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Structure and Seasonal Patterns of Ground Beetles Community in Wangpi-Cheon Watershed, South Korea

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ABSTRACT

Ground beetle fauna of Wangpi-cheon watershed in Yeongyang-gun to Uljin-gun, Gyeongsangbuk-do was investigated from May to October in 2012. Ground beetles were collected by pitfall trapping. A total of 38 species of 20 genera belonging to 8 subfamilies were identified from 2,486 collected ground beetles. Species richness was high in Pterostichinae (16 species), Carabinae (8 species), Harpalinae (5 species), Callistinae (3 species), Nebriinae (3 species) and others (1 species). Dominant species were *Synuchus cycloderus* (1,025 individuals) and *Aulonocarabus seishinensis seishinensis* (332 individuals), *Pristosia vigil* (133 individuals), and *Coptolabrus smaragdinus branickii* (117 individuals) in order. Monthly changes in abundance of upper dominante genera *Pterostichus*, *Aulonocarabus*, *Coptolabrus* species and Synuchus, Pristosia, Colpodes species showed that the former had the highest number in August whereas the latter increased in June and September. The genus *Pterostichus* species were preferred in deciduous forest in Wangpi-cheon watershed, while the genus *Synuchus* species were collected in mixes forest adjacent to farmland and recreation facilities and the genera *Chlaenius*, *Harpalus* species were collected in mixes forest adjacent to farmland nearby stream. Non-metric multidimensional scaling (NMDS), ground beetles and sites could be divided into two distinct groups: St. 1, St. 2, St. 3 group and St. 4 group. Some species such as *Pterostichus orientalis orientalis*, *P. vicinus* and *P. bellatrix* were particularly abundant at St. 4.

Keywords: Carabidae, Diversity, Ground beetle, Korea, Wangpi-cheon watershed

Introduction

Mountainous areas generally have high biodiversity because vegetation and habitat environment of wildlife are more dependent on the altitude and slope compare to low-altitude areas, which enables animals to adapt to certain environment, and they have better preserved environment than lower areas where a wide range of human activities take place (Lomolino, 2001). The ecosystem monitoring aims to assess how the structure, composition and functions of an ecosystem would change according to natural factors or human activities (Noss, 1990; Spellerberg, 1991), and data on the regional biota, density and distribution of species, and biological/non-biological

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environment are very important monitoring factors. Bioindicators can be used to assess biodiversity in certain areas, by monitoring environmental changes including wildlife habitat, assemblage or ecosystem (McGeogh, 1998). In particular, data on biodiversity in mountainous areas, whose environment is less disrupted by human, are important in the long-term for effective management and use of bioresources as well as biodiversity conservation. However, there have been few studies regarding long-term biodiversity monitoring, more specifically, few systematic analyses on ground beetles, which play an important ecological role in mountainous areas.

Ground beetles are generally known that more than the majority of the species are carnivorous and that they show dimorphism in their hind wings according to environmental characteristics (Lövei & Sunderland, 1996). To collect ground beetles, pitfall traps are standardized and wildly used around the world thanks to their low cost and easy comparison among collecting sites (Lövei & Sunderland, 1996; Niemelä *et al*., 2000; Southwood, 1978). Most species of Carabidae, except for some such as Halpalinae and Zabrinae, are carnivorous, eating small arthropods including earthworms, aphids, and snails, which indicates they play a significant role in the ecosystem (Lövei & Sunderland, 1996). Due to these eating properties, ground beetles are considered an important natural enemy in the agricultural industry (Holland, 2002; Kromp, 1999) and domestically there was an attempt to use them as a natural enemy of gall-midge (*Thecodiplosis japonensis*), which did not succeed (Kubota *et al*., 2001). Meanwhile, when it comes to wing athrophy in hind wings, brachypterous individuals were more likely to be found than macropterous ones in the habitats with less environmental changes like mountainous areas (Darlington, 1943). Particularly, most species belonging to Carabinae or Pterostichinae were brachypterous, with their hind wings atrophied, which weakens their flight capabilities, or the ability to move a long distance. Therefore, severance or changes in their habitats could lead to a decrease in biodiversity (Niemelä *et al*., 2000). Due to these ecological locations and biological characteristics, Carabidae have been reported as a taxonomic group suitable to be used as bioindicators (Lovei & Sunderland, 1996; Pearce & Venier, 2006; Thiele, 1977).

Regarding studies on insect fauna around the Wangpi-cheon watershed, a survey conducted by the Daegu Regional Environmental Office (2010) reported 209 species of 15 orders of insect fauna and more recently Gyeongsangbuk-do (2012) reported 304 species of 16 orders of insect fauna in its feasibility survey and master plan report for the designation of the Wangpi-cheon watershed as UNESCO Biosphere Reserve. However, those studies were based on light traps and sweeping for collection and even some reports didn't include Carabidae in their lists. This study aims to provide basic and biodiversity information on distribution characteristics and assemblage structures of Carabidae that inhabit the Wangpi-cheon watershed by using pitfall traps.

