pISSN 1229-3857 eISSN 2288-131X
Korean J. Environ. Ecol. 29(2): 200-209, April 2015 http://dx.doi.org/10.13047/KJEE.2015.29.2.200

Distribution of ground beetles (Coleoptera: Carabidae) in Naejangsan National Park, Korea[1a]

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ABSTRACT

This study was conducted to investigate the distributional characteristics of ground beetles and to provide basis information for biodiversity management including the ground beetles in the Naejangsan National Park area. Pitfall traps were installed throughout 20 sites within Naejangsan National Park during 2008 to 2011 to collect ground beetles. A total of 2,409 collected ground beetles were identified with 35 species belonging to 19 genera of 8 subfamilies. *Coptolabrus jankowskii jankowskii*, *Eucarabus sternbergi sternbergi*, and *Pterosticus audax* were dominant at the core area, while *Pheropsophus jessoensis*, *Synuchus nitidus*, *Synuchus cycloderus,* and *Chlaenius naeviger* were dominant at the border of the National Park and adjacent to the road or grassland. These differences of dominant species also affected to the similarity of species composition between core and border area, and caused increasing dissimilarities between sites with cluster analysis. Although the result of the present study was a case study using ground beetles, it will be helpful to develop a management strategy of biodiversity conservation in Naejangsan National Park and its surroundings.

KEY WORDS: CONSERVATION, BIODIVERSITY, MONITORING, SPECIES COMPOSITION

INTRODUCTION

Rapid environmental changes due to urbanization and climate change in recent are expected to have a serious impact on biodiversity, such changes are thought to caused by an increase in human activities (Czech *et al*., 2000). In particular, changes in land use due to urbanization, agriculture, and forestry are known to have a direct influence on the loss of biodiversity (Myers and Knoll 2001, Novacek and Cleland 2001). For this reason, the importance of nature reserves has been steadily increased. In addition, identification of key factors determining the distribution of species in habitats is necessary for biodiversity conservation. Although several attempts have been conducted in order to identify the relationship between insects distribution and environment in Korea (Park and An, 2000; Kwon and Park, 2005; Kang *et al*., 2009; Park, 2010; Do *et al*., 2012; Jung *et al*., 2011a, 2012), many studies conducted in Korea have been focused on biodiversity study (i.e., fauna=species list) through surveys on a specific area.

Performing a monitoring of whole biota is the best way to investigate biodiversity in a certain area (Weibull *et al*., 2003), but this is generally impossible due to limitations in human resources for monitoring and identification. For this reason, bioindicators should be applied for monitoring (Lindenmayer *et al*., 2006), because information on a

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monitoring program for the biodiversity management can be obtained if the bioindicators are monitored (Ferris and Humphrey, 1999). In this study, ground beetles was selected as bioindicators, because their taxonomic and biological characteristics are generally well known, and most of them are carnivores belonging to a high trophic level among arthropods (Rainio and Niemelä, 2003). In addition, because ground beetles have a specific habitat preference, they are readily respond to environmental changes (Thiele, 1977; Lövei and Sunderland, 1996; Rainio and Niemelä, 2003). Therefore, many studies have been carried out using ground beetles as a bioindicators to monitor environmental changes.

There were few studies regarding insects conducted in Naejangsan National Park as follows: a study on the entomofauna of Naejangsan Mountain (Kim *et al*., 1993); a report of resource monitoring in Naejangsan National Park published in 2011 (NNPO, 2011); a study on species distribution and the diversity of beetles (Lee, 2011). Although 10 and 17 ground beetle species were reported by Kim *et al*. (1993) and NNPO (2011) respectively, they were mainly reported lepidopteran insects. In case of Lee (2011), 32 coleopteran species belonging to 13 families using various sampling methods (hand collecting, pitfall trap, beating, sweeping). However, regarding the ground beetles distributed in Naejangsan Mountain, more study is necessary, because only six ground beetle species were reported by Lee (2011).

Therefore, this study was conducted to investigate biodiversity of ground beetles that inhabit Naejangsan National Park and identify the their distribution characteristics. This results can be useful for the establishment of long-term strategy on both habitat and biodiversity management.

