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Characterization of the Distribution of Indicator Species Beetles in the Mt. Mangunsan Area

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Abstract

This study aimed to investigate habitat distribution and beetle diversity, using beetles as biological indicator species to assess environmental changes in the Mt. Mangunsan area near the South Sea of Korea. Plots were installed at varying elevations on the southern and northern slopes of Mt. Mangunsan, and the beetle species composition was determined. A total of 1,368 beetles comprising 32 species belonging to ten families were collected between May and September 2023 from the study sites in the Mt. Mangunsan area near the South Sea of Korea. The two most prevalent species consisted of *Synuchus nitidus*, with 152 collected beetles, and *Calosoma chinense*, with 128 collected beetles. In May, June, July, August, and September, 76 beetles comprising 10 species, 180 beetles comprising 18 species, 138 beetles comprising 15 species, 525 beetles comprising 27 species, and 449 beetles comprising 25 species were collected, respectively, with the highest abundance observed in August. In terms of elevation, 239 beetles comprising 19 species were collected at 300 m; 352 beetles comprising 27 species at 400 m; 314 beetles comprising 24 species at 500 m; 280 beetles comprising 22 species at 600 m; 183 beetles comprising 16 species at 700 m. Based on the slope, 442 beetles comprising 18 species belonging to eight families were collected on the southern slope, and 926 beetles comprising 24 species belonging to 10 families were collected on the northern slope. Analysis of the beetles on the southern slope produced the following estimations: diversity of 1.086, evenness of 0.866, and dominance of 0.109. Meanwhile, those in the northern slope yielded a diversity of 1.204, evenness of 0.873, and dominance of 0.081.

Key Words: ground beetles, Mangun mountain, diversity index, similarity index

Introduction

Mt. Mangunsan (786 m above sea level) is located in Gohyeon-myeon and Seo-myeon, Namhae-gun, Gyeongnam-do, and is connected to the north by Mt. Geumosan (849 m) in Geumnam-myeon and Jingyo-myeon of Hadong-gun, and to the southeast by Mt. Hogusan (627 m) in Idong-myeon of Namhae-gun, Mt. Songdeungsan (617 m) in Seo-myeon, and Mt. Geumsan (681 m) wherein the Boriam Temple is also located. Namhae-do comprising Mt. Mangunsan is an island area located in the southern part of the Korean Peninsula, is the fourth largest island after Jeju-do, Geoje-do, and Jin-do, and belongs to the Southern Coast Plant Zone in the floristic division. Its floristic special plants include the beech family Fagaceae, Ostrya japonica, Pittosporum tobira, Illicium anisatum L., Cinnamomum camphora var. cyclophyllum Nakai, Neolitsea sericea, Caesalpinia decapetala (Roth), and Fatsia japonica. A part of Namhae-do belongs to the southern plant zone between the Central and the Southern Coast Plant Zones, in which the floristic special plants include Cephalotaxus koreana Nakai, Aphananthe aspera Planch., Cudrania tricuspidata,

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Mallotus japonicus, Ilex integra Thunb., Meliosma myriantha S. et Z., Camellia japonica, and Trachelospermumasiaticum. Namhae-do is bordered by two plant zones, as there are many places where the vegetation of the Southern Coast Plant Zone and the Southern Plant Zone are present together (Lee 2018).

Global warming is causing unseasonal heat waves, severe rains, and large wildfires around the world, resulting in widespread damage to natural ecosystems. In South Korea, the heat wave, heavy rains, and large forest fires have caused changes in the natural ecosystem. As such problems are becoming more common, the government is actively conducting biological and natural resource surveys to preserve biodiversity (National Institute of Ecology 2022).

To assess such changes in species, the method that utilizes indicator species is commonly employed, as it is appropriate for environmental assessments of biodiversity, habitats, communities, or ecosystems in a particular region (McGeoch 1998). Ground beetles among indicator organisms play an important role in the cycling of materials in ecosystems as top predators that feed mostly on microarthropods (Lövei and Sunderland 1996). Moreover, most beetle species are ambulatory with a low dispersal capacity, being more easily affected by habitat disturbance, and thus can be assessed as indicator organisms of environmental change, because of which beetles were the subject of many studies on disturbance in forest ecosystems (Maleque et al. 2009).

