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Ground beetle (Coleoptera: Carabidae) assemblage in the urban landscape, Korea

Jong-Kook Jung[1], Seung-Tae Kim[2], Sue-Yeon Lee[1], Chang-Kyu Park[3], Eun Heui Lee[4] and Joon-Ho Lee[1,2,*]

[1]Entomology Program, Department of Agricultural Biotechnology, Seoul National University, Seoul 151-921, Korea
[2]Research Institute for Agriculture and Life Sciences, Seoul National University, Seoul 151-921, Korea
[3]Applied Entomology Division, Department of Agricultural Biology, National Academy of Agricultural Science, Suwon 441-857, Korea
[4]Dept. of Hort. Sci. Plant Biotech. and Landscape Architecture, Seoul Women's University, Seoul 139-774, Korea

Abstract
This study was conducted with the intention of clarifying the effects of land-use types on a species of ground beetle's richness, abundance, and composition; the study focused on urban landscapes. We also selected the potential bioindicators classifying land-use types; eleven sites were selected from an urban landscape in Korea. Overall, land-use types in urban landscapes did not appear to cause significant decrease in species richness or the abundance of total ground beetle assemblage. According to habitat preferences, several land-use types and distances from the forest significantly affected the species richness and abundance, while the open-habitat species were not affected by these variables. Land-use types were classified into two major groups, forest and non-forest areas, based on ground beetle assemblage; several indicators, such as *Dolichus halensis halensis* and subfamily Carabinae species, were of particular consideration. In conclusion, environmental change by anthropogenic disturbance can cause different effects on ground beetle assemblages, and forest specialists can be negatively affected.

Key words: bioindicator, conservation, diversity, habitat preference, land-use types

INTRODUCTION

Urbanization, industrialization, and agriculturalization can cause natural habitats to be destroyed, fragmented, or severely modified. This land-use conversion is the primary factor explaining biodiversity loss (Pearce and Moran 1994, Niemelä et al. 2000) because many species are restricted to small areas or certain types of habitats. They may even be forced to be separated from their preferred habitats (Pyle et al. 1981, Wilcox and Murphy 1985, Desender and Turin 1989).

The urban ecosystem should have valuable green and open areas for human well-being and, thus, often contains gardens, parks, and woods in addition to man-made structures such as roads, commercial, and residential constructions. For animals, including arthropods, green areas in the urban landscape are important for moving around an urban area (Angold et al. 2006). However, although the urban green area provides an array of habitats for arthropods (Eversham et al. 1996, McIntyre 2000), urbanization is a leading cause of decline in biodiversity and the abundance of organisms (Pyle et al. 1981, Clark and Samways 1997, Angold et al. 2006) because a man-made environment in a city may be a dispersal barrier to less mobile arthropod species.

Ground beetles, generally consuming insects and

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*Corresponding Author
E-mail: jh7lee@snu.ac.kr
Tel: +82-2-880-4705

other small arthropod species, have been extensively studied because they occur in most terrestrial habitats; their abundance and species composition can be easily monitored by pitfall traps (Lövei and Sunderland 1996). In some studies, the diversity of ground beetles is often higher in urban areas than in suburban ones (Magura et al. 2004), and forest fragmentation can lead to an increase in species richness (Halme and Niemelä 1993, Niemelä 2001, de Warnaffe and Lebrun 2004) because ground beetles in urban ecosystems include open-habitat species, while there is a decrease in forest specialists across the landscape, from a forest area to an urban one (Ishitani et al. 2003, Fujita et al. 2008). According to Niemelä et al. (2000), distribution patterns of ground beetles across the urban-rural gradients could prove useful in measuring the urbanization effects on biota. Therefore, ground beetles have often been studied as bioindicators for fragmentation effects along urban-rural forest gradients in many urban landscapes (Alaruikka et al. 2002, Niemelä et al. 2002, Ishitani et al. 2003, Venn et al. 2003, Magura et al. 2004, 2008a, 2008b, Weller and Ganzhorn 2004, Deichsel 2006, Elek and Lövei 2007, Gaublomme et al. 2008). However, Fujita et al. (2008) argued that more studies regarding various habitat types in urban and rural landscape are necessary.

