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Comparison of Ground Beetle Communities (Coleoptera: Carabidae) between Coniferous and Deciduous Forests in Agricultural Landscapes

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Abstract

This study was conducted to examine the community structure of ground beetles between coniferous- and deciduous-dominant forest in agricultural landscapes, in Miryang-si, Yeongdong-gun, Icheon-si, and Cheolwon-gun during April to October in 2009. A total of 19 species belonging to 15 genera of 9 subfamilies were identified from 6,253 collected ground beetles. Dominant species from 4 regions were *Synuchus nitidus* (3,715 individuals, 59.4% of total) and *Synuchus cyloderus* (1,783 individuals, 28.5%) respectively. Non-metric multidimensional scaling based on Bray-Curtis similarity showed that ground beetle assemblage was not different between forest stands, but it was significantly different among regions. Overall, forest stands of secondary forests may not show a different community structure of ground beetle assemblages in our study. However, monitoring on the ground beetle fauna as well as other arthropods of secondary forests in agricultural landscapes is still important for the management and conservation of biodiversity, because forests provides important habitats for many predatory arthropods, such as ground beetles, spiders and rove beetles.

Key Words: ground beetles, monitoring, biodiversity, conservation, forest stands

Introduction

Due to the increasing of disturbance followed by human activity, natural and semi-natural habitats have been continuously decreased in worldwide. Traditional agricultural landscapes are experiencing pressures from development and intensification (Katoh et al. 2009). Thus, the conservation of biodiversity is also one of the major concerns in these landscapes during environment change. In Korea, agricultural landscapes are composed of mosaic habitats such as forests (natural and artificial forest, coppice woodlands and grasslands), farmlands (rice and upland fields), settlements and reservoirs, and thus, biodiversity in agricultural landscapes is usually rich. The depopulation of rural society and the conversion of land-uses have caused the succession of forests in agricultural landscapes. In particular, land conversions are leading to a loss of biodiversity because of the decrease of heterogeneity (Choi et al. 2009).

Most studies about biodiversity and conservation in Korea have been focused on mountains, especially well con-

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served areas, but secondary forests in agricultural landscapes have been neglected during past decades (Choi et al. 2009). Takeuchi et al. (2003) pointed out that conservation of agricultural forests and its landscapes are important to maintain the biodiversity such as mammals, birds and arthropods, because these forests provide temporary refuges, habitats of reproduction, and overwintering sites for predatory invertebrates including ground beetles (Sotherton 1985; Wallin 1986; Thomas et al. 1991; Kagawa and Maeto 2009). In addition, many predatory invertebrates are needed various habitats including secondary forests for complete of their life cycle (Kagawa and Maeto 2009).

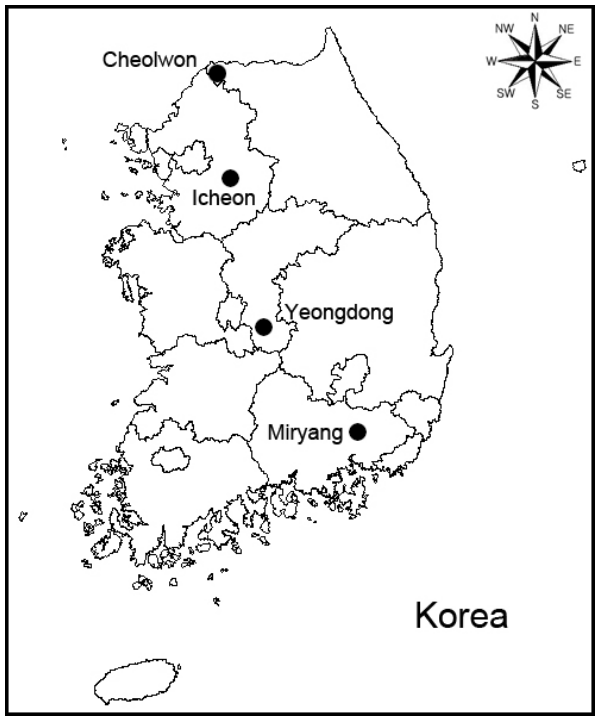

Fig. 1. Locations of 4 study regions.

