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Distribution and Diversity of Beetle Fauna (Coleoptera:Carabidae) on Korean Mountain Jangsan

Chong Kyu Lee[1], Mi Hwha Park[1], Joshua Pope Adams[2] and Young Min Kang[3,*]
[1]*Department of Forest Resources, Gyeongnam National University of Science and Technology, Jinju 660-758, Republic of Korea*
[2]*School of Forest Resources, University of Arkansas at Monticello, P.O. Box 3468, Monticello, AR 71656, USA*
[3]*Herbal Medicine Resources Group, Herbal Medicine Research Division, Korea Institute of Oriental Medicine, Daejeon 305-811, Republic of Korea*

Abstract

This study was conducted during May to September in 2012 to investigate the distribution and diversity of beetles in Mt. Jangsan (634 m) located near Busan, Republic of Korea. The collection of beetles was repeated 11 times in the four areas classified according to altitudes 200 m, 400 m, 600 m, and over 600 m (approximately) on the south and north slopes of Mt. Jangsan. A total of 12 families, 20 species, and 4,343 individual beetles were collected. In the southern slopes, a total of 12 families, 20 species, and 2,264 individuals were collected, whereas a total of 12 families, 20 species, and 2,079 individuals on the northern slopes were captured. The monthly emergence of beetles was the highest in August at 651 individuals followed by 516 individuals in September, 496 individuals in July, 364 individuals in Jun, 237 individuals in May. In the northern slopes, the monthly emergence of beetles was the highest in August as 591 individuals followed by 512 individuals in September, 443 individuals in July, 321 individuals in June, and 212 individuals in May. On the southern slopes, the species diversity index, evenness index, and dominance value were 0.950, 0.730, and 0.181, respectively, while in the northern slopes, the species diversity index, evenness index, and dominance index were 0.946, 0.727, and 0.182, respectively. In the both slopes, the species diversity index and evenness index were the highest in May, while dominance index was the highest in September. This study lays the groundwork for further monitoring of these sites and others through the region for environmental changes using the indicator species.

Key Words: beetles, dominance index, indicator species, Mt. Jangsan, species diversity

Introduction

Beetles belong to the Insecta Class; Coleoptera Order and are widely disseminated across the earth. There are 3,000 known beetle species mostly preferring to live in high humidity ecosystems. These ecosystems include earth's forested areas where beetles can thrive in woody-debris, inside bark, and even in the forest soil of rocky areas. Most beetles are nocturnal and most species reach imago during the winter season. Sometime, a few beetles may pass through one winter season. Depending on the species, beetles can be predators that prey on other arthropods including insects, earthworms, and snails. Beetles decompose animal carcasses, feces, and fallen woody debris or forest pests (Evans and Bellamy 1996). Most of beetles are flightless due to the degeneration of their wings (Kwon and Lee 1984). Because

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Corresponding author: Young Min Kang

Herbal Medicine Resources Group, Herbal Medicine Research Division, Korea Institute of Oriental Medicine, Daejeon 305-811, Republic of Korea
Tel: 82-42-868-9684, Fax: 82-42-863-9434, E-mail: ymkang@kiom.re.kr

many species have limited mobility, changes in population often occur in limited areas making beetles a good indicator species of environmental change (Ishitani and Yano 1994; Thiele 1997).

Most imago beetles distribute only by walking and, in cases of substantial environmental change such as road construction, deforestation near cities, large-scale residential land development, and forest decline, beetles have extreme difficulties moving rapidly to different places. This has led to beetles being recognized as a sensitive insect to changes in the environment. Thus, many studies have focused on the ecology of the beetles as environmental indicator species (Lee 2011). Diversity of beetle species in forests around cities have been carefully examined by many researchers (Kim and Lee 1992; Kwon et al. 1994; Kwon 1996).