The objective of this study was to clarify the effects of land-use types on the species richness, abundance, and composition, regarding ground beetles in urban landscapes. We selected the potential bioindicators classifying land-use types.

MATERIALS AND METHODS

Study area and land-use types

The study area was located in the southwestern part of Korea, Jeonju and Iseo-myeon of Wanju-gun (35°43′-35°53′ N, 126°59′-127°14′ E) (Fig. 1). The area covered 346.7 km², where 262.3 km² of the land cover was green space in the form of parks and forests; theurban area covered 42.2 km². The border of the city included approximately 6 km² of arable land and 0.3 km² of wilderness area. The annual mean temperature and precipitation in the study area were 13.0°C and 1,296.2 mm, respectively.

Eleven study sites were selected according to land-uses, and these were categorized into 4 habitat types: 4 forest areas (F_), 3 agricultural areas (A_), 2 urban roadsides (U_), and 2 riversides (R_). Table 1 shows environmental information for each sampling area, including habitat types, surveyed altitudes (ALT), and distances from the nearest forest margin (DIST). Fujita et al. (2008) showed that ALT and DIST were significant variables in ground beetle assemblage. Proportions of each land-use type around sampling sites are shown in Table 2. The criteria for distinguishing sampling areas were the proportion of the land-use types, based on an aerial photograph within 1 km² quadrat, which was measured by the GIS database in the Environmental Geographic Information System (EGIS 2011). Choi et al. (2008) suggested that the biotope classification system consists of a 4 step system, including the biotope class (large), biotope group (medium), biotope type (small) and sub-biotope type (detail). We followed Choi et al. (2008) for the criteria of land-use types for land-use analysis in the present study. However, some of their criteria (residential, commercial, industrial, public facility and traffic facility areas) were merged into the proportion of built-up areas (PBA), because the built-up areas do not serve the habitats of ground beetles.

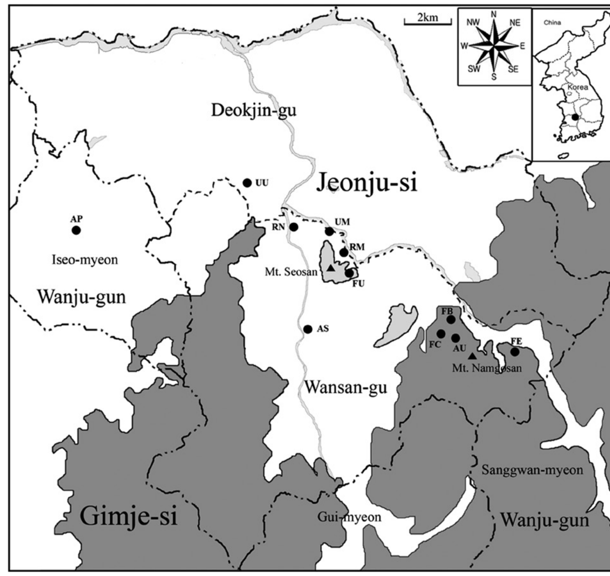

Fig. 1. Location of survey sites in the southern west part of Korea. The shaded areas (dark grey) and closed circles indicate main forests and surveyed sites, respectively. Abbreviation of surveyed sites is defined in Table 1.

Sampling

Sampling was conducted from July to September in 2008. Ground beetles were collected using pitfall traps. Three pitfall traps were installed 10 m apart in each site and were emptied every month. Each pitfall trap was installed at the center of a sampling site, at least 20 m from the nearest habitat edge. A pitfall trap was composed of a plastic container (10.5 cm diameter and 8 cm depth) and a lid with 6 holes (2 cm diameter in each hole), which prevented the collecting of unwanted small mammals. A plastic roof was erected in order to prevent rainfall. Traps were filled with a liquid mixture (300 mL, 95% ethyl-alcohol:95% ethylene-glycol = 1:1) for sample preservation. Collected ground beetles were brought to the laboratory and dried, mounted, and identified to species level under a dissecting microscope. Identification was performed according to Habu (1967, 1973, 1978), Kwon and Lee (1984), Park and Paik (2001) and Sasakawa et al. (2006), and compared to voucher specimens in the laboratory. Nomenclature was confirmed by Park and Paik (2001) and Park (2004). The habitat preferences of species were determined by general characteristics of subfamily level, and some species were confirmed by Fujita et al. (2008). Voucher specimens were deposited in the insect ecology laboratory, Seoul National University.