Materials and Methods

Study sites

Wangpi-cheon watershed is a stream that originates from Mt. Geumjangsan (849 m), stretching from Subi-myeon, Yeongyang-gun, to Onjeong-myeon, Uljin-gun, joins the Gwangcheon and Maehwacheon tributaries, and flows into the Ease Sea. The stream runs through several administrative districts including Uljin-gun and Yeongyang-gun. Although Wangpicheon floristically belongs to the Middle Province, it shows a mixed flora of northern and southern plants due to its geological properties. Around the Seongryu Cave, which is in a limestone area, there are Korean box tree (*Buxus microphylla* var. *koreana* Nakai) and Arbor vitae (*Thuja orientalis* Linne) assemblages and also *Thymus quinquecostatus* Celak, a northern species. We surveyed at the four sites according to the administrative district, habitat characteristics of vegetation, surrounding environment (Table 1).

Sampling and identification

Pitfall traps were installed considering the fact that ground beetles usually live on the surface of land. There were 10 traps with a 10 m interval and the top of the trap was placed at the height of the surface. Transparent plastic bottles with 130 mm height, 95 mm diameter and 500 mL volume were used as the pitfall traps and had plastic filters with 6 holes of 150 mm diameter to protect the captured ground beetles from mid- and large-sized animals like rodents. The traps were filled with a preservative (50 mL, environmentally friendly antifreeze,

Table 1. Habitat environments of each survey sites in Wangpi-cheon Watershed

Site	Habitat environment	Location
1	Mixed forest adjacent to recreation facilities (pensions etc)	Suha-ri, Subimyeon, Yeongyang-gun, Gyeongbuk
2	Mixed forest adjacent to farmland nearby stream	Suha-ri, Subi-myeon, Yeongyang-gun, Gyeongbuk
3	Mixed forest adjacent to a few farmland and deserted house	Ssangjeon-ri, Seo-myeon, Uljin-gun, Gyeongbuk
4	Decideous forest with limited outside access	Wangpi-ri, Seo-myeon, Uljin-gun, Gyeongbuk

Table 2. List of ground beetles collected in Wangpi-cheon Watershed

Subfamily	Species	Wing forms	Sites			
			St. 1	St. 2	St. 3	St. 4
Carabinae	*Aulonocarabus seishinensis seishinensis*	B	17	26	87	202
	Aulonocarabus koreanus koreanus	B			1	
	Calosoma maximowiczi	B	1			
	Coptolabrus jankowskii jankowskii	B	8	7	1	14
	Coptolabrus smaragdinus branickii	B	56	58	3	
	Coreocarabus fraterculus affinis	B			21	7
	Eucarabus sternbergi sternbergi	B	2	11	25	13
Nebriinae	*Leistus niger niger*	M			7	14
	Nebria chinensis chinensis	M	3	6		
	Nebria komarovi	M				6
Pterostichinae	*Dolichus halensis halensis*	B				7
	Colpodes xestus	B			7	88
	Pristosia vigil	B		27	16	90
	Synuchus cycloderus	M	430	226	340	29
	Synuchus nitidus	M	22		5	1
	Synuchus sp.1	M	17	7	1	
	Pterostichus ishikawai	B		11	2	5
	Pterostichus scurrus	B		3	1	82
	Pterostichus audax	B		2	3	74
	Pterostichus orientalis	B				122
	Pterostichus teretis	B			3	39
	Pterostichus bellator bellator	B				36
	Pterostichus microcephalus	B			1	
	Pterostichus vicinus	B				50
	Pterostichus sp.1	B				1
	Trigonognatha coreana	M	2	7	1	
Harpalinae	*Harpalus griseus*	M				1
	Harpalus eous	M		4		
	Harpalus vicarius	M		1		
	Harpalus sinicus sinicus	M		1		
	Trichotichus sp.1	M		2		
Patrobinae	*Patrobus flavipes*	M				1
Callistinae	*Chlaenius naeviger*	M	6	45	2	
	Chlaenius virgulifer	M	2			
	Chlaenius pallipes	M	1			
Lebiinae	*Cymindis collaris*	B		2	3	
Brachininae	*Brachinus stenoderus*	M		1		50
Number of species			13	19	20	34
Number of individuals			567	447	530	942

B, brachypterous; M, macropterous.

Super-A Green; SK chemicals, Suwon, Korea). The survey was conducted 14 times from May to October in 2012. The pitfall traps were collected at a 10 day interval - one time in May and October and three times from June to September each. Collected ground beetles were brought to a laboratory and dried, mounted, and identified with the species level under a dissecting microscope (SZ40, ×20; Olympus, Tokyo, Japan). The identification was performed according to Habu (1967; 1973; 1978), Kwon and Lee (1984), and Park and Paik (2001), Löbl and Smetana (2003), and Park (2004). The specimens examined were deposited in the J.Y. Park Collection, Gusan, South Korea.