According to the Korean geo-historical literature, the old nomenclature of Mt. Jangsan (650 m above sea level) located at Haeundae-gu, Busan metropolitan city was Jangsanguk (Dongraehyun, Naesanguk). Mt. Jangsan has a broad plain with a pampas grass land. The dominant plant species of this mountain are hardwoods such as *Quercus aliena*, *Quercus mongolica*, *Styrax japonica*, and *Alnus sibiroca*. Minor species, such as *Pinus thunbergii* Parl., grow interspersed with the dominant hardwoods. However, *Pinus densiflora* was introduced as plantations after 1950 to improve diversity of hardwood.

Mt. Jangsan is located within the Busan metropolitan city, but it is about 10 km away from city's downtown. It is used for recreation such as mountain-climbing by Busan citizens, while some areas of Mt. Jangsan have been under military protection and public access is tightly regulated resulting in relative vegetation conservation in these areas.

The purpose of this study was to investigate the diversity of beetle species and their populations in the forest areas of Mt. Jangsan. Therefore, these results might be useful as a basis of ecological research on beetles as the indicator species of other similar forest areas.

Materials and Methods

Beetle study area selection and collection period

Most land area on Mt. Jangsan is used as recreational areas by citizens of Busan, but some areas are currently military protection facilities with little public access. Geographical information on this site is available at http://en.wikipedia.org/wiki/ Jangsan_(Busan). The survey area was divided into two sections (i.e., southern and northern slopes) (Fig. 1). Southern slopes stretched from

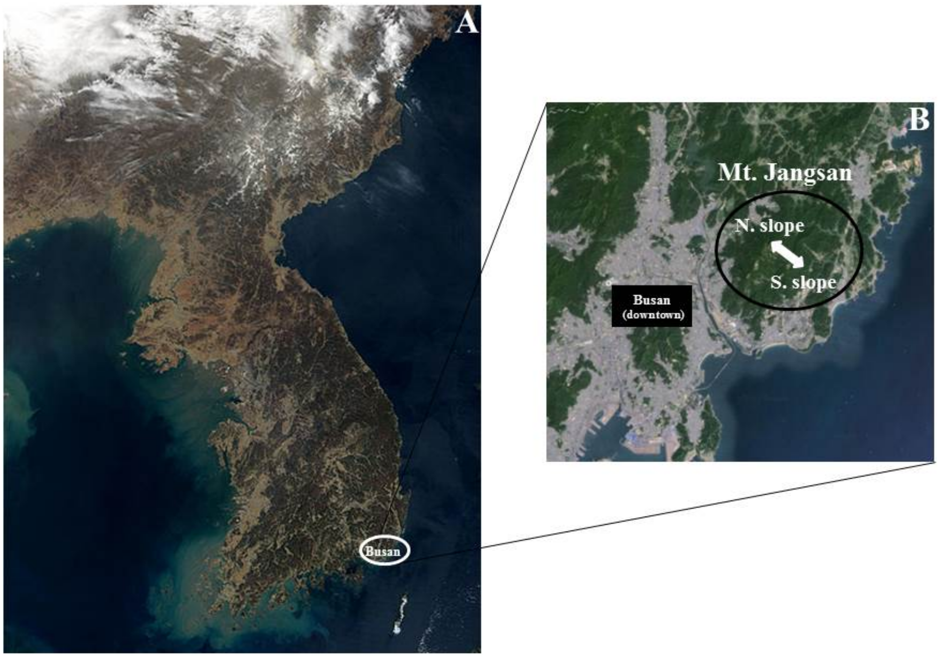

Fig. 1. The map of survey area (Korean Peninsula topographic map) (A) and study site (B). The Mt. Jangsan is approximately 10km away from a city of Busan (see the map).