Data analyses

Abundance and species richness were measured based on the number of individuals and the number of species collected in each sampling site, respectively. Stepwise multiple linear regressions were used in order to study the relationships between the 9 variables, species richness,

Table 1. Land-use type and habitat environment of each surveyed site

Land-use type	Abbreviation	Habitat environment	ALT	DIST
Agricultural area	AP	Levee in paddy field	11	3.76
	AU	Upland in the Mt. Namgosan	159	0.59
	AS	Smallholding with flowering plants, in urban area	30	2.32
Forest	FE	Mixed forest edge of the Mt. Namgosan	78	-
	FC	Coniferous-dominated forest in the Mt. Namgosan	149	-
	FB	Broadleaf-dominated forest in the Mt. Namgosan	230	-
	FU	Mixed forest in urban area as campus having shallow leaf litter	58	2.43
Riverside	RM	Managed grass habitat with small coniferous tree next to riverside	43	2.69
	RN	Nature grass habitat next to riverside	21	1.10
Urban roadside	UM	Open habitat and managed small-size patch in urban	33	2.29
	UU	Open habitat and unmanaged small-size patch in urban near paddy fields	34	1.59

ALT, surveyed altitude; DIST, distance from nearest forest margin.

Table 2. Proportions of land-use types within 1 km^2 quadrat around sampling sites

Surveyed sites Abbreviation		Land-use types (%)						
		Natural forests	Green areas*	Agricultural areas		River environments		PBA†
				Rice	Crop	River	Riverside	
Agricultural area	AP	10.5	-	68.0	11.6	-	-	9.9
	AU	91.8	-	-	7.1	-	-	1.1
	AS	1.1	4.6	-	1.5	4.8	4.3	83.7
Forest areas	FE	39.1	0.7	39.5	6.2	3.0	8.9	11.5
	FC	96.0	-	-	2.8	-	-	1.2
	FB	95.1	-	-	0.3	0.3	0.8	3.5
	FU	29.7	1.7	-	-	3.2	5.9	59.5
River	RM	31.8	1.6	-	-	3.2	6.5	63.4
	RN	4.7	10.0	-	-	6.1	15.6	79.2
Urban roadsides	UU	1.9	0.6	3.9	0.3	-	-	93.3
	UM	1.6	1.8	0.0	-	6.4	8.7	90.2

*Sparsely wooded on park or garden.
†Proportion of built-up areas, including roads, residential, commercial, industrial, and public facility areas.

and abundance of ground beetle assemblages.

For analysis of the species composition of ground beetles among sites, a non-metric multidimensional scaling (MDS), with Bray-Curtis similarity and a two-way indicator species analysis (TWINSPAN) (Hill 1979), were conducted using the PRIMER v5.0 (Clarke and Gorley 2001, Clarke and Warwick 2001) and community analysis package v2.0 (Seaby and Henderson 2002), respectively. MDS was chosen because it performs well with ecological data that do not meet the assumption of normality (McCune and Grace 2002). On the other hand, a TWINSPAN not only classifies the sites but constructs an ordered two-way table from a sites-by-species matrix (Jongman et al. 1995). TWINSPAN creates pseudo-species, and each species is subdivided into presence/absence vectors for several relative abundance levels (Dufrêne and Legendre 1997). Thus, MDS and TWINSPAN are the most generally effective ordination and classification methods for ecological community data (Jongman et al. 1995, McCune and Grace 2002). In the MDS, stress is a measure of distortion between the positions of real data points from the graphical representation. Thus, low stress represents few distortions from the real position of the data points and is associated with a graph that more accurately represents dissimilarities in species composition.