MATERIALS AND METHODS

1. Study Site

Naejangsan National Park has been recognized for its importance as a nature reserve and was designated as a IUCN Category II protected area in 2010. According to the Dong'guk yeoji seungnam: an Augmented Geography Survey of the Eastern Nation (Korea), Naejangsan Mountain is one of the famous five mountains in Honam along with Jirisan Mountain, Wolchulsan Mountain, Cheongwansan Mountain and Neunggasan Mountain (Korea National Park Service, http://knps.or.kr/). Naejangsan National Park, which was designated as the eighth national park in 1971, is located in Naejang-dong, Jeongeup-si, Jeollanam-do and Bonkheung- myeon, Sunchang-gun, Jeollabuk-do, and covers an area of 80,708 ㎢ (Korea National Park Service, http://knps.or.kr/). There is Naejangsan (763 m) to the east, Ipamsan Mountain (626 m) to the west and Baekamsan Mountain (741 m) to the north of Naejangsan National Park. Although the height of these mountains are not high about 700 m, their slopes are very steep and ravined (NNPO, 2011). The dominant plant species in Naejangsan National Park are *Pinus densiflora* Sieb. et Zucc., *Quercus variabilis* Blume, *Carpinus laxiflora* Blume, *Torreya nucifera* Siebold & Zucc., *Acer palmatum* Thunb., *Quercus serrata* Thunb., *Daphniphyllum macropodum* Miq., *Quercus mongolica* Fisch. ex Turcz., *Cornus controversa* Hemsl. and *Salix koreensis* Andersson. In particular, *Torreya nucifera* Siebold & Zucc. in Baegyangsa Temple and *Daphniphyllum macropodum* Miq. in Seoraebong are geographically acknowledged as the northern limit line of plant distribution and are designated as natural monuments (Lee, 2011).

To collect ground beetles, 12 sites from 2008 to 2010 and 7 sites in 2011 were surveyed, and the management number of the grid 2×2 ㎞, that assigned by the Korea National Park Research Institute, was used for each study site (Table 1). The major vegetation types at the survey sites were classified into three subgroups, such as coniferous-dominated forests (5 sites), broadleaf deciduous forests (14 sites), and bamboo forest (1 site). In the coniferous-dominated forests, *P. densiflora*, *Pinus koraiensis* Sieb. et Zucc. and *Thuja orientalis* L. were dominant and *Q. mongolica*, *Q. variabilis*, *Quercus aliena* Blume and *A. palmatum* were dominant in the broadleaf deciduous forests.

Althougt, this study was conducted on the forest environment in Naejangsan National Park, the surrounding habitat of study sites located at forest edge habitats were different, such as grassland, farmland, and road. As for information on the land use of study sites, land-use within a 1-kilometer radius of study sites were confirmed using the land cover map (scale of 1:2,500) provided by the National Geographic Information Institute. While forest

Table 1. The environmental characteristics and studied year of each study site. The percent of forest area was calculated by land use map within a 1㎞ radius of study sites

Study site code	Dominant tree species	Forest type	Surrounding	Altitude (m)	Percent of forest area (%)	Study site			
						2008	2009	2010	2011
6	*Pinus densiflora*	Coniferous dominated	grassland	173	77.7				○
8.1	*Quercus mongolica*	Broad-leaved deciduous	crop	156	68.3	○	○		
8.2	*Phyllostachys bambusoides*	Bamboo	grassland	182	75.4			○	
9	*Acer palmatum, Ilex macropoda*	Broad-leaved deciduous	forest	151	51.5	○	○	○	
14	*Daphniphyllum macropodum, Cornus controversa*	Broad-leaved deciduous	forest	285	99.5	○	○	○	
15.1	*Quercus variabilis*	Broad-leaved deciduous	forest	246	96.2	○	○	○	
15.2	*Quercus variabilis*	Broad-leaved deciduous	roadside	222	94.9				○
17	*Pinus densiflora*	Coniferous dominated	crop	149	83.1				○
18	*Quercus mongolica*	Broad-leaved deciduous	forest	190	95.7	○	○	○	
19	*Quercus variabilis, Quercus mongolica*	Broad-leaved deciduous	forest	498	100.0	○	○	○	
20	*Cornus controversa, Castanea crenata*	Broad-leaved deciduous	forest	339	79.7	○	○	○	
23.1	*Quercus aliena, Quercus mongolica*	Broad-leaved deciduous	roadside	132	93.4	○	○	○	
23.2	*Salix koreensis*	Broad-leaved deciduous	grassland	148	90.4				○
24	*Quercus mongolica*	Broad-leaved deciduous	roadside	495	98.8		○	○	
25.1	*Zelkova serrate*	Broad-leaved deciduous	forest	216	96.6	○	○	○	
25.2	*Quercus mongolica*	Broad-leaved deciduous	crop	324	62.4				○
26.1	*Quercus mongolica*	Broad-leaved deciduous	roadside	116	79.5	○	○	○	
26.2	*Pinus densiflora, Thuja orientalis*	Coniferous dominated	grassland	135	70.4				○
27	*Pinus densiflora*	Coniferous dominated	grassland	161	82.8	○	○	○	
28	*Pinus densiflora*	Coniferous dominated	grassland	136	91.5				○