Beetles have been actively studied in Korea and abroad as a biologically important species to evaluate the health of the environment, such as rapid environmental changes caused by forest ecosystem damage due to forest fires, logging, and control (Rainio and Niemelä 2003; Pearce and Venier 2006; Kwon et al. 2011; Lee et al. 2012; Kang et al. 2013; Kim et al. 2022). Beetles that mainly live in forests have been used to identify population changes due to climate change (Lee 2021), which is useful for research on changes in forest ecosystems. However, compared to other taxonomic groups, there have been fewer studies on damage to beetles as indicator species and forest ecosystems due to global warming in forested areas, accounting for the largest area in South Korea.

Thus, the present study aimed to investigate population changes due to global warming and also the habitat distribution of beetles in the Mt. Mangunsan area of Namhae-gun, providing fundamental data on ecosystem changes in forest areas.

Materials and Methods

Selection of study site

The study site Mt. Mangunsan is located in Seo-myeon, Namhae-gun, Gyeongnam-do. To the south of the study area is the sea, which belongs to Hallihan Marine National Park, and famous temples and hiking trails popular with hikers are located in the north. Considering these surrounding environments comprehensively, we collected beetles that could provide environmental indicators and investigated their number of species, population, etc.

As for plots for the identification of habitat distribution and population of beetles, the southern and northern slopes of the study site were selected, in which 5 plots were chosen to install traps at 300, 400, 500, 600, and 700 m by altitude along trails of the northern and southern slopes, and then 5 traps per plot were set up in a row, spaced 5 m apart, to conduct the survey.

The main tree species of Mt. Mangunsan were *Pinus thunbergii, Quercus mongolica, Quercus serrata, Quercus variabilis, Quercus acutissima, Carpinus laxiflora* Bl., *Styrax japonica,* and *Sorbus alnifolia,* forming a dominant population, while the vegetation near the summit was composed of *Quercus mongolica, Rhododendron yedoense,* and *Lespedeza maximowiczii* (Fig. 1).

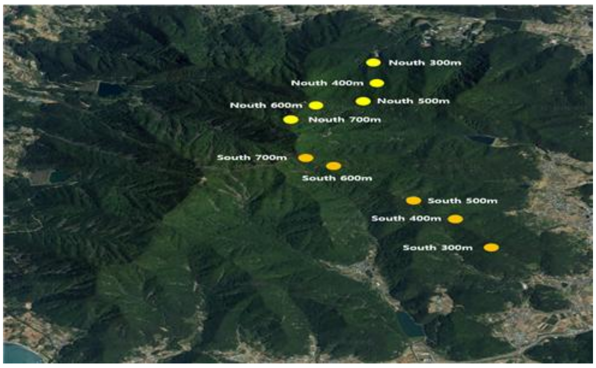

Fig. 1. Location map of the survey areas.

Survey methods and classification

Beetles were selected as the environmental indicator species of Mt. Mangunsan, and traps were set up to survey them using an internationally standardized method that utilizes their characteristics of roaming on the ground surface. The type of trap was a pitfall trap, and the container used for the collection was made of plastic (12 cm in depth, 8 cm in diameter, 5 cm in diameter at the bottom). A mixed food attractant (fruit+ham) was used to attract beetles. We used a combination of hand-catching and sweeping methods in addition to the pitfall trap.

Collected beetles were classified and identified in the field and released back into the forest. In classification and identification, insect names were identified based on the Korean Insect Catalogue (Korean Society of Applied Entomology 1994). In cases of species that classification and identification in the study site were difficult, pictures were taken, followed by identification referring to the Insect Ecology Atlas in the lab (Kim 1998).

Data analysis

Collected beetles were classified by species, by month, and by altitude. To examine the composition and diversity of species, species diversity was analyzed based on the species and population of beetles in each study site. The analysis was conducted using the diversity index of the diversity index (D') and dominance index (D) of Simpson (1949), and the evenness index (E) of Pielou (1975). The formulas are as follows:

Shannon-Wiener's diversity index $H' = -\Sigma Pi \log (Pi)$
Simpson's diversity index $D' = [1-(\Sigma ni(ni-1))/(N(N-1))]$
Simpson's dominance index $D = \Sigma Pi^2$
Pielou's evenness index $E = H'/\log(S)$
(Pi, ni/N; ni, number of the ith species; N, total population; S, the sum of species numbers).