Table 1. Pusan meteorological monthly data collected from 2002 to 2011

Factor \ Month	1	2	3	4	5	6	7	8	9	10	11	12	Avg.
Ave. Temper. (°C)	3.5	5.8	8.9	13.6	17.5	20.9	23.9	25.8	22.6	18.0	11.6	5.6	14.8
Precipitation (mm)	30.5	57.2	77.1	154.7	190.3	177.9	381.8	239.4	131.0	61.1	26.8	26.7	1,295
Ave. Wind Speed (m/s)	3.5	3.4	3.7	3.6	3.3	3.0	3.2	3.3	3.4	2.9	3.1	3.3	3.3
Ave. Realt. Humiduty (%)	46.4	49.0	55.2	60.5	69.2	74.3	83.4	77.2	72.4	61.6	52.8	46.1	62.3

Fig. 2. A pit-fall trap used to capture beetles. First, the (A) pit-fall trap is set-up using a cup with bait on the bottom. Nearby woody debris is used a cover from other interested animals. Secondly, (B) beetles access the trap to feed on the bait and become trapped until sampling occurs.

Daechun Park entrance to JungBong (361 m) through OknyoBong (370 m). The total survey trail distance of the southern slopes was about 1.5 km. In this area, four survey sites were recognized at different elevations of 200 m, 400 m, 600 m, and over 600 m (approximately). The survey area of the northern slopes was from Banyeo Elementary School to the top of Mt. Jangsan (634 m) across Jangchun-am. Four sites on the northern slopes were also identified across the elevation gradient to match the southern slope sites.

The beetles were collected a total of 11 times, two or three times in a month during May to September in 2012 (May 5, May 19, June 2, June 16, June 28, July 16, July 29, Aug. 12, Aug. 26, Sep. 11, and Sep. 23). The weather changes over the last 10 years are summarized in (Table 1) based on data from Korea Meteorological Administration in 2012. The previous studies found that plant and insect diversity influenced the overall ecological diversity of forests. Southern part of mountain in Korea had abundant diversity of insect because of warm weather (Kang et al. 2010; Kim and Song 2011; Kang et al. 2013). Therefore, these areas were good places to study the ecology of the beetles. In this study, we investigated the emergence species numbers and population etc. about the beetles living in the forest area of Mt. Jangsan.

Method of Beetle Collection

Internationally standardized methods such as pit-fall trap and sweep were adopted to collect the beetles (Fig. 2). Briefly, pit-fall trap was installed parallel to the ground with a slice of ham (with 2x1 cm) and banana (with 1x1 cm) in a paper cup (Lövei & Sunderland 1996; Niemelä et al. 2000). Sweeping method captures beetles with an insect net (length 250 cm x diameter 35 cm) around the area (1x1 m) installed with pit-fall trap at night (between 1 p.m. to 4 p.m). Three Pit-fall traps were installed at each elevation, each survey area at 10 m intervals. The attractants were exposed for 2 weeks. In order to prevent the intrusion of large animals and reptiles, the paper cup was covered with branches and leaves. The captured beetles were released after identification.

Vegetation profile of the survey area

On the southern slopes, *Pinus densiflora* was the dominant species in the valley overstory. Understory vegetation was *Dioscorea batatas*, *D.quingueloba*, *Lindera obtusiloba*, *Parthenocissus tricuspidata*, *Stephanandra incisa*, *Fraxinus sieboldiana*, *Eurya japonica*, *Phryma leptostachya*, and Quercus etc. The upper vegetation was *Ternstroenia gymnanthera*, *Alnus japonica*, *Alnus firma*, *Styrax japonicas*, *Carpinus laxiflora*, *Pinus densiflora*, *Quercus serrata*, *Quercus aliena*, *Quercus acutissina* etc. The hardwoods in the southern slopes were more dominant than the softwood.

The northern slopes are from Banyeo Elementary School to the top of Mt. Jangsan across Janchun-am. In this area, *Zanthoxylum piperitum*, *Eurya japonica*, *Pinus densiflora*, *Oplismenus undulatifolius*, *Lespedeza bicolor*, *Boehmeria spicata*, *Paithenocissus tricuspiditi*, *Ampelopsis brevipedunculata* var. heterophylla etc were distributed. The upper vegetation was *Alnus firma*, *Quercus serrata*, *Quercus aliena*, *Quercus dentata*, and *Quercus mongolica*. *Pinus densiflora* was rarely distributed, while hardwoods such as *Lindera obtusiloba*, *Styrax japonicus*, *Alnus japonica* etc. were dominant (Table 2).