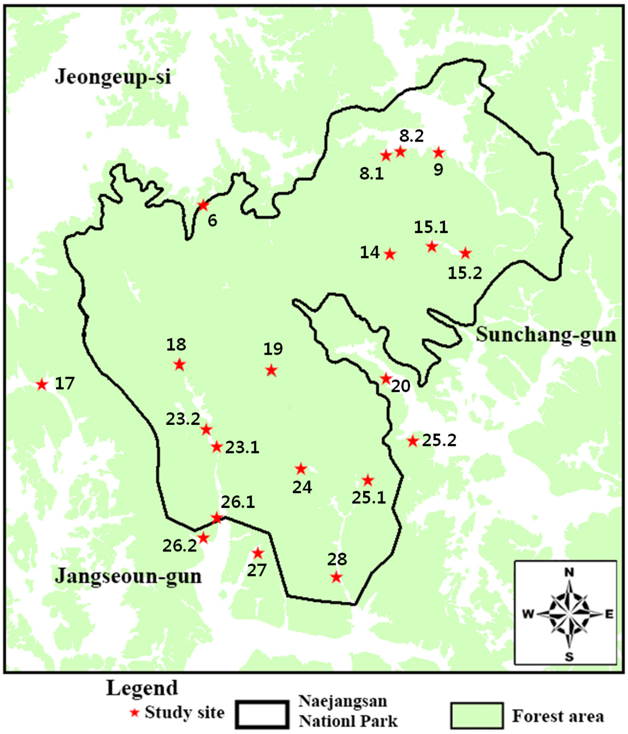

Figure 1. The distribution map of study sites in Naejangsan National Park, Korea

coverage rates in most areas in the National Park were considerably high (more than 90 %), that of study sites adjacent to built-up area or boundary area of the National Park were 60~83 %. Such environmental information was used to understand the distribution characteristics of ground beetles in Naejangsan National Park.

2. Collecting Method and Identification

Three pitfall traps were installed in each study site to collect ground beetles. The trap (10.5 ㎝ in diameter, 8 ㎝ in height) was plastic containers with six perforated holes (2.5 ㎝ in diameter) at mouthpart of trap to prevent trapping non-target animals (rodent, amphibian, and reptile), and a plastic roof was placed 3 ㎝ above each trap to prevent the inflow of rainfall and litter. Pitfall traps were un-baited, containing preservatives (300 ㎖, 95 % Ethyl-Alcohol:95 % Ethylene-Glycol=1:1) as killing- preserving solution, which replaced every month (3~4times a year). Collected ground beetles were brought to the laboratory and dried, mounted, and identified to the species level under a dessecting microscope (63×, Olympus SZ61).

Identification was performed according to Habu (1967, 1973, 1978, 1987), Kwon and Lee (1984) and Park and Paik (2001), and nomenclature confirms to list of Korean Carabidae by Park and Paik (2001) and Park (2004). The identified ground beetles were stored in the Insect Ecology Laboratory at Seoul National University.