Results and Discussion

Habitat distribution of beetles in Mt. Mangunsan area near the South Sea

Distribution by individual species

Beetles were surveyed using pitfall traps and net sweeping methods in Mt. Mangunsan area near the South Sea between May and September in 2023, identifying 1,368 beetles of 32 species under 10 families (Table 1). The major beetle species in Mt. Mangunsan were Attelabidae with 18 beetles of 3 species, Buprestidae with 33 beetles of 2 species, Cetoniidae with 34 beetles of 1 species, Cerabidae with 601 beetles of 9 species, Cerambycidae with 66 beetles of 2 species, Chrysomelidae with 65 beetles of 2 species, Coccinellidae with 128 beetles of 3 species, Curculionidae with 48 beetles of 3 species, Rutelinae with 108 beetles of 3 species, and Silphidae with 267 beetles of 4 species. Of a total of 1,368 beetles, Cerabidae accounted for a relatively high proportion, which was consistent with the results of previous habitat distribution studies, performed in forest areas close to the South Coast where Mt. Mangunsan is located, showing that species in Cerabidae appeared to be the highest among those in other families (Hong et al. 2022, Seon et al. 2022). In addition, beetle distribution studies in the control area of pine wilt and black pine bast scale (Heo et al. 2019; Kim et al. 2022) found the highest number of beetles that belong to the species of Cerabidae. These results suggested that beetles in the species of Cerabidae had a stronger adaptability to environmental changes than those in other families.

Table 1. Species of insect in the survey area

Family	Species	Individual	Family	Species	Individual
Attelabidae	3	18	Chrysomelidae	2	65
Buprestidae	2	33	Coccinellidae	3	128
Cetoniidae	1	34	Curculionidae	3	48
Cerabidae	9	601	Rutelinae	3	108
Cerambycidae	2	66	Silphidae	4	267
Total			10	32	1,368

The major dominant species in all beetles collected from plots on Mt. Mangunsan were *Synuchus nitidus* with 152 beetles accounting for 11% of classified and identified beetles, followed by *Calosoma chinense* (9%), *Coccinella septempunctata* (7%), *Chlaenius* (Lissauchenius) *naeviger* Morawitz, 1862 (7%), *Necrophila* (Eusilpha) *jakowlewi jakowlewi* (7%), *Nicrophorus japonicus* (6%), *Coptolabrus jankowskii kojensis* (5%), and *Nicrophorus maculifrons Kraatz*, 1877 (5%) in order (Fig. 2). As such, *Synuchus nitidus* was the most dominant species. Similarly, studies on beetles in Mt. Geumsan of Namhae, Mt. Geumosan of Hadong, and the forest of Hallyeohaesang National Park which are located close to Mt. Mangunsan (Kim 2017; Seon et al. 2022) also reported Harpalinae and Cerabidae as major dominant species. These findings were also similar to the study results in that the dominant species were closely affected by habitat environments like average temperature and vegetation (Thiele 1977). Species that belong to the Harpalinae or Cerabidae families are known to be primarily nocturnal and have strong viability due to their excellent hunting skills and aggressive nature compared to other species (Lee 2011; Park and Lee 2013), which seems to be the reason why *Synuchus nitidus* and *Calosoma chinense* were the most predominantly found species.

Number of individuals by month

The classified and identified species and their numbers after collection in Mt. Mangunsan area near the South Sea from May to September were as follows: 76 beetles of 10 species in May, 180 beetles of 18 species in June, 138 beetles of 15 species in July, 525 beetles of 27 species in August (the highest number), and 449 beetles of 25 species in September (Fig. 3). As such, the highest number of beetles was collected in August, the summer month, followed by September. These results were contrary to previous study results in that the number of beetles increased between late spring and summer while the temperature rose (Kim et al. 2004; Kang et al. 2013; Choi et al. 2015). The weather in 2023 was abnormal, with frequent heavy rainfall and more precipitation days in July than usual (Korea Meteorological Administration 2023), which may have affected the reproductive activity of beetles. In the most recent study performed in Mt. Waryong of Sacheon (Kim 2023) which is close to Mt. Mangunsan and has a marine climate similar to Mt. Mangunsan, Mt. Waryong of Sacheon had 2,314 beetles of 42 species, showing a significant difference from those of Mt. Mangunsan. These findings were similar to previous study results that rainfall affected beetle habitats, reducing populations (Kim 2005; Lee 2021), and the beetles of Mt. Mangunsan also had fewer species and populations in July than in June due to increased rainfall and higher number of rainy days. In addition, it seems that heavy rainfall during the most active period of the year may have significantly affected the species and population of the beetles in Mt. Mangunsan. Given that there are localized heavy rains and heat waves caused by abnormal weather every year, it is necessary to monitor beetles as an environmental indicator species even more.