Ground beetles are important in the agricultural ecosystem generally, because they feed on many invertebrate pests such as aphids, snails, lepidopteran larvae and so on (Lövei and Sunderland 1996; Kromp 1999; Holland 2002). In addition, many studies showed that ground beetles can be used a bioindicator for assessing the environmental status (Rainio and Niemelä 2003; Pearce and Venier 2006), because they adapt to certain habitats and many factors can affect to their distributions generally. Thus, to investigate the ground beetles in agricultural ecosystems will be important for the managements of semi-natural habitat and biodiversity.

This study was conducted to examine the community structure of ground beetles between coniferous and deciduous forests in agricultural landscapes along latitudinal gradient in Miryang-si, Yeongdong-gun, Icheon-si, and Cheolwon-gun, Korea.

Materials and Methods

Study areas and its environmental variables

Study sites were selected along latitudinal gradient as surrogate for annual mean temperature (Fig. 1, Table 1). Each study sites were composed of 2 forest stands between coniferous and deciduous forests. Descriptions of each sampling site were showed in Table 2. In general, forests in the rural landscapes of Korea are composed of *Pinus densi-*

Table 1. Habitat environments in each investigated rural forest

Region	Stand	Environmental variable (mean±SE)					
		Temp. (°C)	S.T. (°C)	R.H. (%)	S.H. (%)	L. (cm)	I. (°)
Miryang-si, Gyeongsangnam-do	Coniferous	24.1±0.9	18.6±1.0	53.9±5.2	10.9±2.0	4.1±0.2	16.7±2.6
	Deciduous	23.4±1.0	16.6±1.2	54.6±4.5	26.1±2.7	5.4±0.3	18.5±2.4
Yeongdong-gun, Chungcheongbuk-do	Coniferous	24.6±0.6	16.9±1.2	49.5±4.1	16.4±2.2	5.5±0.3	18.3±1.2
	Deciduous	24.5±0.9	15.9±1.2	48.5±4.1	24.8±2.9	5.8±0.6	16.8±1.9
Icheon-si, Gyeonggi-do	Coniferous	24.0±0.9	15.5±1.2	46.3±3.1	18.3±2.0	5.7±0.4	12.6±1.0
	Deciduous	24.3±0.8	15.3±1.3	48.8±3.6	34.3±2.8	5.4±0.5	10.4±1.0
Cheolwon-gun, Gangwon-do	Coniferous	22.0±1.5	13.5±1.6	54.0±2.9	24.3±2.8	5.7±0.4	16.6±1.6
	Deciduous	23.4±1.1	13.2±1.6	53.1±3.8	22.7±2.3	5.8±0.5	21.2±1.4

Temp., temperature; S.T., soil temperature; R.H., air relative humidity; S.H., soil humidity; L., leaf litter depth; I., incline.

Table 2. Habitat environments, coordinates and altitudes of each investigated location

Location	Abbreviation	Stand and environment	Dominant tree	Longitude	Latitude	Altitude (m)
Miryang-si, Gyeongsangnam-do	MC	Coniferous forest adjacent to paddy field and residential area	*Pinus densiflora*	128°49'43.8"	35°30'04.4"	55
	MD	Deciduous forest adjacent to river	*Castanea crenata* var.*dulcis*	128°50'34.3"	35°30'15.0"	65
Yeongdong-gun, Chungcheongbuk-do	YC	Coniferous forest adjacent to vineyard	*Pinus rigida*	127°52'16.4"	36°11'44.8"	205
	YD	Deciduous forest adjacent to vineyard	*Quercus acutissima* *Castanea crenata* var.*dulcis*	127°52'15.4"	36°11'58.4"	200
Icheon-si, Gyeonggi-do	IC	Coniferous forest adjacent to upland	*Pinus rigida*	127°26'44.6"	37°16'05.5"	95
	ID	Deciduous forest adjacent to paddy field and residential area	*Quercus acutissima*	127°26'39.0"	37°15'51.3"	70
Cheolwon-gun, Gangwon-do	CC	Coniferous forest adjacent to paddy field	*Pinus densiflora*	127°14'00.5"	38°10'45.4"	196
	CD	Deciduous forest adjacent to upland	*Populus davidiana*	127°13'52.0"	38°10'28.7"	220