The analysis of similarity (ANOSIM) and a multiple response permutation procedure (MRPP) were conducted to further confirm significant differences in community structure among land-use types and between groups of MDS. The ANOSIM permutation test, with a maximum of 999 permutations, was used to assess significant differences among groups, and Global *R* value approaches 1 if differences among land-use types exist (Clarke and Warwick 2001). Similarly, the MRPP provides a measure of within-habitat homogeneity (*A*), which increases as the communities in different habitats deviate, to a maximum of 1. An *A* value greater than 0.3 is considered to be relatively high, but statistical significance may occur for a small *A* value if the sample size is large (McCune and Grace 2002). The ANOSIM was conducted using the PRIMER v5.0 (Clarke and Gorley 2001, Clarke and Warwick 2001), MRPP, Pearson's correlation, and stepwise multiple regression analyses were conducted using the statistical software package R (R Development Core Team 2010).

RESULTS

A total of 29 species, belonging to 18 genera of 11 subfamilies, were identified from 915 ground beetles in this study (Appendix 1). Most of the collected ground beetles were macropterous (884 individuals of 25 species) and only four brachypterous species were collected (Appendix 1). The species richness was relatively higher in the FE and RM, and abundance was extremely high in the AS (Fig. 2). Overall, land-use types in the urban landscape did not appear to cause a significant decrease in species richness and abundance of ground beetle assemblage. However, species richness and abundance of forest species were higher in forest areas than in open-habitat ones, but they were lower in non-forest areas.

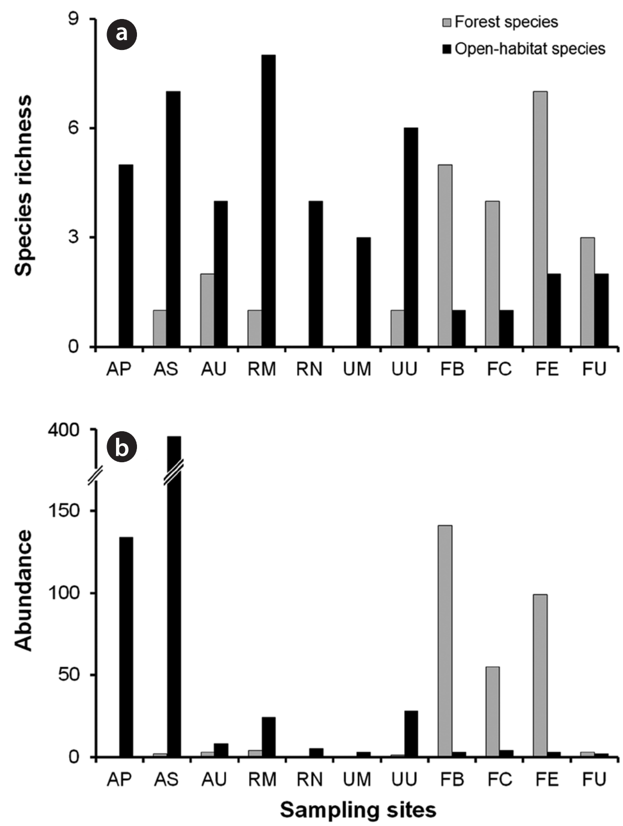

Fig. 2. Species richness (a) and abundance (b) of ground beetles of surveyed sites. Abbreviation of surveyed sites is defined in Table 1.

The dominant species was *Pheropsophus jessoensis*, comprising 32.7% of all ground beetles captured. *Harpalus* (*Psedoophonus*) sp. was the most second dominant species, comprising 16.7%. *Synuchus nitidus* and *Synuchus* sp.1 made up 11.0% each. Thus, these four dominant species accounted for 71.2% of total abundance.

The Pearson's correlation matrix among variables is illustrated in Table 3. The PBA was significantly correlated with other variables except on the paddy field area. Stepwise multiple regression analyses between ground beetle assemblages and variables are presented in Table 4.

Overall, many variables significantly affected the species richness ($r^2 = 0.9654$, $F = 47.57$, $P = 0.001$) and abundance ($r^2 = 0.9737$, $F = 62.80$, $P < 0.001$) of forest species, but not the total ground beetles and open-habitat species.