Community structure analysis

Pielou's species diversity index (H', Pielou, 1966), McNaughton's dominance index (DI, McNaughton 1967), Margalef's species richness index (RI, Margalef, 1958) and Pielou's species evenness index (EI, Pielou, 1975) were calculated and the formulas are as follows:

$$H' = -\Sigma\ [ni/N \cdot \log_2 ni/N]$$

n_i means the number of individuals at i-th species and N means the total number of individuals (Pielou, 1966).

$$DI = ni + n2/N$$

n_1 means the number of dominant species individuals, n_2 means the number of subdominant species individuals, N means the total number of individuals (McNaughton, 1967).

$$\text{Species } RI = S - 1/\ln(N)$$

S means the total number of species and N means the total number of individuals (Margalef, 1958).

$$EI = H'/\log_2 S$$

H' means the species diversity index and S means the total number of species (Pielou, 1975).

To summarize and compare ground beetle compositions at four sties, a similarity matrix of Bray-Curtis similarity values (Clarke & Warwick, 2001) obtained from the long-transformed ground beetle assemblage data was analyzed. Non-metric multidimensional scaling (NMDS) was performed with 30 permutations because this scaling performs well for ecological data that are non-normal or are on arbitrary, discontinuous, or otherwise questionable scales (McCune *et al.*, 2002). The NMDS is an iterative procedure, constructing the plot by successively refining the positions of points until satisfied (Clarke & Warwick, 2001). In addition, first two dimensions often provide a reasonable starting point to the iterative computations for the 2-dimensional configuration (Clarke & Warwick, 2001). The stress value obtained from the NMDS analysis is a measure of distortion between the positions of real data points and their graphical representation. Thus, a low stress value 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. A one-way ANOSIM permutation test with a maximum of 999 permutations was used to assess the significance of differences between pre-defined groups of sample sites in multidimensional analyses; the Global R value approaches 1 if differences among ecological grades exist (Clarke & Warwick, 2001). Group averaging cluster analysis was also performed for determining of groups. Ground beetle assemblage data were transformed by log10 (N+1) when necessary to meet the assumption of normality. All multivariate analyses and calculation of the biodiversity index were performed using PRIMER v5.0 software (Premier Biosoft, Palo Alto, CA, USA; Clarke & Warwick, 2001).

Results

A total of 38 species belonging to seven subfamilies were identified from 2,486 collected ground beetles (Table 2). The numbers of species and individuals of each taxonomic group identified in this study were as follows: 16 species (42.11%) and 1,758 individuals (70.72%) of

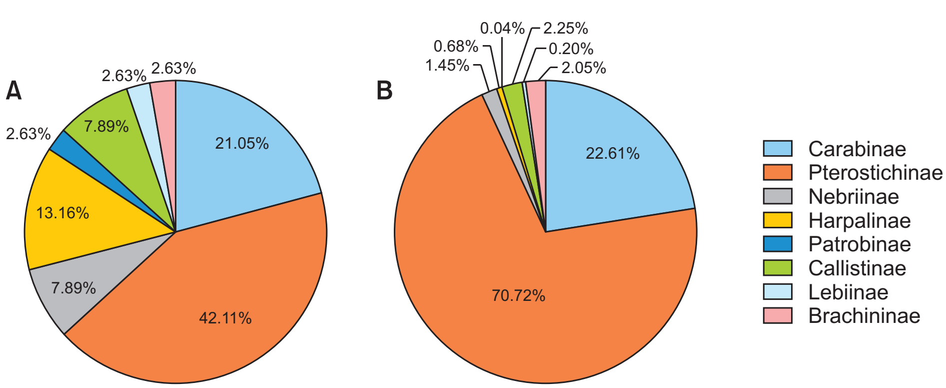

Fig. 1. Composition of species richness and abundance of each taxa in the subfamilies of Carabidae. (A) species ratio, (B) abundance ratio.

