Regular Article
pISSN: 2288-9744, eISSN: 2288-9752
Journal of Forest and Environmental Science
Vol. 35, No. 3, pp. 189-196, September, 2019
https://doi.org/10.7747/JFES.2019.35.3.189

JFES
Journal of Forest and Environmental Science

Composition and Abundance of Wood-Boring Beetles Inhabited by Pine Trees

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Abstract

Plants are consumed by a myriad of organisms that compete for resources. Direct interactions among multiple plant-feeding organisms in a single host can range for each species from positive to negative. Wood-boring beetle faces a number of biotic and abiotic constraints that interfere with the good prospects from the tree. Biotic factors, including arthropod pests and diseases, and abiotic factors, such as drought and water-logging, are the major constraints affecting the species. The present study aimed to provide basic data for analyzing forest health, identify the kinds of wood-boring beetles in the central part of Korea. Our second goal was to analyze the species composition and diversity of regional communities and to examine. A total of 10,461 individual wood-boring beetles belonging to 8 families and 50 species attracted to trap trees in the pine forests were recorded during the study period on study sites. The results of the analysis of collected species showed that the community structure on all study sites was similar. Seasonal occurrences of dominant wood-boring beetles (5 species) from each study site showed the highest number of all species, except for *Siphalinus gigas* in May, followed by a gradual decline, and the largest number of *Siphalinus gigas* appeared in June. The similarity index of species composition was relatively high, ranging from 0.75 to 0.90 for each study site.

Key Words: pine forest, wood-boring beetle, canonical correspondence analysis, community structure, species richness

Introduction

Species diversity in forests is important in conservation management and is frequently used as an indicator of the stability of community systems (Pausas 1994; Hosen and Ahamed 2017). In community ecology, structural variability and high species diversity are central research themes (Sarker et al. 2013).

forest resources are the backbone of most of the tribal and indigenous communities for their livelihood and socio-economic development (Bamin et al. 2017). Among them plants are consumed by a myriad of organisms that compete for resources (Stout et al. 2006; Karban et al. 2012). Direct interactions among multiple plant-feeding organisms in a single host can range for each species from positive to negative (Stout et al. 2006). Herbivore interactions also can occur indirectly via plant-mediated interactions, where initial infestation of the plant by an attacker positively or negatively affects the performance of the subsequent attacker on the shared host through inducing changes in the host plant characteristics (Stout et al. 2006; Karban et al. 2012; Tack and Dicke 2013).

Wood-boring beetle faces a number of biotic and abiotic constraints that interfere with the good prospects from the tree. Biotic factors, such as arthropod pests and diseases, and abiotic factors, such as drought and water-logging, are

Received: May 17, 2019. Revised: July 19, 2019. Accepted: July 19, 2019.

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the major constraints affecting the species (Wargo 1996; Hakeem et al. 2012). While a vast majority of wood-boring beetles are ecologically important and economically benign, some species are pests of economic importance. These pests attack relatively healthy trees, untreated wood, and downed trees in lumber yards (Findlay 1985). Additionally, some wood-boring beetles are invasive species that threaten natural forest ecosystems. Most wood-boring beetles belong to the families *Lyctidae*, *Anobiidae*, and *Bostrichidae*, with approximately 570 species in 89 genera worldwide (Lawrence et al. 2010).

Recently, pine forests have suffered from various kinds of damage, the most significant of them being the biological damage. Among several types of damage, the damage caused by insect pests is particularly serious. Wood-boring beetles are major forest pests that parasitize on trunks and branches of trees, inhibit the growth of trees, and make trees lose value as wood. Previous research on the ecology of wood-boring beetle has been conducted by several researchers, including Kim (1975), Ko et al. (1980), Kim and Han (1985). The present study aimed to provide basic data for the analysis of forest health, identify the kinds of wood-boring beetles in the central part of Korea, and analyze the species composition and diversity of corresponding regional communities.