In the MDS, eleven study sites were clustered into 2 major groups (i.e., forest areas vs. non-forest areas) and 5 subgroups at species level (Fig. 3a). On the other hand, eleven sites were clustered into 2 major groups and 3 subgroups at subfamily level (Fig. 3b). The axis 1 in both the MDS of species and subfamily level may represent the gradient from forest to non-forest areas. The ANOSIM and MRPP showed that similarity among land-use types and between 2 major groups, forest and non-forest areas, in MDS were significantly different at both the species and subfamily level (Table 5).

According to the TWINSPAN, all study sites were divided into 2 groups at species level (Fig. 4a), forest and non-forest groups by the first indicator species, *Dolichus halensis halensis* for non-forest. The second indicator species of forest and non-forest areas were *Harpalus discrepans* and *Chlaenius costiger*, respectively. However, classification at subfamily level showed relatively unclear rather than analysis at species level (Fig. 4b).

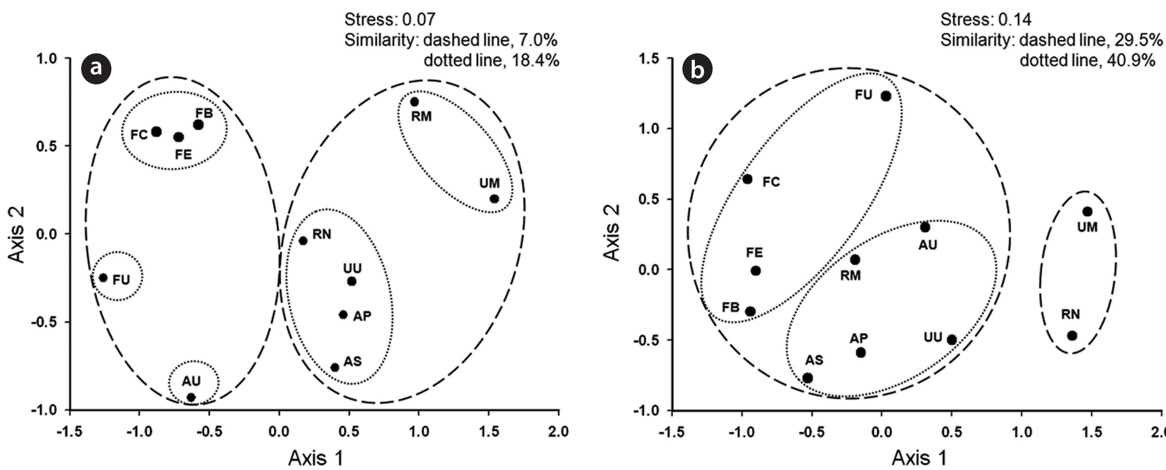

Fig. 3. Multidimensional scaling ordination of ground beetle assemblage at species level (a) and subfamily level (b). Abbreviation of surveyed sites is defined in Table 1.

Table 3. Pearson's correlation matrix among proportion of land-use types, proportion of built-up areas (PBA), distance from the nearest forest margin (DIST), and surveyed altitude (ALT) in each sampling site

Variables	Land-use types							ALT
	Natural forests	Green areas	Rice	Crop	River	Riverside	PBA	
Natural forests	1							
Green areas	-0.618*	1						
Rice	-0.055	-0.339	1					
Crop	0.314	-0.542	0.660*	1				
River	-0.473	0.846**	-0.268	-0.511	1			
Riverside	-0.323	0.796**	-0.182	-0.494	0.965***	1		
PBA	-0.818**	0.756**	-0.114	-0.649*	0.704*	0.629*	1	
ALT	0.781*	-0.511	-0.383	0.040	-0.366	-0.293	-0.687*	1
DIST	-0.628*	0.354	0.067	-0.194	0.305	0.174	0.670*	-0.805**