Table 2. Overstory and understory vegetation within study areas of Mt. Jangsan

Overstory vegetation	Understory vegetation
Ternstroenia gymnanthera	*Dioscorea batatas*
Alnus japonica	*D.quingueloba*
Alnus firma	*Lindera obtusiloba*
Styrax japonicas	*Paithenocissus tricuspiditi*
Carpinus laxiflora	*Stephanandra incisa*
Pinus densiflora	*Fraxinus sieboldiana*
Quercus serrate	*Eurya japonica*
Quercus aliena	*Phryma leptostachya*
Quercus acutissina	*Quercus etc.*

S, southern slope; N, northern slope; T, total.

Statistical analysis for species diversity and cluster analysis

Statistical analysis was performed for species diversity on slopes by two-way analysis of variance (ANOVA) and Tukey's test (alpha =0.05) for randomized complete block design (RCBD) using SAS program (SAS9.1, SAS Institute Inc., Cary, NC, USA). Simpson method (Simpson 1949) for index of species diversity (D′) and index of dominance (D) and Pielou method (Pielou 1996) for evenness index (E) were used.

Calculation Formula (Pi)
Shannon-Wiener $D' = -\sum Pi \log$,
Simpson $D = \sum Pi2$,
Pielou $E = D'/\log(S)$
(Pi: ni/N, ni: the number of i^{th} species, N: total number of population, S: total number of species)

Similarity index
$Si = 2C/(A+B)$
(A: southern slopes species, B: northern slopes species, C: 2 species commonly observed from both slopes)

Results and Discussion

Distribution of beetle species along altitudes and mountain slopes

Anisodactylus punctatipenni belonging to Harpalidae was the most abundant species collected in the southern slopes followed by *Moechotypa diphysis* (Cerambycidae), *Moechotypa diphysis* (Languriidae), and *Moechotypa diphysis* (Silphidae). In the northern slopes, the most abundant species was *Moechotypa diphysis* of Cerambycidae followed by *Anisodactylus punctatipenni* of Harpalidae, *Moechotypa diphysis* of Silphidae, and *Moechotypa diphysis* of Languriidae.

The investigation was carried out a total of 11 times from May to September 2012 and a total of 12 families and 20 species were captured. The dominant species was *Anisodactylus punctatipenni* and *Moechotypa diphysis*. 1,267 individuals of *Anisodactylus Punctatipenni* were collected. Among them, 739 (58%) individuals were captured between elevation 400 m and 600 m. A total of 1,228 individuals of *Moechotypa diphysis* were collected and 689 (56%) individuals of them

Table 3. Summarization of the beetle species and number of individuals collected according to altitudes and slopes

