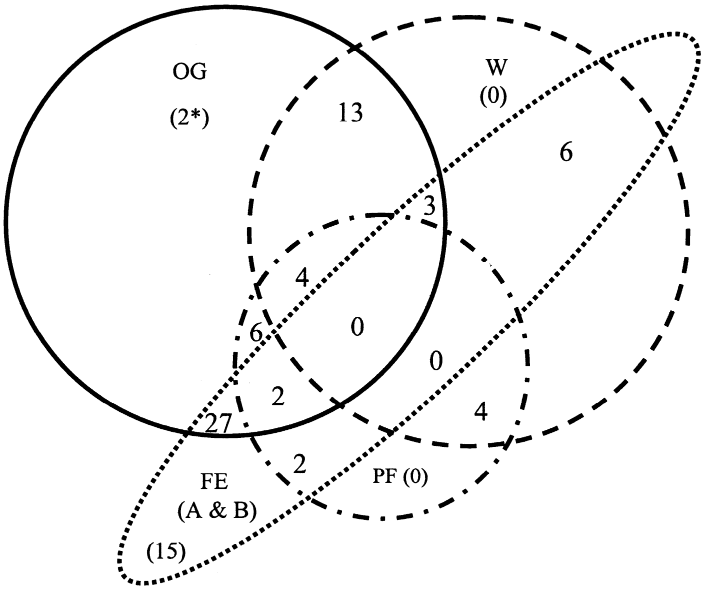

Fig. 4. Diagram showing the overlap of the carabid species sampled among four different habitats of Kitadan Valley. Numerals in the figure: number of overlapping species. (*) – number between parentheses is the number of species that captured only in one site and data are combined for the consecutive years, 2007 and 2008. Site codes are the same as Fig. 1.

4.4. Species shared among different habitats of Kitadan Valley. The highest number of species shared among habitats was observed between the forest edges (A & B) and open grassland (27 species), as indicated in Figure 4. This was followed by 13 species shared between open grassland and wetland. Only 4 species were shared between wetland and paddy fields. In addition, the same number of species (4 species) was shared between three habitats (open grassland, wetland and paddy fields). No species were shared among wetland, paddy fields and forest edges (A & B). In addition, no species were shared among all habitat types in Kitadan Valley. Indeed, the highest number of species captured at only one site was at the forest edges (A & B) (15 species). This was followed by open grassland with only two species (Fig. 4). As illustrated by Figure 4, no species was captured only at paddy fields or wetland (Fig. 4).

4.5. Similarity among different habitats of Kitadan and between years. Cluster analysis enables visualization of the similarity of carabid species composition among the five sampling sites in Kitadan Valley during the two years of the study. Figure 5 shows a dendrogram produced by this clustering system indicating how the cluster analysis grouped the five habitats for the two years. Paddy fields in 2007 and 2008 were more similar in carabid species richness and degree of population oscillation. Forest edges A and B for the year 2007 were grouped together, indicating a good degree of similarity between the two plots in the same year. Forest edges A and B during 2007 formed a distinct cluster.

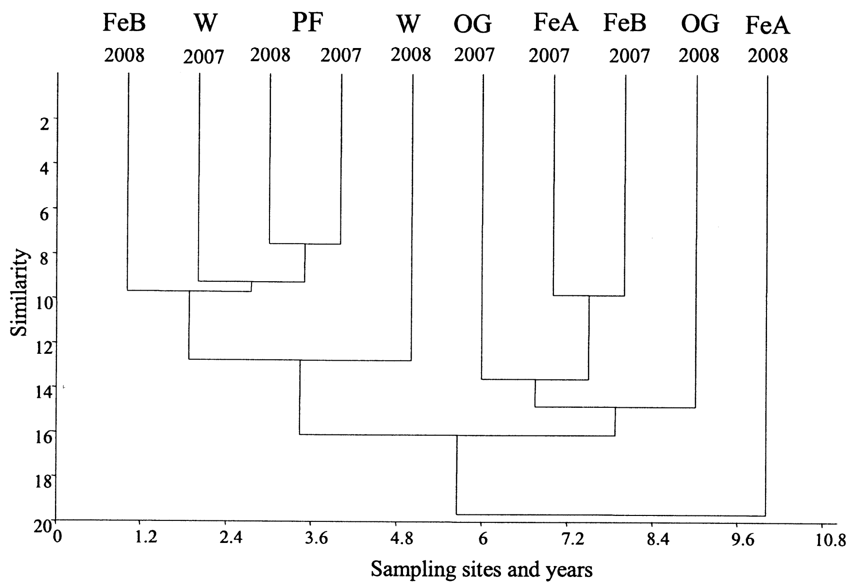

Fig. 5. Dendrogram showing the similarity of carabid assemblage among the sampling sites of Kitadan Valley in 2007 and 2008. Site codes are the same as Fig. 1.