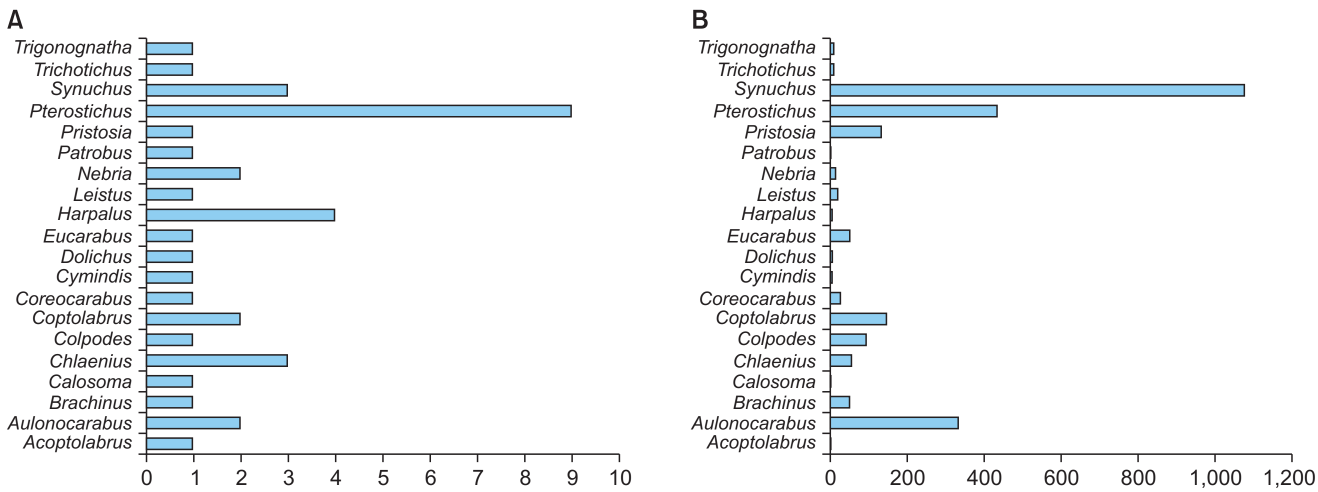

Fig. 2. Composition of species richness and abundance of each genus. (A) species, (B) abundance.

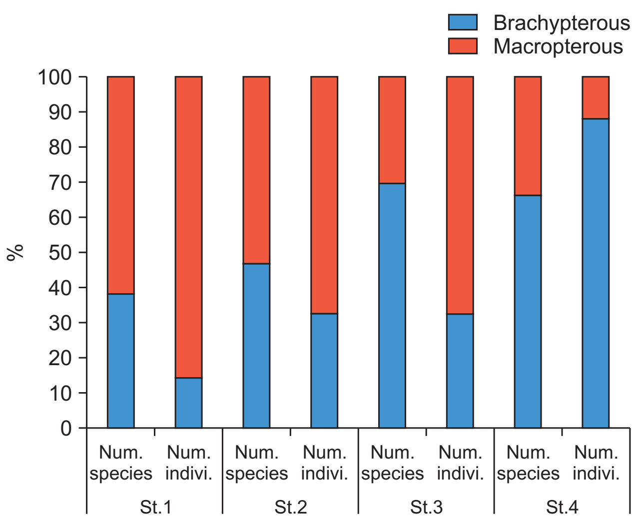

Fig. 3. Composition of species richness and abundance ratio of each wing forms to surveyed sites. Num., number; Indivi., individual.

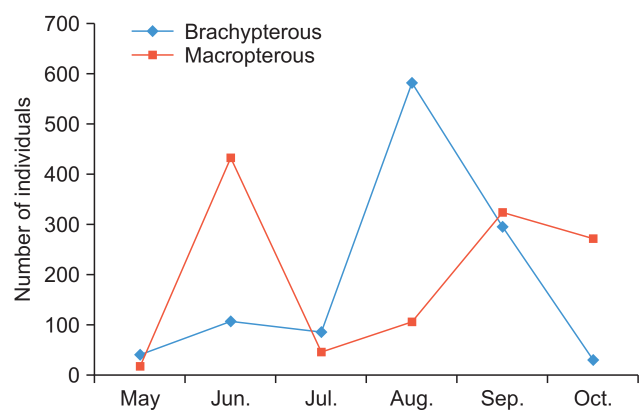

Fig. 4. The change of individual of each wing forms according to surveyed seasons. Jun., June; Jul., July; Aug., August; Sep., September; Oct., October.

Pterostichinae, 8 species (21.05%) and 562 individuals (22.61%) of Carabinae, 5 species (13.16%) and 17 individuals (0.68%) of Harpalinae, 3 species (7.89%) and 56 individuals (2.25%) of Callistinae, 3 species (7.89%) and 36 individuals (1.45%) of Nebriinae, 1 species (2.63%) and 51 individuals (2.05%) of Brachininae, 1 species (2.63%) and 5 individuals (0.20%) of Lebiinae, and 1 species (2.63%) and 1 individual (0.04%) of Patrobinae (Fig. 1). At the genus level, 9 species and 435 individuals of *Pterostichus*, 4 species and 7 individuals of *Harpalus*, 3 species and 56 individuals of *Chlaenius*, 3 species and 1,078 individuals, of *Synuchus*, were collected, followed by 2 species and 15 individuals of *Nebria* and *Aulonocarabus*, respectively. Other 9 genus for 1 species, respectively (Fig. 2). Twenty-one species (1,237 individuals) were brachypterous and 17 species (1,249 individuals) were macropterous (Table 2). Site 4 had the highest number of species and individual compared to other sites (Fig. 3). Monthly changes in individual numbers of brachypterous and macropterous showed that the former had the highest number in August whereas the latter increased in June and September (Fig. 4).