flora Sieb. et Zucc., *Pinus rigida* Mill., *Quercus* spp. and *Robinia pseudoacacia* L. (Hong 1999). In particular, *P. rigida* and *R. pseudoacacia* are known to be introduced plants from North America for Forest Greenification in the past (Hong 1999). These trees are also dominant in our study sites generally.

Six environmental variables were measured in order to obtain the information of habitat conditions, such as air temperature and air relative humidity, soil temperature, soil humidity, leaf litter depth and incline (Table 2). Air and soil temperature, air and soil relative humidity were measured monthly on the afternoon of a typical sunny day around each pitfall trap within radius 5 m.

Sampling and identification

Ground beetles were collected by pitfall traps during April to October in 2009. Three pitfall traps were installed 10 m apart from each other and were emptied every month. 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 prevents collecting unwanted small mammals. A plastic roof was set up to prevent rainfall. Traps were filled with preservative (95% ethyl-alcohol:95% ethylene-glycol=1:1) for sample preservation. Collected ground beetles were brought to the laboratory and were dried, mounted, and identified to the species level under a dissecting microscope. Identification was performed according to Habu (1967, 1973, 1978, 1987), Kwon and Lee (1984), and Park and Paik (2001) and compared to voucher specimens in the laboratory. Nomenclature was confirmed by Park and Paik (2001) and Park (2004). Voucher specimens were stored in the insect ecology laboratory, Seoul National University.

Data analyses

Abundance and species richness were measured based on the number of individuals, and number of species collected in each sampling site, respectively. We pooled the data of collected ground beetles in each site and used in statistical analysis. For analysis of the species composition of the ground beetles among sites, a non-metric multidimensional scaling (MDS) with Bray-Curtis similarity was conducted using the PRIMER 6.0 (Clarke and Warwick 2001; Clarke and Gorley 2006). MDS was chosen because it performs well with ecological data that do not meet the assumption of normality (McCune and Grace 2002). Thus,

Table 3. List of ground beetles in rural landscape between coniferous and hardwood forests

Subfamily	Scientific name	Coniferous forest				Deciduous forest			
		MC	YC	IC	CC	MD	YD	ID	CD
Carabinae	*Aulonocarabus koreanus koreanus*							42	
	Coptolabrus jankowskii jankowskii		1					10	
	Coptolabrus smaragdinus branickii	7	9		1	1	1		
Nebriinae	*Nebria chinensis chinensis*							1	
Pterostichinae	*Pristosia vigil*						1		
	Synuchus cycloderus		823	177	92	1	410	196	84
	Synuchus nitidus		1,161	53	136	32	1,525	603	205
	Synuchus sp.1	2	286	67	36		132	91	30
	Trigonognatha coreana		1	3				2	
Harpalinae	*Bradycellus* sp.1		1						
	Harpalus discrepans			1				1	
Zabrinae	*Amara* sp.1			1					
Callistinae	*Chlaenius naeviger*		1	8	3		1	2	1
	Chlaenius pallipes			1					
Licininae	*Diplocheila zeelandica*					5			
Lebiinae	*Calleida onoha*				1				
	Dolichoctis luctuosus								1
	Galerita orientalis	1				1			
Brachininae	*Brachinus stenoderus*		1						
Number of species		3	9	8	6	5	6	9	5
Number of individuals		10	2,284	311	269	40	2,070	948	321

Abbreviated study site are: MC, YC, IC and CC are coniferous forests in Miryang-si, Yeongdong-gun, Icheon-si and Cheolwon-gun, respectively; MD, YD, ID and CD are deciduous forests in Miryang-si, Yeongdong-gun, Icheon-si and Cheolwon-gun, respectively.