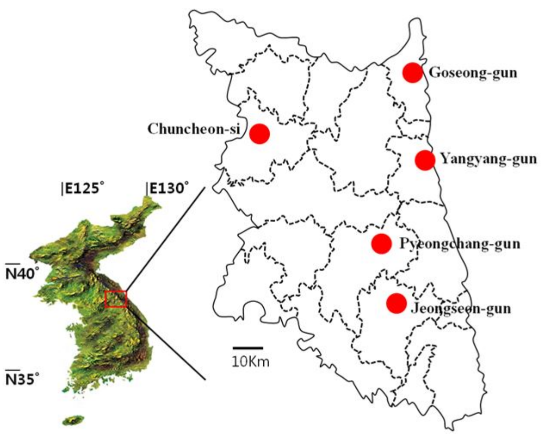

Fig. 1. Locations of study sites in Gangwon-do, Korea.

Materials and Methods

Study site

The study was conducted in Gangwon-do. A total of five study sites were selected on the Gangwon-do. We surveyed two sites in the western area, two sites in the eastern area, and one site in southern area. The western area was selected from the Dong-myeon area of Chuncheon-si and the Yongpyeong-myeon area of Pyeongchang-gun. The eastern area was selected from Jugwang-myeon of Gosung-gun and Hyeonnam-myeon of Yangyang-gun, while the southern area was Yeoryang-myeon of Jeongseon-gun (Fig. 1).

An area of 2 m×10 m was selected as a survey area, and the lower layer was investigated. *Rhododendron schlippenbachii*, *Quercus* spp., *Rhus* spp., *Rhododendron mucronulatum*, *Securinega suffruticosa*, *Castanea* spp., *Robinia pseudoacacia*, and *Alnus japonica* were observed as the common lower layer vegetation in the study area. Additionally, 30 trees were randomly selected within each study site. We measured the age and height pf these trees, as well as their diameter at breast height (Table 1).

Abundance of wood-boring beetles

In order to collect wood-boring beetles, trap trees were used. Specifically, pine trees on three points were selected from each study area. On each site, three trees were cut in April, and, after preparing 1m length, mesh was laid on the ground and built on trees (Fig. 2).

Table 1. Location and conditions of tpine stands

Stand locations	Density (/ha)	Height (m)	D.B.H (cm)	Clear length (m)	Slope (°)	Direction
Chunchon-si	1,000	14/9-18	23/20-28	8/6-10	15-20°	S
Pyeongchang-gun	1,200	10/5-13	18/15-27	6/4-8	15-20°	S
Goseong-gun	1,250	10/6-13	18/14-24	6/4-9	15° below	S
Jeongseon-gun	1,400	11/8-13	16/11-24	6/4-8	15-20°	S
Yangyang-gun	1,500	9/7-11	15/9-25	4/2-6	10° below	SW

Fig. 2. Bait logs in pine forest.

We visited each site twice a month and collected the insects attracted to the trap trees for scattering, parasitism, and predation. Afterwards, we classified and investigated a number of individuals. Wood-boring beetles were collected using an insect net and an aspirator. Additionally, dried specimens and immersion specimens were prepared to identify and classify the collected species.

Data analysis

Abundance of wood-boring beetle species was calculated as percentage of the total number of individual beetles collected. Composition of wood-boring beetles was defined using Shanon index (Shannon and Weaver 1998; Brower and Zar 1984), evenness index (Pielou 1969), and Sørensen similarity index (Sørensen 1948). Shannon index ($H'=-\Sigma$ pi log pi, where pi is the relative abundance of the i^{th} species), evenness index ($J'=H'/\log S$, where S is the number of species) and similarity index ($QS=2C/(S1+S2)$, S1: Number of species that appeared in community 1, S2: Number of species that appeared in community 2, C: Number of Species that appeared in common in two communities).

To summarize and visualize variation in community composition in relation to environmental factors, we performed the canonical correspondence analysis (CCA). We also examined whether temporal changes in wood-boring beetle communities differed across the five sites. We constructed GLMs with one of two measures of community composition as a dependent variable and site as an independent variable. Statistical significance was based on likelihood ratio tests. Significant interactions were expected if the patterns of temporal change in communities differed between sites. Additionally, we constructed generalized linear mixed models (GLMMs). These analyses were performed using the software package R 3.1.3 (R Development Core Team, 2015).