3. Data analysis

The abundance and species richness of ground beetles were calculated in each study site. And non-parametric estimation methods, rarefaction curves (Gotelli and Colwell, 2001) and Chao I (Chao, 1984), were used to estimate the number of species in Naejangsan National Park. Also, for species composition analysis, data of ground beetles were pooled in each study site. Because the study period was different by study sites (92~310 days), the number of individuals of ground beetles at each site was transformed by trap-days (i.e., divided by the total study period per trap) for standardization. After that, the Bray-Curtis similarity among study sites was calculated and a cluster analysis was carried out (Clarke and Warwick, 2001). Species Diversity and Richness v3.0, the biodiversity analysis program was used for the rarefaction curves and Chao I (Henderson and Seaby 2002), and PRIMER v6.0 was used for the Bray-Curtis similarity and the cluster analysis (Clacke and Gorley, 2006).

RESULTS AND DISCUSSION

A total of 2,409 individuals belonging to 35 species were collected during 2008 and 2011 (Table 2). Estimated species richness of ground beetles in Naejangsan National Park was also approximately 35 species derived from rarefaction curves and Chao I (Figure 2). However, because the rarefaction curves did not asymptotic and there were large variations in the result of Chao I, which was reflected in rare species such as singleton, there is the possibility that more species will be collected in the further monitoring.

In species richness, 15 species were collected in site 25.2, followed by site 25.1 (13 species) and site 15.2 (12 species) (Table 2). In abundance, 368 individuals were caught in site 25.1, followed by site 16 (246 individuals), site 6 (218 individuals) and site 28 (217 individuals). Because all pitfall traps were installed within forests, the distribution of medium- and large-bodied species (*Aulonocarabus* spp., *Coptolabrus* spp., *Eucarabus* spp., and *Pterostichus* spp.) affected the species richness of ground beetles in each study site. On the other hand, the distribution of open-habitat species may differed according to the characteristics of the surrounding environment. For example, in case of the study sites within the well- protected area, medium- and large-bodied species including *Coptolabrus jankowskii jankowskii* Oberthur, *Eucarabus sternbergi sternbergi* Roeschke and *Pterosticus audax* Tschitschérine were dominant. On the other hand, *Pheropsophus jessoensis* Morawitz, *Synuchus nitidus* (Motschulsky), *Synuchus cycloderus* (Bates) or *Chlaenius naeviger* Morawitz were dominant at the boundary area of the National Park.

The result of cluster analysis also showed that the distribution of ground beetles was affected by the surrounding habitats in accordance with the characteristic of forests (Figure 3). In particular, the abundance and species richness of medium- and large-bodied species groups were high in well-preserved sites as broad-leaved deciduous forests (site 8.1, 9, 14, 15.1, 18, 19, 20, 25.1, 25.2), showing a clear difference from other study sites. But species composition of some broad-leaved deciduous forests sites, which were adjacent to non-forest environment with a rocky ground surface, Such results were thought to be relevant to the difference in distribution of dominant

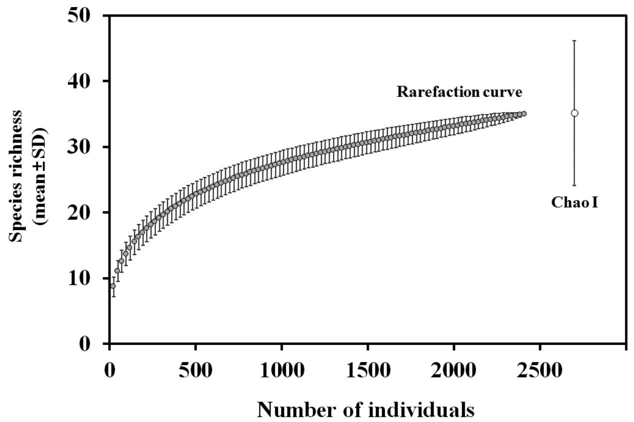

Figure 2. Estimated species richness with standard deviation by individual-based rarefaction curves (grey-circle) and Chao I (opened-circle) for ground beetles

Table 2. List of ground beetle assemblages in Naejangsan National Park during 2008 to 2011