MDS are the most generally effective ordination and classification methods for ecological community data (McCune and Grace 2002). In the MDS, the 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 the dissimilarities in species composition. Group averaging cluster analysis was also performed for determining characteristics of groups. The one-way ANOSIM permutation test with a maximum of 999 permutations was used to assess the significant differences among land-use types in the MDS, and then Global R value approaches 1 if differences among land-use types exist (Clarke and Warwick 2001).

Results

A total of 19 species belonging to 9 subfamilies were identified from 6,253 collected ground beetles (Table 3). Pterostichinae was dominant and diverse subfamily in all sampling sites except on coniferous forest in Miryang-si (MC) (Table 3). The dominant species of all sampling sites were *Synuchus nitidus* (3,715 individuals, 59.4% of total abundance) and *Synuchus cycloderus* (1,783 individuals, 28.5%) (Fig. 2). Two dominant species, *S. nitidus* and *S. cycloderus*, showed two peaks in seasonal activity and showed a similar pattern between stands and among regions generally (Fig. 3), while the seasonal activity of *S. nitidus* in coniferous forest in Cheolwon-gun (CC) seems likely a peak (Fig. 3D).

Some large-sized ground beetles as Carabinae species were collected (Table 3). *Coptolabrus smaragdinus branickii* was mainly collected from coniferous forests in both Miryang-si (MC) and Yeongdong-gun (YC), while *Coptolabrus jankowskii jankowskii* was mainly collected from deciduous forest in Icheon-si (ID). In particular, *Aulonocara-*

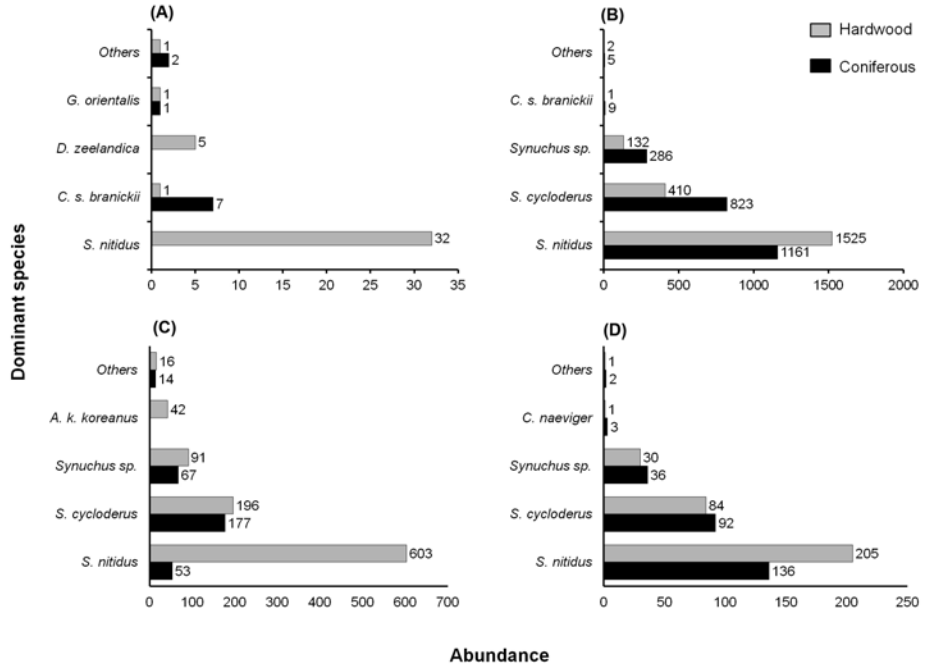

Fig. 2. Dominant species between rural coniferous and deciduous forests in Miryang-si (A), Yeongdong-gun (B), Icheon-si (C) and Cheolwon-gun (D).