The most collected species in Mt. Mangunsan near the South Sea were as follows: in May *Coccinella septempunctata* with 28 beetles, *Nicrophorus japonicus* with 14 beetles, and *Calosoma maximowiczi* with 8 beetles in order; in June, *Chlaenius* (Lissauchenius) *naeviger* Morawitz, 1,862 with 32 beetles, *Nicrophorus maculifrons* Kraatz, 1,877 with 24 beetles, and *Coccinella septempunctata* with 20 beetles in order; in July, *Synuchus nitidus* with 27 beetles, *Bifurcanomala aulax* with 18 beetles, *Physosmaragdina nigrifrons* with 14 beetles in order; in August, *Calosoma*

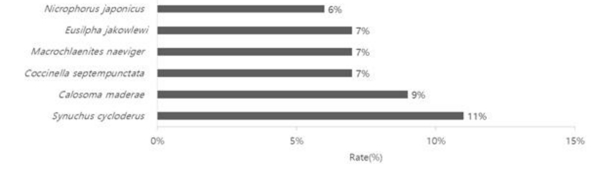

Fig. 2. Dominant species in the survey area.

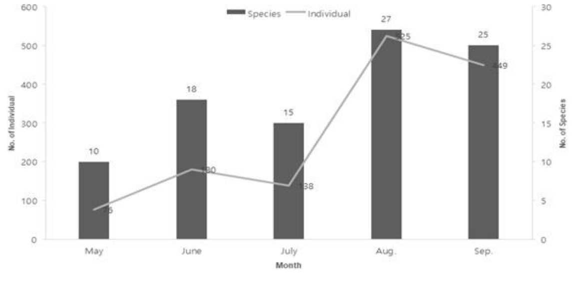

Fig. 3. Species and number of individuals by season.

chinense with 65 beetles, *Synuchus nitidus* with 49 beetles, and *Chlaenius* (Lissauchenius) *naeviger* Morawitz, 1,862 with 47 beetles in order; in September, *Synuchus nitidus* with 76 beetles, *Calosoma chinense* with 38 beetles, and *Necrophila* (Eusilpha) *jakowlewi jakowlewi* with 39 beetles in order (Fig. 4). These results showed that *Coccinella septempunctata* was the most active species from May to June, while *Calosoma chinense* was the most active one from August to September. In addition, *Synuchus nitidus* is the dominant species of Cerabidae known to appear in forests of South Korea (Yeon et al. 2005). Consistently, it was also the dominant species active in Mt. Mangunsan from July to September.

Species distribution by altitude

The distribution of species collected at different elevations (300, 400, 500, 600, and 700 m) of the study site at Mt. Mangunsan near the South Sea by altitude was as follows:

239 beetles of 19 species at 300 m, 352 beetles of 27 species at 400 m, 314 beetles of 24 species at 500 m, 280 beetles of 22 species at 600 m, and 183 beetles of 16 species at 700 m (Fig. 5). Since the 300 m point in the Mt. Mangunsan area is adjacent to a temple, agricultural fields, and villages, it seemed that the population of beetles was affected by external factors such as human influence and the use of pesticides in agricultural fields. These results were similar to those in a report by Lee et al. (2010) in that species were abundant at lower elevations, and also to previous studies that the highest number of species and individuals were collected at an altitude of 400 m (Park 2013; Kim 2017; Jeong 2019; Lee 2020). Taken together, it appears that Mt. Mangunsan has suitable habitat conditions for beetles between 400 and 600 m above sea level. It was reported that the population of beetles rapidly decreased because the summit area is mainly rocky, forming poor vegetation (Lee et al. 2010; Park 2013). In Mt. Mangunsan, on the other hand, the vegetation is dominated by *Quercus mongolica* community, *Rhododendron yedoense*, and *Lespedeza maximowiczii* and there are few rocky areas, providing desirable habitats, so there was no drastic change even though the population did decrease.