Monthly changes in abundance of upper dominante genera *Pterostichus*, *Aulonocarabus*, *Coptolabrus* species and *Synuchus*, *Pristosia*, species showed that the former had the highest number in August whereas the latter increased in June and September. While *Colpodes* species showed that had the highest number in June and August (Fig. 5).

The DI for each site was 0.54 to 0.85, and the average DI was in the order of St. 3> St. 1> St. 2> St. 4. The H'

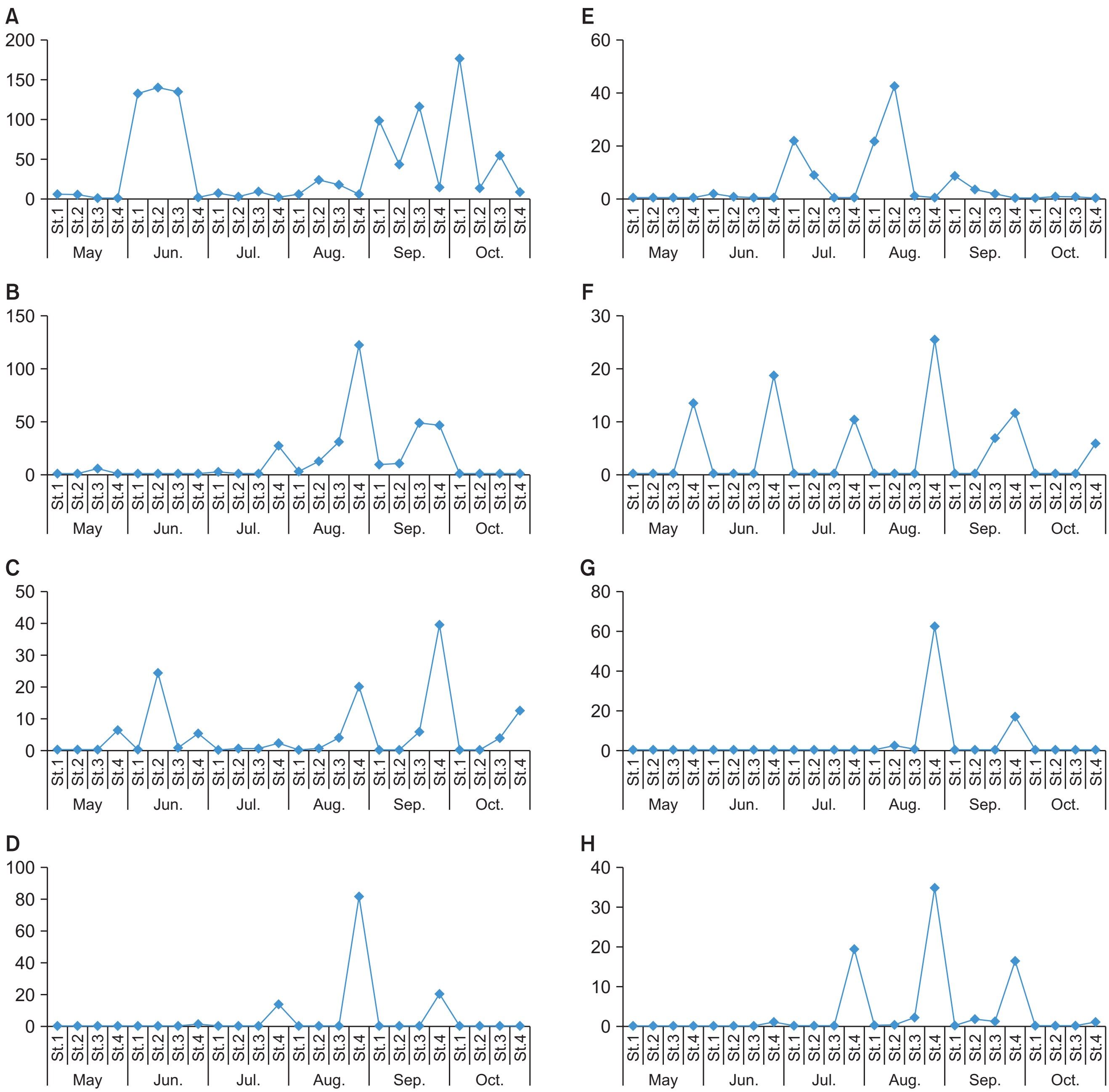

Fig. 5. Seasonal fluctuation of eight dominant species at each month. (A) *Synuchus cycloderus*, (B) *Aulonocarabus seishinensis seishinensis*, (C) *Pristosia vigil*, (D) *Pterostichus orientalis*, (E) *Coptolabrus smaragdinus branickii*, (F) *Colpodes xestus*, (G) *Pterostichus scurrus*, (H) *Pterostichus audax*. Jun., June; Jul., July; Aug., August; Sep., September; Oct., October.

for each site was 1.31 to 2.73, and the average H' was in the order of St. 4> St. 2> St. 3> St. 1. The species RI for each site was 1.21 to 2.31, and the average RI was in the order of St. 4> St. 2> St. 3> St. 1. The species EI for each site was 0.54 to 0.81, and the average EI was in the order of St. 4> St. 2> St. 3> St. 1. St. 4 had the lowest dominance and the highest diversity, richness and evenness (Table 3).