Species (family)	200 m			400 m			600 m			Over 600 m			Total		
	S	N	T	S	N	T	S	N	T	S	N	T	S	N	T
Chromogeotrupes auratus (Geotrupidae)	0	0	0	2	1	3	0	2	2	0	1	1	2	4	6
Calosilpha brunneicollis (Silphidae)	2	5	7	3	5	8	1	2	3	0	1	1	6	13	19
Calvia quatuodecimgutta (Coccinellidae)	3	5	8	6	4	10	4	1	5	1	1	2	14	11	25
Calosoma maximowiczi (Carabidae)	4	5	9	6	8	14	8	5	13	6	4	10	24	22	46
Platynus magnus (Harpalidae)	9	7	16	8	6	14	6	3	9	5	3	8	28	19	47
Chilocorus kuwana (Coccinellidae)	13	8	21	9	6	15	6	4	10	4	2	6	32	20	52
Carabus tubercuosus (Carabidae)	12	11	23	9	9	18	6	5	11	3	3	6	30	28	58
Linaeidea adamsi (Chrysomelidae)	21	17	38	14	7	21	2	1	3	0	0	0	37	25	62
Nebria livida (Carabidae)	22	19	41	15	11	26	1	1	2	0	0	0	38	31	69
Pseudotorynorrhina japonica (Cetoniidae)	4	5	9	15	23	38	15	14	29	11	2	13	45	44	89
Plesiophthalmus davidis (Tenebrionidae)	18	19	37	17	5	22	12	8	20	10	4	14	57	36	93
Uloma latimanu (Tenebrionidae)	16	11	27	12	11	23	13	12	25	10	11	21	51	45	96
Carabus sternbergi (Carabidae)	25	23	56	22	25	51	5	3	2	3	3	0	55	54	109
Macrodorcas recta (Lucanidae)	12	8	20	18	24	42	22	24	46	15	19	34	67	75	142
Carabus smaragdinus (Carabidae)	18	19	37	19	19	38	24	21	45	17	18	35	78	77	155
Mimela splendens (Rutelidae)	22	23	45	32	26	58	28	27	55	18	18	36	100	94	194
Melantotus restrict (Languriidae)	37	39	76	43	44	87	32	35	67	26	27	53	138	145	283
Eusilpha jakowlewi (Silphidae)	35	30	65	49	44	93	50	48	98	26	21	47	160	143	303
Moechotypa diphysis (Cerambycidae)	140	137	277	196	156	352	182	155	337	135	127	262	653	575	1,228
Anisodactylus punctatipenni (Harpalidae)	142	144	286	175	188	363	197	179	376	135	107	242	649	618	1,267

S, southern slope; N, northern slope; T, total.

were captured between elevation 400 m and 600 m. These results indicate that most of the beetles preferred elevation in the range of 400 m to 600 m of Mt. Jangsan (Table 3).

Through the entire survey period, 303 individuals of *Eusilpha jakowlewi* were collected. Despite 98 individuals of *Eusilpha jakowlewi* were collected at an elevation of 600 m, they were evenly distributed regardless of the elevation because Mt. Jangsan is not a steep mountain. A total of 283

Melanotus restrictus individuals emerging from mountainous elevation 200 m and 400 m were collected. Because these sites were valleys and wetlands, it is likely that *Melanotus restrictus* prefer to habit humid lowlands. A total of 194 individuals of *Mimela splendens* were captured throughout all areas regardless of altitude. *Carabus smaragdinus* (155 individuals) were evenly collected throughout all survey areas of Mt. Jangsan. In addition 142 individuals of *Macrodorcas recta* were collected between 400 m and 600 m, in which Quercus was the dominant species. A total of 109 individuals of *Carabus sternbergi* were collected at altitudes of 200 m and 400 m. It is likely that *Carabus sternbergi* preferably inhabits lowlands compared to other species.

Mt. Jangsan beetle species diversity index calculated by Menhinic index, was 1.069 and 1.059 respectively for southern and northern slopes. During the study period, month of May showed the highest species diversity index. However, a previous study reports month of September to be period for the highest species diversity index (1.78) and the lowest species diversity index 0.99 in January (Jeon et al. 2008). In Mt. Jangsan, the species diversity index was maximum when the beetle emerges. In contrast, it was reported that the beetle species diversity index was highest when the beetle emergence is reduced. These differences are likely due to the differences of species in response to changes in temperature.

Among a total of 4,343 beetle individuals collected over all altitudes of both slopes, *Anisodactylus punctatipenni* and *Moechotypa diphysis* represented 1,267 (29.2%) and 1,228 (28.3%) individuals, respectively. Two species accounted for 57.5% of the total beetles collected. The reasons are likely because two species are known representative indicator species associated with piles of rotten woods of lowlands (Lee 2011).

As seen results in the overstory and understory vegetation within study areas of Mt. Jangsan, species of genus *Quercus* were dominant in the northern slope. Possibly, plenty of foods for beetles could be provided from lumbers and woods. Therefore, distribution and diversity of beetle fauna was high compared to northern slope.