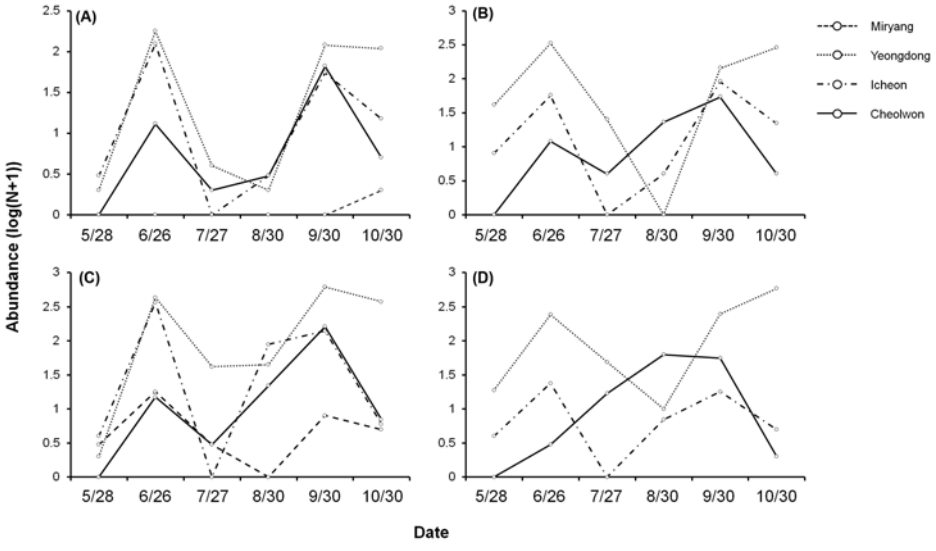

Fig. 3. Seasonality of 2 dominant species in each investigated region; *Synuchus cycloderus* in deciduous (A) and coniferous forest (B); Synuchus nitidus in deciduous (C) and coniferous forest (D).

bus koreanus koreanus was only collected from deciduous forest in Icheon-si (ID).

Analysis of similarity showed that there was no difference between forest stands (Global R=-0.146, p=0.886), while there was a significant difference among study regions (Global R=0.573, p=0.019). Non-metric multidimensional scaling and cluster analysis showed that 8 study sites diverged into 2 groups, Miryang (MC and MD) and other regions (Yeongdong, Icheon, and Cheolwon), at similarity level 36.1% (Fig. 4).

Discussion

Studying ground beetles between forest stands, i.e. con-

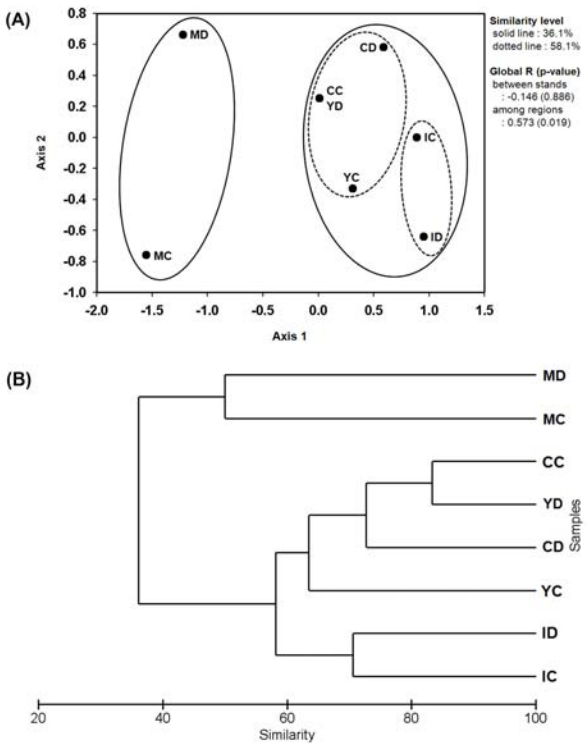

Fig. 4. NMDS ordination (A) and group averaging cluster analysis (B) based on Bray-Curtis similarity using presence-absence data of ground beetle assemblage among investigated regions and its forest stands.