Species distributions by altitude are as follows: at 300 m, 32 beetles of *Synuchus nitidus*, 31 beetles of *Nicrophorus japonicus*, and 28 beetles of *Crepidodera plutus* in order; at 400 m, 67 beetles of *Synuchus nitidus*, 31 beetles of *Coptolabrus jankowskii kojensis,* and 26 beetles of *Necrophila* (Eusilpha) *jakowlewi jakowlewi* in order; at 500 m, 71 beetles of *Calosoma chinense*, 22 beetles of *Synuchus nitidus*, and 21 beetles of *Eucarabus* (Parhomopterus) *namhaedoensis* in order; at 600 m, 38 beetles of *Calosoma chinense*, 32 beetles of *Coccinella septempunctata*, and 28 beetles of *Chlaenius* (Lissauchenius) *naeviger* Morawitz, 1,862; at 700 m, 52 beetles of *Coccinella septempunctata*, 28 beetles of *Chlaenius* (Lissauchenius) *naeviger* Morawitz, 1,862, and 21 beetles of *Nicrophorus maculifrons* Kraatz, 1,877 in

Fig. 4. Distribution of insect species by season.

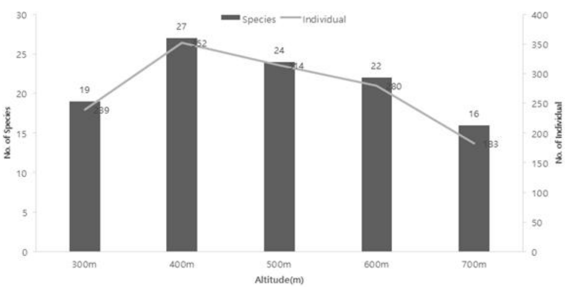

Fig. 5. Species and number of individuals by altitude.

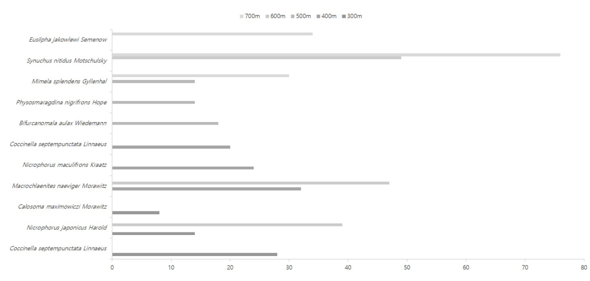

Fig. 6. Distribution of beetle species by altitude.

order (Fig. 6). Considering that a number of *Synuchus nitidus* beetles was found between 300 and 500 m in altitude, it seems that they are the dominant species of Mt. Mangunsan, while *Nicrophorus japonicus* was found to be the dominant species in all altitudes. Species that primarily live in broadleaf forests were found at lower elevations due to the presence of more broadleaf trees than at other elevations.

Population by slope

A total of 442 beetles of 18 species in 8 families of beetles were collected on the southern slope of Mt. Mangunsan near the South Sea, which included 10 beetles of 2 species in Attelabidae, 15 beetles of 1 species in Buprestidae, 150 beetles of 6 species in Cerabidae, 2 beetles of 1 species in Cerambycidae, 8 beetles of 1 species in Chrysomelidae, 121 beetles of 3 species in Coccinellidae, 15 beetles of 1 species in Curculionidae, and 121 beetles of 3 species in Silphidae (Table 2). As for the number of individuals by species, 101 beetles of *Coccinella septempunctata*, 67 beetles of *Nicrophorus maculifrons* Kraatz, 1877, and 38 beetles of *Coptolabrus jankowskii kojensis* were collected in the highest numbers, indicating that they were dominant species in the southern slope. While there were *Rhododendron yedoense* community and *Lespedeza maximowiczii* community near the summit, Coccinellidae was more abundant in the southern slope, which mainly comprised coniferous forests. In addition, the southern slope showed a larger difference in number of individuals than the northern slope. A previous study reported that decaying leaves in broadleaf forests facilitated the formation of humus and that ambulatory beetles were highly abundant in these soils (Lee and Lee 1995). Another study also reported that differences in numbers were due to the vegetation structure of the site rather than the slope (Lee 2021). Our results were similar to these studies, suggesting that species and populations were reduced on the southern slope compared to the northern slope due to the dominance of conifers in the vegetation.