*$P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

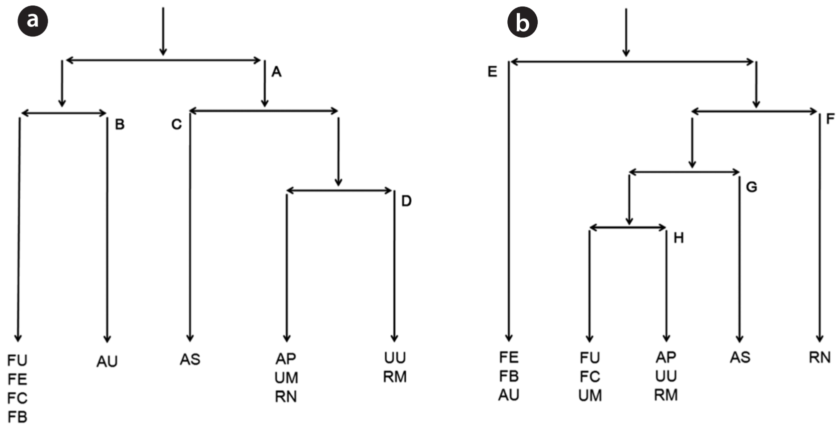

Fig. 4. Two-way indicator species analysis (TWINSPAN) dendrogram of surveyed areas were arranged into 5 groups based on species level (a) and subfamily level (b). Indicators are listed to the left or right of each branch line: A, *Dolichus halensis halensis*; B, *Harpalus discrepans*; C, *Chlaenius costiger*; D, *Chlaenius naeviger*; E, Carabinae; F, Licininae; G, Scaritinae; H, Harpalinae. Abbreviation of surveyed sites is defined in Table 1.

Table 4. Relationship between ground beetle assemblages and selected variables as determined by stepwise multiple regressions†

Variables	Total		Forest species		Open-habitat species	
	Species richness	Abundance	Species richness	Abundance	Species richness	Abundance
Natural forests			-7.63**	-5.74**	-2.68*	-3.06*
Green areas						
Rice			-6.11**			
Crop			-2.89*	-6.92**		
River			-4.71**			
Riverside						-3.46*
PBA			-8.18**	-7.39**		
ALT						
DIST			-10.64***	-9.63***		
F	1.59	2.26	47.57	62.80	1.93	4.32
r^2	0.229	0.468	0.9654	0.974	0.271	0.624
P	0.311	0.271	0.001	<0.001	0.225	0.067

PBA, proportion of built-up areas; ALT, surveyed altitude; DIST, distance from nearest forest margin.
*$P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.
†Negative relationships are indicated.

Table 5. Significance test of dissimilarity of ground beetle assemblage among land-use types and between 2 major groups in MDS (i.e., forest and non-forest areas)

Groups	ANOSIM		MRPP	
	R	P	A	P
Among land-use types				
Species level	0.620	0.004	0.144	0.021
Subfamily level	0.380	0.038	0.116	0.043
Between forest and non-forest				
Species level	0.664	0.003	0.141	0.001
Subfamily level	0.386	0.021	0.110	0.003

MDS, multidimensional scaling; ANOSIM, analysis of similarities; MRPP, multiple response permutation procedure.

DISCUSSION

Our results showed that land-use types in urban landscapes did not appear to cause significant decrease in overall species richness and abundance of ground beetle assemblage. In the gradient of land-use disturbance, previous studies (Vanbergen et al. 2005, da Silva et al. 2008) revealed that more disturbed areas, such as agricultural areas, had high species richness and a greater abundance of ground beetles. In our study, most non-forest areas were highly disturbed by human activity, such as agriculture, construction, or habitat management. These disturbances may have lead to relatively low species richness and abundance of ground beetles in non-forest areas, compared to the results of Vanbergen et al. (2005) and da Silva et al. (2008). Park (2010), studying the urban park, noted that the management strategy of the inhabitants can also affect insect diversity, including ground beetles.