The dominant species was *Synuchus cycloderus* (41.2%), followed by *Aulonocarabus seishinensis seishinensis* (13.4%) and *Pristosia vigil* (5.4%). *S. cycloderus* were found in all study sites but the highest number of 430 was from St.1 followed by St. 3 (340), St. 2 (226) and St. 4 (29). Also, *A. seishinensis seishinensis* were found in all study sites but the highest number of 202 was from St.4 followed by St. 3 (87), St. 2 (26) and St. 1 (17) (Table 2).

Table 3. Community structure and diversity of each surveyed site in Wangpi-cheon Watershed

Site	Season	Community structure		Diversity			
		Species	Abundance	DI	H′	RI	EI
St. 1	May	4	9	0.78	1.45	1.37	0.72
	Jun.	7	151	0.95	0.77	1.20	0.27
	Jul.	8	44	0.73	2.08	1.85	0.69
	Aug.	4	36	0.75	1.61	0.84	0.81
	Sep.	8	138	0.80	1.51	1.42	0.50
	Oct.	4	189	0.97	0.42	0.57	0.21
	Mean	13	567	0.83	1.31	1.21	0.54
St. 2	May	2	7	1.00	0.86	0.51	0.86
	Jun.	8	199	0.83	1.41	1.32	0.47
	Jul.	7	26	0.69	2.25	1.84	0.80
	Aug.	11	118	0.57	2.76	2.10	0.80
	Sep.	11	78	0.69	2.33	2.30	0.67
	Oct.	4	19	0.89	1.29	1.02	0.65
	Mean	19	447	0.78	1.82	1.51	0.71
St. 3	May	2	16	1.00	0.95	0.36	0.95
	Jun.	7	151	0.93	0.74	1.20	0.26
	Jul.	6	18	0.78	1.79	1.73	0.69
	Aug.	14	87	0.57	2.76	2.91	0.72
	Sep.	11	196	0.86	1.71	1.89	0.49
	Oct.	4	62	0.97	0.58	0.73	0.29
	Mean	20	530	0.85	1.42	1.47	0.57
St. 4	May	3	24	0.88	1.35	0.63	0.85
	Jun.	12	67	0.46	3.00	2.62	0.84
	Jul.	16	117	0.42	3.14	3.15	0.78
	Aug.	19	481	0.43	3.33	2.91	0.78
	Sep.	16	222	0.39	3.42	2.78	0.86
	Oct.	7	31	0.68	2.13	1.75	0.76
	Mean	24	942	0.54	2.73	2.31	0.81
Total	Mean	38	2,486	0.75	1.82	1.62	0.66

DI, dominance index; H′, species diversity; RI, species richness index; EI, evenness index; Jun., June; Jul., July; Aug., August; Sep., September; Oct., October.

Except St. 4, the dominant species of in May, June, September, and October were macropterous *Synuchus cycloderus*, and the subdominant species were relatively diverse (Table 4). The seasonal fluctuation of eight dominant species at each month is shown in Fig. 5. *A. seishinensis seishinensis*, *Pterostichus orientalis*, *P. scurrus*, *P. audax* and *Coptolabrus smaragdinus branickii* were more abundant in August (Fig. 5B-H). *S. cycloderus*, *P. vigil* and *Colpodes xestus* were abundant in June and September (Fig. 5A, C, F). The genus *Pterostichus* were the highest at St. 4 compared to other sties (Fig. 5).

NMDS and cluster analysis with Simprof test based on the monthly data of ground beetle assemblages revealed that 4 studied sites could be divided into two distinct groups: St. 4 and the others (Fig. 6). ANOSIM results also indicated that the species composition of ground beetles was different according to the sites (Global R=0.432, *P*=0.001). The stress value for the NMDS configuration was low (stress=0.19), indicating the validity of the graphical representation of the data.

Table 4. Composition of dominant and subdominant species ratio of each surveyed site according to surveyed seasons