Monthly distribution of beetle species

The dominant beetle species captured during May to September 2012 was *Anisodactylus Punctatipenni* followed by *Moechotypa diphysis* (Table 4). It is because the movement of the two beetle species was active from July to September compared to other species (Kim and Lee 1992; Kwon 1996).

The dominance value of two species was the highest in August. At the same time, *Eusilpha jakowlewi* and *Melantotus restrictu* were evenly distributed throughout the survey period. In May, which the beetles begin to appear, a total of 18 species was collected. Among them, 97 individuals were *Moechotypa diphysis*. Five individuals of *Carabus tubercuosus*, corresponding to a relatively small percentage of beetle diversity were also collected. This may be likely due to the low activity of *Carabus tubercuosus*. A total of 20 species of beetles were collected during June. Among those beetles were 175 individuals of *Anisodactylus punctatipenni*. Only 15 *Calosoma maximowiczi* beetles were collected. However, because this beetle species inhabits trees, many more individuals of *Calosoma maximowiczi* might be present on Mt. Jangsan than were sampled using our techniques. In July, a total of 20 species of beetles were collected and the most dominant species was *Calosoma maximowiczi* with 286 individuals. Interestingly, 22 individuals of *Particularly linaeidea*, which emerges mainly in early summer, were captured. These results indicate that there is a potential to collect many species of beetles because the average temperature was over 20°C and is ideal for beetle activity.

A total of 20 beetle species were collected in August. Among them, 142 individuals were *Moechotypa diphysis*, which move vigorously at this time (Kim and Lee 1992; Lee 2011). However, the sample size of *Calosoma maximowiczi* decreased to 5 individuals. The most likely reasons for this observation is that most beetle larvae become prey and very few undergo metamorphosis.

In the month of September, a total of 18 species were captured. *Anisodactylus punctatipenni* was the highest with 366 individuals as in August. *Calvia quatuodecimg* and *Calosoma maximowiczi* were not collected in this time. A total of 7 individuals of *Linaeidea adamsi* were collected. *Calvia quatuodecimg* beetle mainly eats larva found inhabiting sprout of *Elaeagnus umbellate* in the spring. However, at this time most of the prey larva pass into imago. Therefore, it seems like *Linaeidea adamsi* become inactive due to lack of food.

Table 4. Beetle species and number of individuals collected from May to September

Species	May			June			July			Aug.			Sep.			Total		
	S	N	T	S	N	T	S	N	T	S	N	T	S	N	T	S	N	T
Chromogeotrupes auratus (Geotrupidae)	0	0	0	1	0	1	0	2	2	1	1	2	0	1	1	2	4	6
Calosilpha brunneicollis (Silphidae)	0	0	0	1	3	4	2	3	5	2	4	6	1	3	4	6	13	19
Calvia quatuodecimgutta (Coccinellidae)	3	3	6	4	3	7	6	4	10	1	1	2	0	0	0	14	11	25
Calosoma maximowiczi (Carabidae)	7	6	13	8	7	15	6	7	13	3	2	5	0	0	0	24	22	46
Platynus magnus (Harpalidae)	4	4	8	5	4	9	8	5	13	6	4	10	5	2	7	28	19	47
Chilocorus kuwana (Coccinellidae)	5	3	8	9	4	13	6	3	9	7	5	12	5	5	10	32	20	52
Carabus tubercuosus (Carabidae)	3	2	5	4	6	10	5	7	12	10	8	18	8	5	13	30	28	58
Linaeidea adamsi (Chrysomelidae)	5	3	8	7	5	12	12	10	22	8	5	13	5	2	7	37	25	62
Nebria livida (Carabidae)	5	5	10	7	4	11	8	7	15	9	7	16	9	8	17	38	31	69
Pseudotorynorrhina japonica (Cetoniidae)	5	4	9	6	5	11	7	5	12	11	9	20	16	21	37	45	44	89
Plesiophthalmus davidis (Tenebrionidae)	10	7	17	12	6	18	7	6	13	13	9	22	15	8	23	57	36	93
Uloma latimanu (Tenebrionidae)	8	7	15	8	8	16	9	9	18	14	11	25	12	10	22	51	45	96
Carabus sternbergi (Carabidae)	5	5	10	10	8	18	13	10	23	16	17	33	11	14	25	55	54	109
Macrodorcas recta (Lucanidae)	7	5	12	12	12	24	16	19	35	18	20	38	14	19	33	67	75	142
Carabus smaragdinus (Carabidae)	8	7	15	10	12	22	14	19	33	28	25	53	18	14	32	78	77	155
Mimela splendens (Rutelidae)	15	18	33	18	18	36	22	23	45	24	18	42	21	17	38	100	94	194
Melantotus restrict (Languriidae)	26	36	62	34	41	75	37	30	67	27	23	50	14	15	29	138	145	283
Eusilpha jakowlewi (Silphidae)	30	26	56	27	25	52	38	37	75	46	42	88	19	13	32	160	143	303
Moechotypa diphysis (Cerambycidae)	55	42	97	89	67	156	126	105	231	221	191	412	162	170	332	653	575	1,228
Anisodactylus punctatipenni (Harpalidae)	36	29	65	92	83	175	154	132	286	186	189	375	181	185	366	649	618	1,267