Instead of the taxonomic approach, however, the use of habitat preferences of ground beetles might become a more comprehensive tool with which to assess and monitor biodiversity (Niemelä 2000, da Silva et al. 2008). Our results can also be explained by the predominance of some forest and open-habitat species. Forest species, such as large (*Aulonocarabus semiopacus* and *Coptolabrus jankowskii jankowskii*), middle, or small species (*Synuchus* spp.) are generally found in natural forest areas but not in non-forest ones. This is consistent with findings from recent studies (Fujita et al. 2008, Gaublomme et al. 2008). This may explain that the abundance of these species tended to decrease from forest areas to urban ones. In addition, ground beetles in a forest environment are more influenced by habitat complexity due to the restriction of flight capability (Darlington 1943, Kavanaugh 1985, Gobbi et al. 2006), and many forest species are predominantly composed of brachypterous species (Darlington 1943). In particular, Fujita et al. (2008) discussed that large and/or flightless species are vulnerable to natural and human disturbances. Unlike forest species, most open-habitat species, such as species in subfamilies Harpalinae, Zabrinae, Brachininae and Callistinae, were abundant in non-forest areas. In the Korean agricultural landscapes, subfamilies Harpalinae, Brachininae, and Callistinae are known to be dominant groups (Choi et al. 2004, Kang et al. 2009), and our results also showed a similar species composition in non-forest areas where *D. h. halensis*, *Harpalus* (*Psedoophonus*) sp., *Pheropsophus javanus*, and *P. jessoensis* were dominant. Gray (1989) hypothesized that opportunistic species, in other words, generalist species or open-habitat species, should gain dominance in disturbed habitats, although overall diversity should decrease. Therefore, differences between forest and non-forest areas may be explained by the habitat preferences of ground beetles. Consequently, these ecological characteristics of ground beetles may be important to understanding their biodiversity patterns and species compositions.

From these findings, we speculate that the species richness and abundance of ground beetles according to habitat preferences, especially forest species, would be explained by specific patterns, with several variables such as PBA, DIST, crop, and natural forests. These findings mean that forest species should be considered in accurately detecting the diversity pattern along the urban-rural gradient, but open-habitat species or total ground beetles may not appropriate to detecting the diversity pattern along the urban-rural gradient. In many previous studies, such as the GLOBENET project (Alaruikka et al. 2002, Ishitani et al. 2003, Magura et al. 2004, 2008a, 2008b, Deichsel 2006, Elek and Lövei 2007, Gaublomme et al. 2008), species richness and the abundance of forest specialists showed a negative relationship along the urban-rural forest gradient. Unlike the GLOBENET project, we focused on the effects of change in ground beetle assemblage according to various land-use types and variables; we did not focus on the urban-rural forest gradient. Thus, species richness and abundance of forest species in our studies were significantly decreased with variables for urbanization or environmental status. However, many variables in our studies generally represented the proportion of the disturbed area. In addition, variables in our studies do not directly represent habitat conditions. For example, PBA and DIST were not surrogates for other environmental variables, such as temperature, humidity, canopy covers, and leaf litter. Therefore, further studies on the relationships between ground beetles and environmental variables are necessary.

The ordination and classification at species level showed that several land-use types are clustered into 2 major groups of forest and non-forest areas, while analyses at subfamily levels are relatively less appropriate for classifying land-use types. By TWINSPAN, some species (*D. h. halensis*, *H. discrepans*, *C. costiger*, and *Chlaenius naeviger*) and subfamilies (Carabinae, Licininae, Scaritinae, Harpalinae) can be used as candidates for indicators. In general, *D. h. halensis*, *H. discrepans*, *C. costiger* and *C. naeviger* are known to be open-habitat species. Carabinae and Licininae species are generally forest specialists, while Scaritinae and Harpalinae species are generalists. However, there is little information about their ecological roles in ecosystems because only a few references can be applied to Korean ground beetles. Thus, we still need more information in order to determine the indicators for classifying land-use types. For example, Magura (2002) studied the spatial distribution of ground beetles and the effects of edge on their diversity; the study indicated the habitat preferences of each ground beetle species.