Table 2. Composition of species in each location

Stand locations	No. of families	No. of species	No. of individuals
Chunchon-si	8	39	2,335
Pyeongchang-gun	8	30	798
Goseong-gun	8	36	2,338
Jeongseon-gun	8	37	2,154
Yangyang-gun	8	30	2,386

Results

Abundance and distribution of wood-boring beetles

A total of 10,461 individual wood-boring beetles belonging to 8 families and 50 species were recorded on the selected sites in Chuncheon-si, Jeongseon-gun, Pyeongchang-gun, Goseong-gun, and Yangyang-gun (Table 2).

At the family level, Cerambycidae (16 families) and Scolytidae (9 families) were dominant, followed by Curculionidae (6 families). Additionally, at the species level, *Hylurgops interstitialis* (2,242 individuals, 21.3%), *Pissodes nitidus* (1,976 individuals, 18.8%), *Tomicus piniperda* (1,480 individuals, 14.0%), and *Shirahoshizo rufescens* (1,205 individuals, 11.5%) were dominant, followed by *Siphalinus gigas* (642 individuals, 6.0%). *Hylurgops interstitialis* was higher in Chuncheon-si, Pyeongchang-gun and Yangyang-gun, while *Pissodes nitidus* was higher in Jeongseon-gun and Goseong-gun. Among 2,836 individuals, 2,338, 2,335, 2,154 and 798 individuals were observed in Yangyang-gun, Pyeongchang-gun, Chuncheon-si, Jeongseon-gun and Goseong-gun area, respectively. A relatively large number of wood-boring beetles was collected from Yangyang-gun (Table S1).

Chuncheon-si

At the Chuncheon-si study site, the collected wood-boring beetles came from 8 families, 39 species, and comprised 2,335 individuals. At the family level, Cerambycidae (16 species), Scolytidae (9) were dominant, followed by Curculionidae (6), and, at the species level, *Hylurgops interstitialis* (490 individuals, 21.0%), *Pissodes nitidus* (380 individuals, 16.3%), *Tomicus piniperda* (315 individuals, 13.5%), *Shirahoshizo rufescens* (281, 12.0%) were dominant, followed by *Siphalinus gigas* (147 individuals, 6.3%) (Table 3). The diversity index of species was the highest (1.21) in June and the lowest (0.77) in April. The evenness index of species was the highest (0.84) in July and the lowest (0.74) in May (Fig. 3a).

Seasonal occurrences of dominant wood-boring beetles (5 species) in the Chuncheon-si area showed the highest number of all species except for *Siphalinus gigas* in May, followed by a gradual decline, and the largest number of *Siphalinus gigas* appeared in June (Fig. 4a).

Pyeongchang-gun

At the Pyeongchang-gun study site, the collected wood-boring beetles came from 8 families, 36 species, and comprised 2,338 individuals. At the family level, Cerambycidae (12 species), Scolytidae (10) were dominant, followed by Curculionidae (6), and, at the species level, *Hylurgops interstitialis* (527 individuals, 22.5%), *Pissodes nitidus* (502 individuals, 21.5%), *Tomicus piniperda* (310 individuals, 13.3%), *Shirahoshizo rufescens* (188 individuals, 8.0%) were dominant, followed by *Niphades variegatus* (123 individuals, 5.3%) (Table 3). The diversity index of species was the highest (1.15) in June and the lowest (0.75) in April. The evenness index of species was the highest (0.83) in April and lowest (0.72) in May (Fig. 3b).

Seasonal occurrences of dominant wood-boring beetles (5 species) on Pyeongchang-gun area showed the highest number of all species except for *Siphalinus gigas* in May, followed by a gradual decline, and the largest number of *Siphalinus gigas* appeared in June (Fig. 4b).