Scientific name	Study site code																			
	6	8.1	8.2	9	14	15.1	15.2	17	18	19	20	23.1	23.2	24	25.1	25.2	26.1	26.2	27	28
Carabinae																				
Aulonocarabus seishinensis seishinensis					1															
Aulonocarabus semiopacus		12		15	4	2	1		5	1	10	2			2	1				
Coptolabrus jankowskii jankowskii	7	6	1	25	29	41	2	2	51	16	23	2		19	227	68	3	2	1	7
Coptolabrus smaragdinus branickii		2	1								1					1			2	
Eucarabus sternbergi sternbergi		2	1	3	17	20	1			9	17			1	69	2				
Nebriinae																				
Nebria chinensis chinensis	1			1				1					1					1		
Pterostichinae																				
Cosmodiscus platynotus																			1	
Dolichus halensis halensis																			3	
Pristosia vigil		1				1						2			1	3		1		
Pterostichus bifoveolatus						1														
Pterostichus audax					35	36	1			47		4		3	2	1	5			
Pterostichus raptor																	1			
Pterostichus solskyi																1				
Pterostichus togyusanus						8														
Pterostichus (*Koreonialoe*) sp.1						6									2					
Pterostichus sp.1					1															
Synuchus arcuaticollis	9	7	3	13	2	3	1	12		8	1				4	11		3		
Synuchus nitidus	79	3	7	17	1	4	25	20	8	17	4	23	33	66	7	10	9	6	16	3
Synuchus cycloderus	56	1		6			26	197		4	6		1			17		4	4	
Synuchus sp.1										3										
Trigonognatha coreana							3		1											
Trigonotoma lewisii	1																1	1		
Harpalinae																				
Anisodactylus tricuspidatus							1													
Harpalus chalcentus												1								
Harpalus discrepans				1				1							1	1				
Harpalus griseus												1								
Harpalus tridens											1	1		1					19	
Callistinae																				
Chlaenius variicornis																		1		
Chlaenius naeviger	55	2	7	1				6				1	13	1	3	5	13	32	2	
Chlaenius virgulifer	1																			
Licininae																				
Diplocheila zeelandica				2			1	1				1		1	7	2	1			
Lebiinae																				
Galerita orientalis	3													1						1
Planetes puncticeps	5						1						1			2	1		1	
Brachininae																				
Brachinus scotomedes				1		1		1	1			1	1	10	9	3	13	4	1	
Pheropsophus jessoensis	1				7		9	5				17	4	33	34		26	15	126	206
Number of species	11	9	6	11	9	11	12	10	5	8	8	12	7	10	13	15	10	11	11	4
Number of individuals	218	36	20	85	97	123	72	246	66	105	63	56	54	136	368	128	73	70	176	217