Taxa	Season	St. 1	St. 2	St. 3	St. 4
DS	May	*Synuchus cycloderus*	*Synuchus cycloderus*	*Eucarabus sternbergi sternbergi*	*Colpodes xestus*
	Jun.	*Synuchus cycloderus*	*Synuchus cycloderus*	*Synuchus cycloderus*	*Colpodes xestus*
	Jul.	*Coptolabrus smaragdinus branickii*	*Coptolabrus smaragdinus branickii*	*Synuchus nitidus*	*Aulonocarabus seishinensis seishinensis*
	Aug.	*Coptolabrus smaragdinus branickii*	*Coptolabrus smaragdinus branickii*	*Aulonocarabus seishinensis seishinensis*	*Aulonocarabus seishinensis seishinensis*
	Sep.	*Synuchus cycloderus*	*Synuchus cycloderus*	*Synuchus cycloderus*	*Aulonocarabus seishinensis seishinensis*
	Oct.	*Synuchus cycloderus*	*Synuchus cycloderus*	*Synuchus cycloderus*	*Pristosia vigil*
DS ratio (%)	May	23.2	71.4	62.5	58.3
	Jun.	87.4	75.8	89.4	31.7
	Jul.	66.7	40.5	56.1	23.5
	Aug.	61.5	35.9	38.8	25.0
	Sep.	72.5	53.8	61.3	20.3
	Oct.	93.7	68.4	90.3	41.9
SDS	May	*Chlaenius naeviger* *Nebria chinensis chinensis* *Coptolabrus smaragdinus branickii*	*Eucarabus sternbergi sternbergi*	*Coreocarabus fraterculus affinis*	*Pristosia vigil*
	Jun.	*Synuchus nitidus*	*Pristosia vigil*	*Coreocarabus fraterculus affinis*	*Eucarabus sternbergi sternbergi*
	Jul.	*Aulonocarabus seishinensis seishinensis*	*Chlaenius naeviger*	*Synuchus cycloderus*	*Pterostichus audax*
	Aug.	*Coptolabrus jankowskii jankowskii*	*Synuchus cycloderus*	*Coreocarabus fraterculus affinis*	*Pterostichus orientalis orientalis*
	Sep.	*Aulonocarabus seishinensis seishinensis*	*Aulonocarabus seishinensis seishinensis*	*Aulonocarabus seishinensis seishinensis*	*Pristosia vigil*
	Oct.	*Synuchus* sp.1	*Synuchus* sp.1	*Pristosia vigil*	*Synuchus cycloderus*
SDS ratio (%)	May	14.9	28.6	37.5	29.2
	Jun.	7.9	10.2	3.3	13.3
	Jul.	9.5	31.0	36.8	16.8
	Aug.	17.9	20.3	25.0	16.7
	Sep.	7.2	15.4	25.8	17.8
	Oct.	3.7	21.1	6.5	25.8

DS, dominant species; SDS, subdominant species; Jun., June; Jul., July; Aug., August; Sep., September; Oct., October.

Discussion

The NMDS analysis results divided ground beetles largely into two assemblage patterns: one is St. 1-2, 3 group and the other is St. 4 group (Fig. 6). Despite the long physical distance between them, St. 1-2 and St. 3 showed a similar assemblage pattern. This seems to be because St. 1-3 has mixed forest and St. 2-3 has farmland, which show that the two sites share similarities, resulting in the similar ground beetle assemblage pattern. On the other hand, St. 1 has a different external environment, for example, pensions, camping sites, and adolescent training