Goseong-gun

At the Goseong-gun study site, the collected wood-boring beetles came from 8 families, 30 species, and comprised 798 individuals. At the family level, Cerambycidae (7 species), Scolytidae (7) and Curculionidae (7) were dominant, and, at the species level, *Pissodes nitidus* (159 individuals,

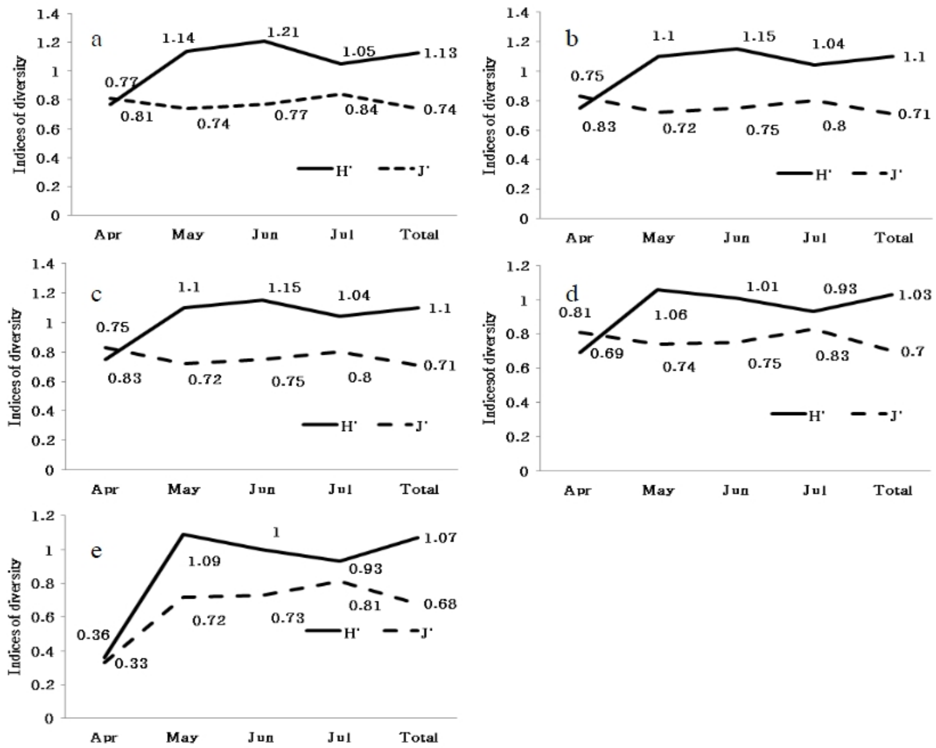

Fig. 3. Diversity index and evenness index of wood-boring beetles on study sites.