Implication for management of urban habitat

In general, an urban landscape can provide an important habitat for the maintenance of biodiversity due to mosaic landscapes. Recent studies regarding urban landscape, using ground beetles, have focused on examining the connectivity and change of diversity of ground beetles among habitat patches along urban-rural forest gradients (Alaruikka et al. 2002, Niemelä et al. 2002, Ishitani et al. 2003, Venn et al. 2003, Magura et al. 2004, 2008a, 2008b, Weller and Ganzhorn 2004, Deichsel 2006, Elek and Lövei 2007, Gaublomme et al. 2008). However, Sadler et al. (2006) and Fujita et al. (2008) suggested that continuous forests do not necessary serve as a "mainland" for forest specialists. However, Fujita et al. (2008) concluded that every urban habitat acts as a temporary reservoir of species possibly. In the present study, although most forest specialists were not found in non-forest areas, some forest species, including *C. j. jankowskii*, *Pterostichus* (*Nialoe*) sp., *Pterostichus sulcitarsis*, and *Synuchus* sp.1, were collected in non-forest areas such as AU, RM and UU. Indeed, AU is located within mountain areas, but RM and UU are located in urban environments, which are man-made green areas or habitat patches. This finding indicates that several habitat patches in the urban landscape may operate as "stepping-stones" for small-scale dispersion. However, interpretation of connectivity among various habitat types regarding results from anthropogenic disturbance is still limited because characterizing various forms of anthropogenic landscape modification effects is a difficult task (Csorba and Szabó 2009) and mechanisms in habitat use of ground beetles is uncertain.

In conclusion, environmental change by anthropogenic disturbance can cause different effects on ground beetle assemblages; examples of consequences are negative effects on forest specialists. However, we needed a greater understanding of the response mechanisms of ground beetles in changing the environment. In addition, studying the ground beetles in Korea has been mainly focused on the diversity of mountainous areas rather than relationships between ground beetles and habitat conditions. Therefore, an examination of the characteristics of ground beetles will be required prior to evaluating anthropogenic disturbance.

ACKNOWLEDGMENTS

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Appendix 1. List of ground beetle assemblage in the southern west part of Korea

Subfamily	Species	Wing form	Habitat type	Agricultural areas			Forest areas				Riversides		Urban roadsides	
				AP	AS	AU	FC	FB	FU	FE	RM	RN	UU	UM
Carabinae	*Aulonocarabus semiopacus*	B	F							6				
	Coptolabrus jankowskii jankowskii	B	F			2		2		18				
Nebriinae	*Nebria chinensis chinensis*	M	O					1						
Scaritinae	*Scarites* sp.	M	O		1									
Patrobinae	*Patrobus flavipes*	M	O								1			
Pterostichinae	*Dolichus halensis halensis*	M	O	12	47						11	1	1	1
	Pristosia vigil	B	F							1				
	Pterostichus microcephalus	M	O		4									
	Pterostichus sulcitarsis	M	F		2				1					
	Pterostichus (*Nialoe*) sp.	B	F			1							1	
	Synuchus cycloderus	M	F				9	11	1	47				
	Synuchus nitidus	M	F				17	71	1	12				
	Synuchus sp.1	M	F				27	56		14	4			
	Synuchus sp.2	M	F				2							
Harpalinae	*Anisodactylus signatus*	M	O										1	
	Harpalus capito	M	O									2		
	Harpalus discrepans	M	O			1								
	Harpalus (*Harpalus*) sp.	M	O								1			1
	Harpalus (*Psedoophonus*) sp.	M	O	96	27			3		2	4	1	20	
Zabrinae	*Amara* sp.	M	O	1										1
	Curtonotus gigantea	M	O										1	
Callistinae	*Chlaenius costiger*	M	O		1	1				1				
	Chlaenius micans	M	O	1										
	Chlaenius naeviger	M	O			1	4		1		3		1	
	Chlaenius virgulifer	M	O	1					1		1			
Licininae	*Diplocheila zeelandica*	M	O									1		
Lebiinae	*Pentagonica subcordicollis*	M	F							1				
Brachininae	*Pheropsophus javanus*	M	O	24	20	5								
	Pheropsophus jessoensis	M	O		293						2		4	

B, brachypterous; F, forest habitat species; M, macropterous; O, open-habitat species.