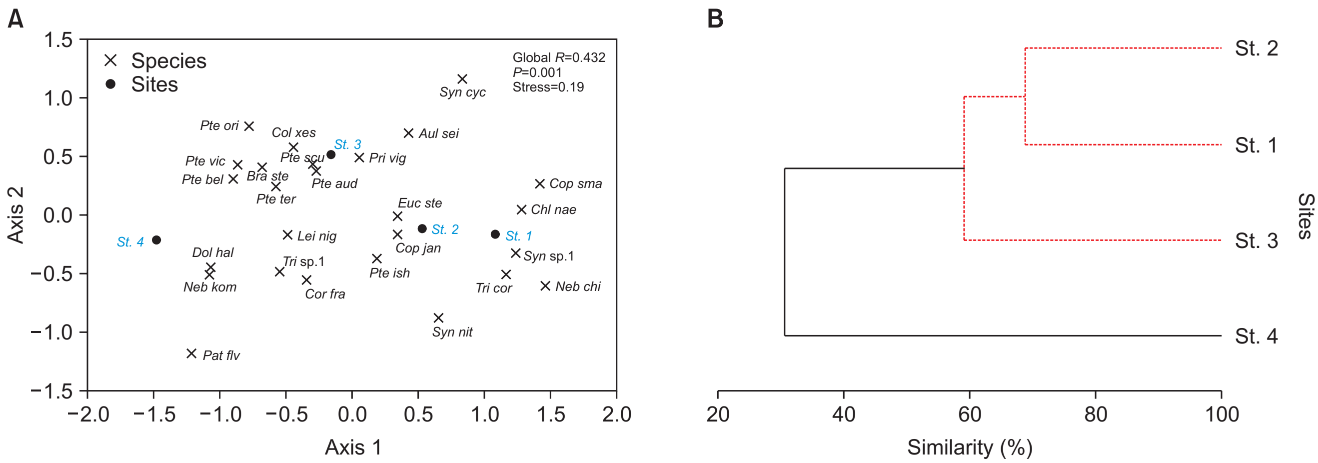

Fig. 6. NMDS (A), cluster analysis with Simprof test (B) and cluster analysis on the ground beetle community data (>5 individuals). *Aul sei*, *Aulonocarabus seishinensis seishinensis*; *Bra ste*, *Brachinus stenoderus*; *Chl nae*, *Chlaenius naeviger*; *Col xes*, *Colpodes xestus*; *Cop jan*, *Coptolabrus jankowskii jankowskii*; *Cor fra*, *Coreocarabus fraterculus affinis*; *Cor fra*, *Coreocarabus fraterculus affinis*; *Dol hal*, *Dolichus halensis halensis*; *Euc ste*, *Eucarabus sternbergi sternbergi*; *Lei nig*, *Leistus niger niger*; *Neb chi*, *Nebria chinensis chinensis*; *Neb kom*, *Nebria komarovi*; *Pat flv*, *Patrobus flavipes*; *Pri vig*, *Pristosia vigil*; *Pte aud*, *Pterostichus audax*; *Pte bel*, *Pterostichus bellator bellator*; *Pte ish*, *Pterostichus ishikawai*; *Pte ori*, *Pterostichus orientalis*; *Pte scu*, *Pterostichus scurrus*; *Pte ter*, *Pterostichus teretis*; *Pte vic*, *Pterostichus vicinus*; *Syn cyc*, *Synuchus cycloderus*; *Syn nit*, *Synuchus nitidus*; *Syn* sp.1, *Synuchus* sp.1; *Tri cor*, *Trigonognatha coreana*; *Tri* sp.1, *Trichotichus* sp.1.

facilities, which draws many visitors external disruption particularly in July and August (vacation seasons). So St. 1 has a different assemblage pattern with St. 2 even though they are close. St. 4, has decideous forest with limited outside access and stable environment compare to other sites because human access is strictly controlled (Fig. 6). This was also shown in the analysis that divided species according to wing atrophy in hind wings (Table 2). This difference could influence the distributions of these species, and result in a significant decrease in the macropterous group in St. 4, because the flight capability of macropterous species may be restricted by factors such as habitat complexity (Darlington, 1943; Gobbi *et al*., 2006; Kavanaugh, 1985). In general, it is important to take the wing form into account when analyzing ground beetle assemblages, because the wing form is closely related to the dispersal ability (Lövei & Sunderland, 1996). Brachypterous ground beetles have short functional hind wings and are more abundant in mountains than macropterous ground beetles because mountains provide relatively stable habitats (Darlington, 1943; Gobbi *et al*., 2006; Kavanaugh, 1985). Furthermore, brachypterous species is associated with climax environments as stable habitats (Brandmayr, 1991). Thus, the changes in community structure of ground beetles may be good indicators for studies on changes in habitats and landscape (Hodkinson & Jackson, 2005). The analysis on eight seasonally dominant species showed that genus *Synuchus* was found in all study sites with the highest number, *Pterostichus orientalis* was found only in St. 4. For *P. scurrus*, and *P. audax*, a few individuals were found in St. 2 (3 and 2 individuals, respectively) and St. 3 (1 and 3 individuals, respectively) whereas many were found in St. 4 (82 and 74, respectively).

Generally genus *Pterostichus* prefers stones, logs, tree bark and debris as shelter (Park & Kwon, 1996a; b). They have been reported as indicator insects in stable forest ecosystems (Langor & Spence, 2006; Molnar *et al*., 2001; Oates *et al*., 2005; Pearce & Venier, 2006; Pearsall, 2004; Riley & Browne, 2011;), which is consistent with a reported published by Jung *et al*. (2012). In comparison with two previous studies that analyzed Carabidae using pitfall traps, 38 species and 2,486 individuals of ground beetles reported in this study for one year showed the similar records with 34 species and 1,041 individuals in Mt. Bangtaesan for one year (Jung *et al*., 2011) and 32 species and 3,259 individuals in Mt. Sobaeksan for three years (Jung *et al*., 2012). This study could serve as base data for long-term monitoring by providing, even to a limited extent, information about distribution, assemblage, habitats, etc. of ground beetles which inhabit the Wangpi-cheon watershed in central-northern Korea

And indigenous species like *A. seishinensis seishinensis*, *A. koreanus koreanus*, *Coptolabrus smaragdinus branickii*, *Pterostichus scurra*, *P. audax*, *P. vicinus*, *P. teretis*, *P. vigil*, *Coreocarabus fraterculus affinis*, and *Dolichus halensis* have been found in all the sites. Considering some other countries conduct long-term monitoring and select indicator species by analyzing the species, Korea also needs to accumulate relative data through long-term monitoring on ground beetles by using pitfall traps in order to select environmental and forest indicator insects based on the data. Moreover, since Korea has many indigenous ground beetle species, continuous monitoring on various environmental and habitat characteristics (forest, soil humidity, temperature, altitude, litter layer, etc.) of indicator species will help find more indigenous species and protect endangered Carabidae species in the country.

This result will provide useful informations with establishment of conservation program and long-term monitoring against environmental change within mountain by using ground beetles.

Conflict of Interest

The authors declare that they have no competing interests.

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