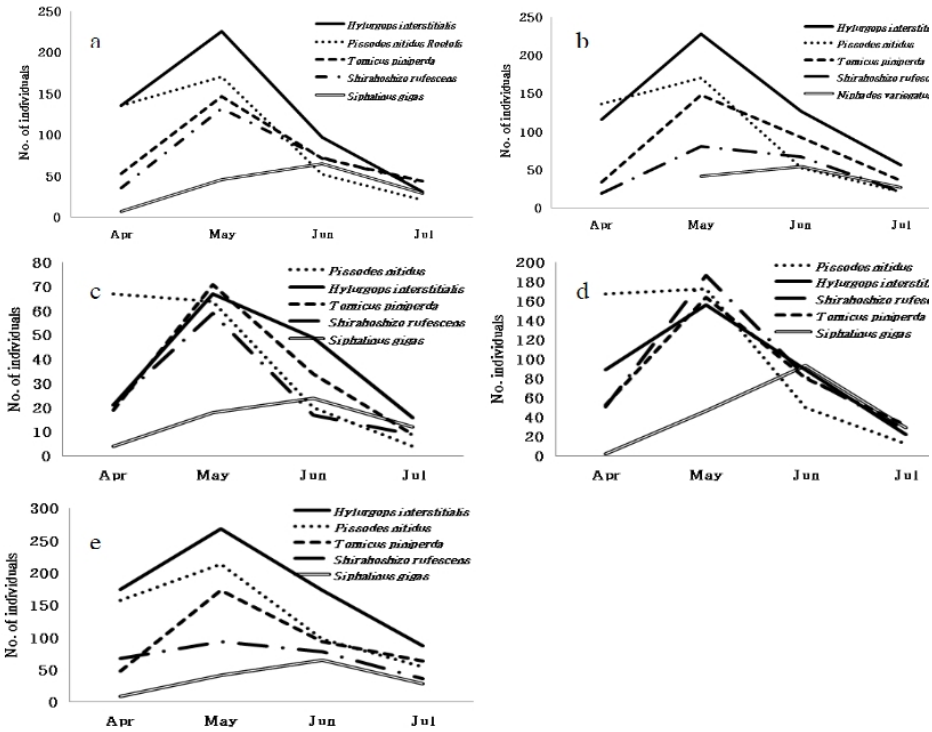

Fig. 4. Seasonal occurrences of dominant wood-boring beetles on study sites.

19.4%), *Hylurgops interstitialis* (156 individuals, 19.2%), *Tomicus piniperda* (133 individuals, 16.7%), *Shirahoshizo rufescens* (106 individuals, 13.3%) were dominant, followed by *Siphalinus gigas* (64 individuals, 7.3%) (Table 3). The diversity index of species was the highest at May, 1.06, and lowest at April, 0.69. The evenness index of species was the highest at July, 0.83, and lowest at May, 0.74 (Fig. 3c).

Seasonal occurrences of dominant wood-boring beetles (5 species) in the Goseong-gun area showed the highest number of all species in May, followed by a gradual decline (Fig. 4c).

Jeongseon-gun

At the Jeongseon-gun study site, the collected wood-boring beetles came from 8 families, 37 species, and comprised 2,154 individuals. At the family level, Scolytidae (11 species) and Curculionidae (9) were dominant, followed by Cerambycidae (7), and, at the species level, *Pissodes nitidus* (414 individuals, 18.7%), *Hylurgops interstitialis* (367 individuals, 16.5%), *Shirahoshizo rufescens* (354 individuals, 16.1%), *Tomicus piniperda* (344 individuals, 15.3%) were dominant, followed by *Siphalinus gigas* (182 individuals, 8.0%) (Table 3). The diversity index of species was the highest (1.09) in May and the lowest (0.36) in April, 0.36. The evenness index of species was the highest (0.81) in July and the lowest (0.33) in April (Fig. 3d).

Seasonal occurrences of dominant wood-boring beetles (5 species) in the Jeongseon-gun area showed the highest number of all species except for *iphalinus gigas* in May, followed by a gradual decline, and the largest number of *Siphalinus gigas* appeared in June (Fig. 4d).

Yangyang-gun

At the Yangyang-gun study site, the collected wood-boring beetles came from 8 families, 30 species, and comprised 2,863 individuals. At the family level, Scolytidae (9 species), Curculionidae (6), and Cerambycidae (6) were dominant, an, at the species level, *Hylurgops interstitialis* (702 individuals, 24.8%), *Pissodes nitidus* (521 individuals, 18.4%), *Tomicus piniperda* (378 individuals, 13.3%), *Shirahoshizo rufescens* (276 individuals, 9.7%) were dominant, followed by *Siphalinus gigas* (144 individuals, 5.0%)