iferous and deciduous forests, can provide some information for forestry due to bioindication characteristics of ground beetles. In Korea, Lee and Lee (1995) and Kubota et al. (2001) compared the ground beetle assemblage between forest stands. Lee and Lee (1995) showed a similar species composition of ground beetles between forest stands, but Kubota et al. (2001) showed some different for species composition and species richness of large-sized species as Carabinae. However, these previous studies could not represent the secondary forest in the agricultural landscapes, because study sites of Lee and Lee (1995) and Kubota et al. (2001) were located in mountainous areas, which are well conserved areas. In our study, on the other hands, forests at low altitudes and adjacent to agricultural areas as secondary forests showed a similar community structure of ground beetles between forest stands. This may general phenomenon in secondary forests, because secondary forests have been experienced by human activity frequently.

In general, habitat conditions, such as plants coverage, leaf litter, and soil humidity, may affect the distribution of ground beetles (Thiele 1977; Lövei and Sunderland 1996). In addition, altitude is one of major factors for community structure of ground beetles (Eyre et al. 2005; Hodkinson 2005), because forests in low altitudes are frequently disturbed by human activity, such as logging, fire, land conversions, and so on. Park (2010) also concluded that habitat management in the urban park may influence to the species composition and diversity of insects. In the results of our study, deciduous forest in Miryang is mainly composed of chestnuts (*Castanea crenata* var. *dulcis*), which indicates that this forest and ground flora has been managed by humans, such as spraying of pesticides and herbicides or clearing and thinning of vegetation. In addition, coniferous forest in Miryang showed lower soil humidity than other regions (Table 2). From these findings, low species richness and abundance of both coniferous and deciduous forest in Miryang can be explained, and thus, species composition was also different from other forests. On the other hands, many forest species of subfamily Carabinae and Pterostichinae did not collected in most our sampling sites compared to previous studies of mountainous area. Typical forest species such as *A. k. koreanus* and *C. j. jankowskii* are mainly collected from the deciduous forest in Icheon-si. Low species richness of Carabinae species can be explained by forest characteristics of our study sites as young secondary forests, because forest history is also important to determine the distribution of forest species (Kubota et al. 2001; Riley and Browne 2011).

Though, Choi et al. (2004), Kang et al. (2009), and Do et al. (2011) reported the community structure of ground beetles in the habitats around levee of rice fields or hillocks in the agricultural landscapes of Korea, but there are still few studies on the ground beetle assemblages in the agricultural landscapes including secondary forests. In many countries, on the other hands, ground beetles have been studied for a long time in both crop and non-crop fields (Holland 2002), because ground beetles can be used as potential predators for reducing the pest populations (Kromp 1999; Holland 2002) and bioindicators for assessing the environmental status (Rainio and Niemelä 2003; Pearce and Venier 2006). For example, some carnivorous species as *S. nitidus*, which is generally dominant species in Korean

forests in addition to Japanese forests (Kubota et al. 2000; Yeon et al. 2005), can be used as indicator for assessing chemical pollution in human-dominated environment, because their abundances are high in every forest along the urban-rural forest gradient as surrogate for the rate of human disturbances (Fujita et al. 2008).

Conclusion

In conclusion, ground beetles of forests in agricultural landscape showed a similar community structure between coniferous- and deciduous-dominant secondary forests, but different among regions due to different habitat conditions in each site. Although forest stands of secondary forests may not show a different community structure of ground beetle assemblages in our study, monitoring on the ground beetle fauna as well as other arthropods of secondary forests in agricultural landscapes are still important for biodiversity management and conservation, because forests adjacent to arable land are important for temporal refuges, habitats of reproduction, and overwintering sites for predatory arthropods, such as ground beetles, spiders and rove beetles.

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