DISCUSSION

From the results of carabid assemblage and community structure in different sampling sites, it can be inferred that carabid assemblage was moderately species-rich in some sampling sites and poor in others. These results are in agreement with those produced from numerous works on different carabid assemblages in different localities (Thiele, 1977; Horvatovich, 1986; Luff, 1987; van Dijk, 1987; Lövei & Sunderland, 1996). However, generalizations are difficult as the extension of an assemblage in space or time is usually not defined (Lövei & Sunderland, 1996).

In the majority of carabid species, activity is closely related to reproduction (Müller & Kashuba, 1986). *Carabus dehaanii punctatostriatus*, for instance, has an activity period from mid-late May to mid-September. *C. maiyasanus maiyasanus* has an activity period from early May to mid-late July. Other rare species have relatively short activity/reproductive periods, especially in comparison to *Synuchus crocatus* which shows an activity period lasting from early May to at least mid-September. Out of all the carabid species collected, *S. crocatus* appeared to have the highest reproductive rate. Consequently, *S. crocatus* would be the least affected by habitat changes, and the best able to colonize habitats vacated owing to decreases in the numbers of other, especially rare, carabid species. This would partially account for the numbers of carabid species that increased in paddy fields in Kitadan Valley. In addition, *Carabus maiyasanus* has been found in various habitats and is considered a habitat generalist (Rivard, 1964; Johnson *et al.,* 1966; Lindroth, 1969; Martel *et al.,* 1991). *Pterostichus yoritomus* and *P. polygenus* have also been found in various habitats and are considered habitat generalists (Lindroth, 1969; Barlow, 1970; Martel *et al.,* 1991; Niemelä & Spence, 1991; Niemelä & Halme, 1992; Carcamo *et al.,* 1995). Therefore, in terms of habitat use, *P. yoritomus*, *P. polygenus* and *Carabus maiyasanus* would be best suited to survive in a variety of environments and/or environments that are in constant change. This would, in part, account for the number of *Pterostichus yoritomus* collected from the paddy fields in Kitadan Valley.

The species compositions of carabids were quite different between the study sites. In general, some carabid species were present in all the sampling sites of Kitadan Valley, characterizing their ubiquitous nature. Many species were exclusively found in a particular sampling site and were likely to show high habitat specificity. This could be explained by differences between the habitats. These sampling sites were composed of different kinds of 'elements', as suggested by Rainio and Niemelä (2006). Open grassland in Kitadan Valley, for instance, had many refuges, relatively good levels of moisture, and many feeding resources such as seeds or prey because of the presence of relatively good canopy. Moreover, arable and flora-rich lands are known to be rich in species of carabids (Purtauf *et al.*, 2003), which are common predators in agroecosystems and feed on various arthropod pests, weeds, seeds and slugs (Sunderland, 1975). As for the forest edges within Kitadan Valley, bunches of dead leaves or logs were the best places to find carabids. In addition, fallen trees and branches were rich in species since they exhibited levels of moisture that attract carabids for breeding, feeding and provide carabid species with overwintering sites (Desender, 1982; Pfiffner & Luka, 2000) or spring-summer shelter (Thomas *et al.*, 2001). In contrast, few species were found in the wetland habitat, probably because this habitat was the wettest (more than 90% water content) and such habitats can exhibit poor 'elements' in which few carabid species can enhance their breeding and feeding.

Paddy fields harbor relatively few species. This could be attributed to the fact that paddy fields are characterized by very poor canopy cover and relatively dryer soil. In addition, paddy fields are subjected to regular man-made disturbances including the removal of weeds and other wild plant species, mowing regimes and rearrangement of field rims. These man-made disturbances may alter the availability of necessary resources for carabid species in a way that results in these resources not being used by carabids or being used inefficiently.