Table 3. Dominant species in each stand location

Stand locations	Number of species	Species (%)
Chunchon-si	39	*Hylurgops interstitialis* (21.0)
		Pissodes nitidus (16.3)
		Tomicus piniperda (13.5)
		Shirahoshizo rufescens (12.0)
		Siphalinus gigas (6.3)
Pyeongchang-gun	36	*Hylurgops interstitialis* (22.5)
		Pissodes nitidus (21.5)
		Tomicus piniperda (13.3)
		Shirahoshizo rufescens (8.0)
		Siphalinus gigas (4.5)
Goseong-gun	30	*Pissodes nitidus* (19.4)
		Hylurgops interstitialis (19.2)
		Tomicus piniperda (16.7)
		Shirahoshizo rufescens (13.3)
		Siphalinus gigas (7.3)
Jeongseon-gun	37	*Pissodes nitidus* (18.7)
		Hylurgops interstitialis (16.5)
		Shirahoshizo rufescens (16.1)
		Tomicus piniperda (15.3)
		Siphalinus gigas (8.0)
Yangyang-gun	30	*Hylurgops interstitialis* (24.8)
		Pissodes nitidus (18.4)
		Tomicus piniperda (13.3)
		Shirahoshizo rufescens (9.7)
		Siphalinus gigas (5.0)

(Table 3). The diversity index of species was the highest (1.14) in June and the lowest (0.76) in April. The evenness index of species was the highest (0.80) in April and the lowest (0.75) in May (Fig. 3e).

Seasonal occurrences of dominant wood-boring beetles (5 species) in the Yangyang-gun area showed the highest number of all species except for *Siphalinus gigas* in May, followed by a gradual decline, and the largest number of *Siphalinus gigas* appeared in June (Fig. 4e).

Temporal variation in communities

Variation among wood-boring beetle communities was significantly influenced by density and height. The CCA1 score was significantly influenced by density and the CCA2 score was significantly influenced by height (Fig. 5).

The results confirmed that the community structure of the wood-boring beetles changed by the height of labor in the Chuncheon-si, Pyeongchang-gun, Yangyang-gun and

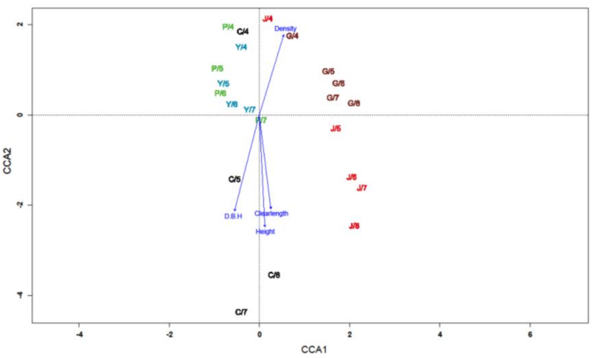

Fig. 5. CCA of associations between environmental factors and temporal variations in communities on study sites.

Jeongseon-gun areas. Specifically, with an increase of the height, the community change of wood-boring beetles increased. It is believed that there are perforated insects that prefer trees over a certain height, and our findings suggest that there is a large range of changes in Chuncheon City and Jeongseon County, and that there are insects that inhabit trees perforated at the height of over 10 meters. Changes in the cluster structure in the Pyeongchang-gun and Yangyang-gun counties were not as large as those in the Chuncheon-si and Jeongseon-gun counties.

In addition, Goseong-gun was found to be affected on the community structure of wood-boring beetles by the density of forestry. Specifically, the higher was the forest density, the greater was the change in the cluster structure. However, according to our results, the changes in the community structure of the wood-boring beetles in Goseong-gun were not significant. This findings requires a verification through continuous investigation (Fig. 5).

The patterns of temporal change in community composition were similar across the sites and varied mostly along the CCA 2 axis (Fig. 5). Between-site differences in temporal community changes were confirmed by the GLM analysis. No significant differences between the temporal community changes were observed in wood-boring beetle species and individuals. However, there were significant differences in the number of individuals depending on the monthly changes, and this finding appears to be related to the life history of wood-boring beetles. Additionally, as shown by the results of GLMM, the number of wood-boring beetle species and the number of beetles on each site were not significant in relation to each environmental

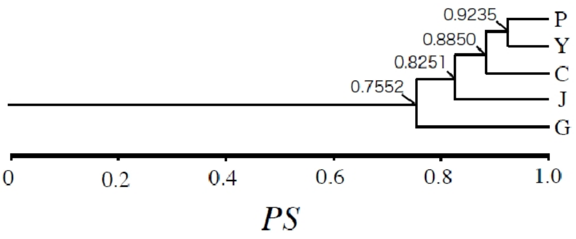

Fig. 6. Cluster analysis using UPGMA (unweighted pair-group method using average) based on PS (Whittaker' s percentage similarity).

variable.