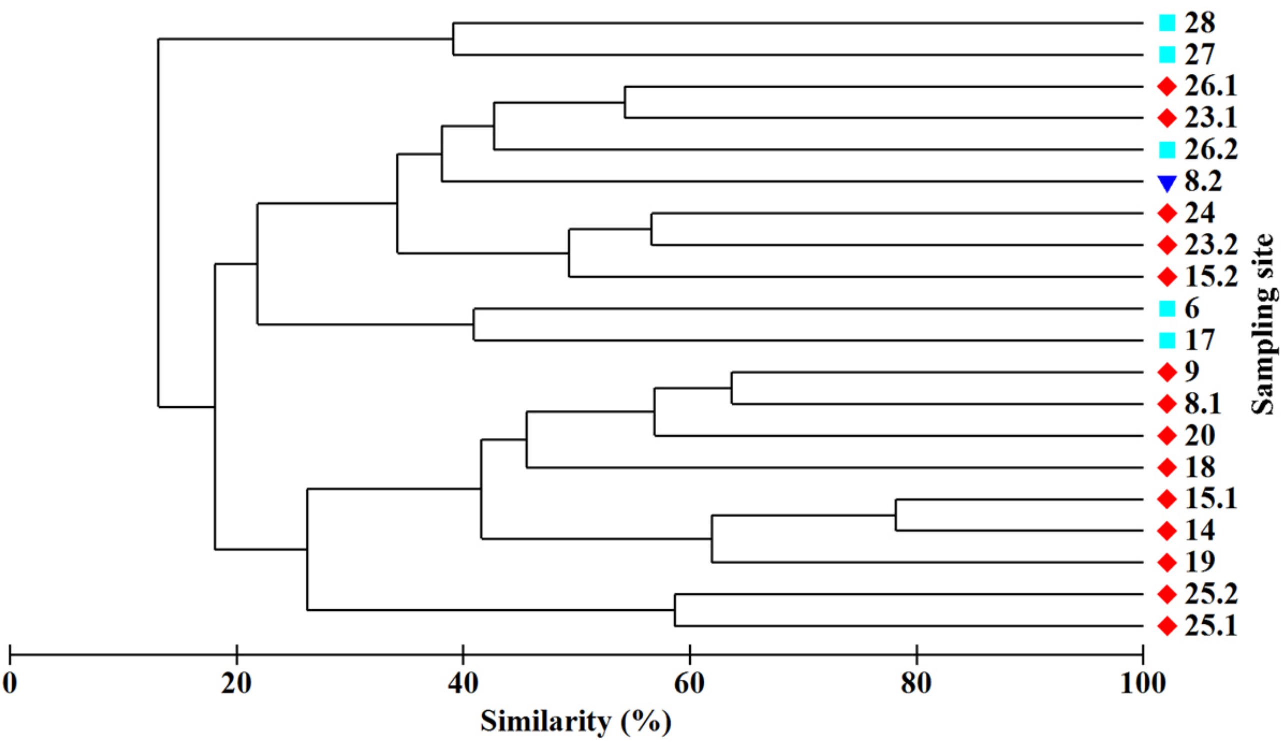

Figure 3. Group averaging cluster analysis based on ground beetles (transformed data by trap-days) in Naejangsan National Park

species by study site. In general, *S. cycloderus* and *S. nitidus* are dominant in Korean forests (Yeon *et al*., 2005), but the results of this study showed some differences according to environmental characteristics of study sites. This is thought to be due to various factors such as competition among species, changes in the surrounding environment, and habitat stability. And this results similar with some of previous studies carried out in Bangtaesan Mountain (Jung *et al*., 2011a) and Gariwangsan Mountain (Jung *et al*., 2011b) in Gangwon-do, the places that have well-preserved forest habitats. In particular, changes in the surrounding environment may play a critical role for species distribution. In fact, if the surrounding environment changes due to newly constructed roads, agricultural activity or urbanization, microclimate factors (e.g., temperature, humidity, wind, etc.) within forests may also change (see edge effect described by Laurance, 2008). These changes in the forest environment can also affect the characteristics of microhabitats and lead to a decrease in abundance of species that prefer stable habitats. In addition, species composition may change greatly when open-habitat species habitats penetrate into forests.

Compared to previous studies that reported 27 ground beetle species in Naejangsan National Park (Kim *et al*., 1993; Lee, 2011; NNPO, 2011), 25 species (including 3 undetermined species) were newly listed except for 1 species (*Pterostichus mucronatus*), which species may be misidentified. Overall, ground beetle fauna in Naejangsan National Park is summarized as 51 species belonging to 28 genera of 11 subfamilies (Appendix-1). In ground beetles, the species richness may vary greatly according to the number of species belonging to Harpalinae or Callistinae, which species are generally known to open-habitat species. However, in this study, because pitfall traps were installed within forest environments, their capture was not much influence on abundance and species richness of whole ground beetles, while species belonging to Carabinae or Pterostichinae, which include many forest species, did have a substantial influence on the abundance and species richness in study sites. The species richness of ground beetles in NNPO (2011) and Kim *et al*. (1993) was lower than that of this study, because they mainly used light traps to collect flying insects. However, pitfall trap is the most commonly used monitoring ground-dwelling arthropods (spiders, rove beetles, and ants) including ground beetles. Therefore, there are some limitations in sampling ground beetles with light traps. On the other hand, only 6 ground beetle species were listed by Lee (2011), although pitfall traps were used in that study. In this case, short installation period in pitfall traps (i.e., 3 times for 3 days) may be resulted in lower diversity. In general, in case of monitoring ground beetles using pitfall traps, a period of at least four months a year is suggested as the reasonable survey period in order to secure species diversity (Woodcock, 2005). This is because the seasonal occurrence is vary according to species. In addition, if long-term monitoring is impossible, it was suggested that at least 20 days a year are required considering the season to collect more than 50% of total species diversity (Niemelä *et al*., 1990).