In addition, paddy fields are more attractive to predators and/or parasites that could attack carabids. Larochelle (1975a, 1975b, 1980) stated that most observational evidence indicated that predation is an important mortality factor for adult carabids. Moreover, the ecological significance of predation pressure by small mammals has been demonstrated in many studies. Parmenter & MacMahon (1988) and Churchfield *et al.* (1991) found that excluding small mammals resulted in an increase in both species richness and density of carabids. However, data concerning predation and/or parasitism are lacking. Nonetheless, we consider that the previously mentioned factors could have significant impacts on both overall species richness and diversity of habitat specific carabids (Haysom *et al.*, 2004; Dauber *et al.*, 2005 Grandchamp *et al.*, 2005; Magura & Ködöböcz, 2007). Many species collected from paddy fields were singleton species. However, simply counting the number of species provides little information on the specific effects of disturbance (Niemelä *et al.,* 2007). Species richness used as a measure of conservation value may be misleading because disturbances may favour widespread and abundant generalists, leading to increased species richness, as can be the case for carabids (Niemelä, 1997; Niemelä *et al.,* 2007).

It can be inferred that open grassland in Kitadan Valley, for instance, harbored the highest number of carabid species compared with other sampling sites in the satoyama area. Furthermore, the open grassland ranked highest in terms of the number of individuals. However, the number of singletons in this habitat over the two years of the study was also the highest, a fact highlighting important contribution of open grassland to biodiversity on a regional scale.

It was possible to roughly classify carabid species according to Rainio & Niemelä (2006) with slight modification into (1) forest species (ex. *Chlaenius ocreatus, Ch. pallipes, Ch. posticalis, Ch. tetragonoderus, Haplochlaenius costiger, Lestichus magnus*), (2) open habitat species (ex. *Carabus dehaanii, C. maiyasanus*), (3) moist or wet habitat (ex. *Cicindela japana, C. ovipennis*) and (4) habitat generalists found in a wide range of habitats (ex. *Amara congurua*, *Pterostichus polygenus, P. yoritomus, Synuchus crocatus*). However, over half of the species were singletons or represented by a very low number of individuals, and hence the classification remains preliminary and should be refined on the basis of additional sampling. A relatively high number of singletons has been noted in many arthropod groups, including carabids (e.g. Floren & Linsenmair, 1998; Lucky *et al.*, 2002; Rainio & Niemelä, 2006). Although we have some knowledge of the habitat of many carabid species from the available literature and from field observations, we must still seek to characterize the exact habitat, particularly microhabitat, requirements of all carabid species since such information is lacking.

From this study, it can be stated that the loss of a definite structure in a disturbed environment involves a shift away from complex arrangements of specialized species toward generalists. This is in agreement with Woodwell (1969). A sharp classification of carabids into specialists and generalists is difficult and probably no carabid fits into only one classification.

Comparatively high similarity between sampling sites or between years within Kitadan Valley could be attributed to the fact that different sampling sites or years could share common elements in a way that carabid species could utilize these elements.

The high similarity in, for instance, paddy fields between 2007 and 2008 could be attributed to the fact that no drastic changes in the carabid assemblage composition occurred in this sampling site over the two-year study. Indeed, the relatively high similarity between forest edges A and B during 2007 could reflect the fact that the carabid species composition are more similar during this year so that this composition did not differ much between these two edges during 2007. However, much more detailed analysis of habitat elements could offer more clues concerning the similarities among habitat types and years.

CONCLUSIONS AND GENERAL RECOMMENDATIONS

The abundance and structure of invertebrate communities, including carabids, are undoubtedly influenced by various ecological factors (Hutcheson *et al.*, 1999, Linawati *et al.*, 2006). For carabid species in different habitats of Kitadan Valley, management activities, cultivation, such as millet or paddy plantations, selective cutting and removal of litter and ground vegetation, are likely to positively or negatively affect the abundance, diversity and faunal composition of the communities. Responses to such activities may differ among carabid species, reflecting their variety in trophic status, habitat preference, food resources, behavioral traits and life history (Linawati *et al.*, 2006; ElSayed & Nakamura, 2008, 2009 a, 2009b; Abu ElEla *et. al.*, 2009).

Understanding biodiversity allows us to describe environmental problems historically instead of by examining individual situations on a species-by-species and stress-by-stress basis (Noss, 1990). Environmental issues, such as natural disturbances or anthropogenic issues, could soon be monitored by calculating habitat biodiversity on a periodic basis.

Generally, the species collected in this study provide a rich database for more detailed research on the ecology and life history of individual species. Moreover, this data can be used to distinguish and classify major habitat groups; however more extensive collection over a longer time is needed to produce a detailed interpretable classification within major habitats.

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