A total of 926 beetles of 24 species in 10 families were collected in the northern slope, which included 8 beetles of 2 species in Attelabidae, 18 beetles of 1 species in Buprestidae, 34 beetles of 1 species in Cetoniidae, 451 beetles of 9 species in Cerabidae, 64 beetles of 2species in Cerambycidae, 57 beetles of 2species in Chrysomelidae, 7 beetles of 1 species in Coccinellidae, 33 beetles of 2 species in Curculionidae, 108 beetles of 2 species in Rutelinae, and 146 beetles of 2 species in Silphidae (Table 3). As for the number of individuals by species, 152 beetles of *Synuchus nitidus*, 128 beetles of *Calosoma chinense*, and 84 beetles of *Nicrophorus japonicus* were collected on the northern slope, indicating that they were dominant species on the northern slope. As such, the northern slope had a higher number of species and individuals than the southern slope. Similarly, a pre-

Table 2. The species of collected insect at the south slope

Family	Species	Individual	Family	Species	Individual
Attelabidae	2	10	Chrysomelidae	1	8
Buprestidae	1	15	Coccinellidae	3	121
Cerabidae	6	150	Curculionidae	1	15
Cerambycidae	1	2	Silphidae	3	121
Total			8	18	442

Table 3. The species of collected insect at the north slope

Family	Species	Individual	Family	Species	Individual
Attelabidae	2	8	Chrysomelidae	2	57
Buprestidae	1	18	Coccinellidae	1	7
Cetoniidae	1	34	Curculionidae	2	33
Cerabidae	9	451	Rutelinae	2	108
Cerambycidae	2	64	Silphidae	2	146
Total			10	24	926

Table 4. Species diversity index of beetles in two study sites

Site	No. of species	No. of individual	Species diversity (H')	Evenness (E)	Dominance (D)
South slop	18	442	2.50 (1.086)	0.866	0.109
North slope	24	926	2.77 (1.204)	0.873	0.081

vious study reported that beetles were the most abundant in areas where broadleaf forests were dominant favoring the reproduction of Coleoptera and there were also a number of oak trees (Lee et al. 2010). Another study presented that beetles were able to find prey and habitats easily in mixed forests containing both broadleaf trees and coniferous trees (Park and Lee 2013). The southern slope of Mt. Mangunsan was mostly dominated by pine forests, whereas the northern slope was dominated by deciduous broadleaf trees, and also had mixed forest with coniferous forests, providing optimal places for beetles to inhabit. These seemed to be the reason why more species and individuals were collected on the northern slope.

Analysis of species diversity

Simpson's diversity and dominance and Pielou's evenness were calculated using numbers of beetles collected from the south and north slopes of Mt. Mangunsan near the South Sea (Table 4).

Analyses using 442 beetles of 18 species collected in the southern slope resulted in 1.086 in diversity, 0.866 in evenness, and 0.109 in dominance, while those using 926 beetles of 24 species from the northern slope yielded 1.204 in diversity, 0.873 in evenness, and 0.081 in dominance. Compared to the diversity indices of Mt. Geumsan in Namhae with 0.927-0.974 (Kim 2017) and Mt. Geumosan in Hadong with 0.981-1.187 (Seon et al. 2022), which are near the study site, its diversity index was relatively higher, suggesting more diverse beetle species in Mt. Mangunsan than in other neighboring mountains. A higher dominance index means the dominance of a particular species. As for Mt. Mangunsan, the southern slope had a relatively higher dominance than the northern slope. These seemed to mean that the species and total population in the southern slope were fewer than the northern slope, while certain species had a higher density, leading to a higher dominance in the southern slope. A study showed that a high dominance result means that the community is dominated by a particular species, so a high dominance index does not necessarily mean a favorable environment, but more weight is added to a low one when considering it in terms of diversity (Kang et al. 2013). Another study also reported that the southern slope had a higher dominance and a lower diversity than the northern slope, influencing the habitat of beetles due to the difference in forest physiognomy between slopes (Kim 2023). These were similar to the results of this study. Taken together, these results suggested that the numbers of species and individuals of beetles should be affected by areas with similar forest physiognomy, and should respond to any changes in forest physiognomy sensitively.

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