The result of this study is limited to ground beetles, however, it will be useful to establish strategy for the habitat and biodiversity management. Species composition and diversity in core habitat in National Park may greatly differed from that of its boundary habitats. In particular, among study sites, Naejangsa Temple ~ Geumseon Valley area, Namchang Valley ~ Monggye Waterfall area, and Baekyangsa Temple area are thought to be the most important areas of biodiversity conservation in Naejangsan National Park. On the other hand, forest habitats located at the boundary of the National Park with thinned litter layer may have a less potential capability to enhance biodiversity, although these areas can be used as buffer zone to protect core habitats or valuable habitat for some threatened and endangered species (Brockerhoff *et al*., 2008). However, more studies are required how various arthropods including ground beetles are affected by environmental characteristics such as vegetation and litter layer in terms of spatial distribution.

In conclusion, because the existence of natural broad-leaved deciduous forests within a forest landscape is very important for the biodiversity conservation in general (Fuller *et al*., 2008), the development and disturbance in these natural forests should be minimized. In addition, the results of this study can be used as basic data for the management of forests and their surrounding habitats to improve biodiversity in national parks, because pitfall trap can be used as useful monitoring tools to study the spatio-temporal distribution of ground beetles (i.e., the relationship between ground beetles and environmental variables) as well as other ground-dwelling arthropods (Woodcock, 2005). In addition, long-term monitoring is necessary to predict the response of organisms under environmental changes.

ACKNOWLEDGEMENT

This research was supported by Resource Monitoring in Naejangsan National Park (2008~2011) and BK21 plus project

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Appendix 1. List of ground beetles in Naejangsan National Park

Subfamily	Scientific name	References			Present study
		Kim *et al.* (1993)	NNPO (2011)	Lee (2011)	
Carabinae	*Aulonocarabus seishinensis seishinensis*				●
	Aulonocarabus semiopacus				●
	Coptolabrus jankowskii jankowskii	○	○	○	○
	Coptolabrus smaragdinus branickii				●
	Eucarabus sternbergi sternbergi			○	○
Nebriinae	*Nebria chinensis chinensis*				●
	Nebria coreica		○		
Patrobinae	*Diplous caligatus*		○		
	Patrobus flavipes		○		
Pterostichinae	*Colpodes buchanani*	○	○		
	Cosmodiscus platynotus				●
	Dolichus halensis halensis	○	○		○
	Pristosia vigil				●
	Pterostichus audax				●
	Pterostichus bifoveolatus				●
	?Pterostichus mucronatus	○			
	Pterostichus raptor				●
	Pterostichus solskyi				●
	Pterostichus togyusanus				●
	Pterostichus sp.1				●
	Pterostichus (Koreonialoe) sp.1				●
	Synuchus arcuaticollis				●
	Synuchus cycloderus			○	○
	Synuchus melantho			○	
	Synuchus nitidus			○	○
	Synuchus sp.1				●
	Trigonognatha coreana		○		○
	Trigonotoma lewisii				●
Harpalinae	*Anisodactylus tricuspidatus*				●
	Bradycellus subditus	○			
	Harpalus capito		○		
	Harpalus chalcentus				●
	Harpalus coreanus		○		
	Harpalus discrepans				●
	Harpalus griseus				●
	Harpalus tridens				●
Zabrinae	*Curtonotus macronotus macronotus*	○			
Callistinae	*Chlaenius costiger*		○		
	Chlaenius naeviger			○	○
	Chlaenius posticalis		○		

Subfamily	Scientific name	References			Present study
		Kim *et al.* (1993)	NNPO (2011)	Lee (2011)	
Callistinae	*Chlaenius variicornis*				●
	Chlaenius virgulifer		○		○
Licininae	*Diplocheila zeelandica*				●
	Lachnocrepis japonica	○			
	Lachnocrepis prolixus	○			
Odacanthinae	*Odacantha aegrota*		○		
Lebiinae	*Anomotarus stigmulus*		○		
	Galerita orientalis				●
	Parena latecincta		○		
	Planetes puncticeps				●
Brachininae	*Brachinus scotomedes*	○	○		○
	Pheropsophus jessoensis	○	○		○

Opened-circle (○) indicates previously recorded species, and filled-circle (●) indicates newly listed in this study.