The results of the analysis of the similarity between the regions of the colony of wood-boring beetles showed that Pyeongchang-gun and Yangyang-gun were the most similar at 0.9235, while Pyeongchang-gun and Goseong-gun were the most similar at 0.7552; the largest difference in the cluster structure among the survey sites. However, the similarity index was relatively high (range: from 0.76 to 0.92), indicating that there was no significant difference in the group structure of wood-boring beetles in all surveyed areas (Figs. 6 and 7).

Discussion

The diversity and abundance of wood-boring beetles observed in the present study in this study demonstrate the importance of these insects in terms of mortality and decomposition of coniferous forest.

A species diversity of 1.13, 1.10, 1.03, 1.07 and 3.29, and species evenness of 0.74, 0.71, 0.70, 0.68 and 2.23 were recorded from the composition of the wood-boring beetles recovered from each study site on coniferous forest.

The results demonstrated that the community structure of all study sites was similar. Seasonal occurrences of dominant wood-boring beetles (5 species) from each study site showed the highest number of all species except for *Siphalinus gigas* in May, followed by a gradual decline, and the largest number of *Siphalinus gigas* appeared in June. The similarity index of species composition was relatively high (range: from 0.75 to 0.90) on each study site. However, the similarity index between the Chuncheon-si and Goseong-gun areas appeared to be the lowest (0.75), which is not the difference between the east and west areas. This can be explained as corresponding to the sudden

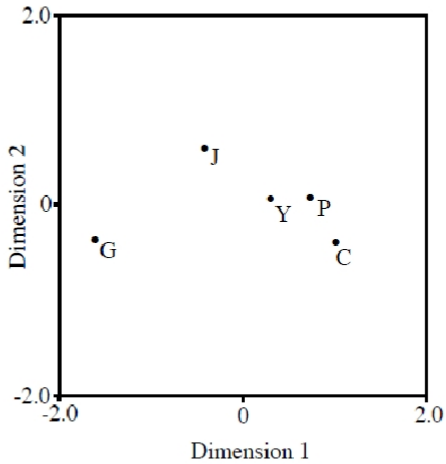

Fig. 7. NMDS (non-metric multidimensional scaling) Ordination of wood boring beetles community structure.

change in the environment due to repetitive large forest fires in the Goseong-gun area (Korea Forest Research Institute 1997). In the event when the biota is completely destroyed by natural disasters such as forest fires and volcanoes, then the biota is gradually recovered by the organisms in the environment (Kwon and Park 2005).

Temporal changes in wood-boring beetles, the patterns of which similar between sites even within study sites (Figs. 1 and 5). The composition of wood-boring beetle communities in Goseong-gun was influenced by various combinations of environmental factors. At this point, a question emerges: Why did responses to environmental factors differ across communities on different sites? The differences in the species composition of communities could play a role, and communities with similar species compositions may respond differently to local environmental conditions, provided that local environments per se vary between sites. This means that a species experiences different environmental conditions on different sites.

Consistently with previous research that found a high density of Curculionidae in the forest fire area (Kwon et al. 2003; Kwon and Park 2005), we also found that the density of the Curculionidae in the Goseong-gun area is relatively high.

Hylobitelus haroldi, which is commonly identified in the areas with frequent forest fires, is a species that eats the roots of coniferous pine trees (Hayashi et al. 1984). The larvae of the other species, *Shrirahoshizo rufescens*, are known to live under the bark of withered pine trees (Lee and Jung 1997). Therefore, we can reason that the high number of Curculionidae collected in the forest fire area can be attributed to the fact that the beetles were attracted to spawn in the damaged trees from adjacent forests.

Acknowledgements

This study was carried out with the support of part of 2017 Research Grant from Kangwon National University (Project No. 520170344).

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