S, south slope; N, north slope; T, total.

Analysis of species diversity

A total of 12 beetle families and 20 species were collected from May to September 2012 at Mt. Jangsan. On the southern slopes, 12 families and 20 species of the beetles were captured, while 12 families and 20 species were collected in the northern slopes (Table 5).

The Simpson's index for beetle dominance was 0.181 in

Table 5. Monthly index of species diversity, evenness, and index of dominance of beetles

Time	South slope			North slope		
	Species diversity (H')	Evenness (J')	Dominance (D)	Species diversity (H')	Evenness (J')	Dominance (D)
May	1.069	0.821	0.114	1.059	0.814	0.112
June	1.019	0.783	0.145	1.017	0.782	0.140
July	0.952	0.732	0.178	0.980	0.753	0.164
Aug.	0.891	0.685	0.209	0.870	0.668	0.218
Sep.	0.850	0.654	0.229	0.815	0.626	0.248
Ave.	0.950	0.730	0.181	0.946	0.727	0.182
No. of species		20			20	
No. of individual		2,264			2,079	

the southern and 0.182 for northern slopes (Table 5). No significant difference was observed between both slopes by the analysis of variance (ANOVA) and Tukey's test on SAS. This result is likely because two slopes have similar vegetation and low altitude. In addition, they showed no significant difference in the species diversity index and the evenness because study was limited to a relatively small area with identical habitat. The index of dominance was the highest in September as 0.248. The index of species diversity and the evenness were the highest in May 1.059 and 0.814, respectively. These results are likely since the monthly index of beetle dominance is increased and the monthly index of species diversity and monthly evenness are both decreased due to restricted mobility by urban development and residential area around Mt. Jangsan.

Conclusion

The site of this study quantifies the distribution and diversity of beetles in mountain near Pusan to obtain baseline data for future investigations and ecological assessments. The concern in the area of study is that urban sprawl near beetle species is increasing, while species diversity may be reduced. The beetles were collected in the summer months when they are highly active and we did not find an overall difference between the two slopes of Mt. Jangsan which would represent undisturbed and moderately used recreational areas. However, this study reaffirmed the specificity of some beetle species to inhabit various altitudes that satisfy their use as environmental indicators. Whether or not impacted by human habitat intervention the beetle diversity and distribution was similar in both slopes. Another consideration that must be empathized in using such studies for future ecological work is the life habits of each of the species. Depending on the species used as indicators, sampling period could have a drastic effect on finding adequate beetle numbers. In the long run, this study may also be beneficial for the detection of climate change, as average temperature changes and their subsequent effect on forage may greatly alter the beetle community. This study lays the groundwork for further monitoring of this site and other sites through the region for environmental changes.

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