한국응용곤충학회지
Korean J. Appl. Entomol. 54(4): 327-333 (2015)
DOI: http://dx.doi.org/10.5656/KSAE.2015.09.0.038

pISSN 1225-0171, eISSN 2287-545X

Ant Assemblages in a Burned Forest in South Korea: Recovery Process and Restoration Method

Tae-Sung Kwon*

Division of Forest Insect Pests and Disease, Korea Forest Research Institute, 57 Hoegi-ro, Dongdaemun-gu, Seoul 02455, Republic of Korea

산불이 난 산림에서의 개미군집: 회복과정과 복원방법

권태성*

국립산림과학원 산림병해충연구과

ABSTRACT: In order to identify the post-fire changes of ant assemblages after a forest fire, ants were surveyed at three survey sites (artificial reforestation site, natural reforestation site, and unburned forest site) in a burned forest area for eight years from 2005 using pitfall traps. 24 species were collected, and *Nylanderia flavipes* was the most abundant. Ant species preferring forest habitats (e.g. *Aphaenogaster japonica*. *Lasius spathepus*, and *Plagiolepis flavescens*) more occurred at the unburned forest site and the natural reforestation site, whereas ant species preferring open habitat (e.g., *Formica japonica*, *Camponotus japonicus*, and *Tetramorium caespitum*) more occurred at the artificial reforestation site. Ordination analysis indicated that ant communities of the artificial reforestation site were more changed compared with those of the natural reforestation site after the fire. The communities of the natural reforestation site were restored to the pre-fire state in five to six years after fire, whereas those of the artificial forest site seemed to take about 25 years to restore.

Key words: Ant, Fire, Community Restoration, Disturbance Index

초 록: 산불 후에 일어나는 개미군집의 변화양상을 파악하기 위해 산불이 난 산림에서 자연적으로 식생복원이 이루어진 곳, 인위적으로 조림한 곳, 산불이 나지 않은 곳의 3개 조사지에서 2005년부터 8년간 함정트랩으로 개미를 조사하였다. 모두 24종이 채집되었고 스미스개미(*Nylanderia flavipes*)가 가장 풍부하였다. 산림을 선호하는 개미종(예, 일본장다리개미, 민냄새개미, 노랑잘록개미)들은 산불이 나지 않은 조사지와 자연적으로 식생이 복원되는 조사지에서 많이 발생한 반면, 개활지를 선호하는 종(예, 곰개미, 일본왕개미, 주름개미)들은 인위적으로 조림된 곳에서 많이 나타났다. 다변량분석 결과는 인위적으로 조림된 곳이 자연적으로 식생이 복원된 곳 보다 개미군집이 산불 후에 더 많이 달라지는 것을 보여준다. 자연복원된 조사지에서는 개미군집이 산불이 난 5-6년후에 산불 이전으로 회복되는 데 비해, 인공복원된 조사지에서는 회복에 약 25년이 소요될 것으로 추정되었다.

검색어: 개미, 산불, 군집회복, 교란지수

In South Korea, there is a high possibility of large forest fires due to the increase of inflammable substances such as dried leaves, twigs and dead trees in the forest as they become old (Kwon et al., 2013b). In April 1996, forests of 3,762 ha were burned in Goseong, Gangwon-do. The largest-ever forest fire burned 23,794 ha across the eastern coastal region of Goseong, Gangneung, Samcheok in Gangwon province and Uljin in Gyongbuk province in 2000 (Shin et al., 2007). Enormous economic losses incurred to the local residents due to this largest fire (Shin et al., 2007). Various types of disturbance play important roles in forming the ecological structure and functions. Mid-level disturbance raises the heterogeneity of habitats, leading to increased biodiversity (Nöske et al., 2008). In forest gaps caused by forest fires or strong wind, newly formed habitats and vegetation being different from the surrounding area could

***Corresponding author:** insectcom@chol.com
Received July 21 2015; **Revised** September 7 2015
Accepted September 10 2015

increase biodiversity (Lain et al., 2008). For example, dead trees provide habitats and food for various living organisms (Gibb et al., 2006). After the mega forest fire in 2000, vegetation of the damaged area, which was mainly covered with pine trees, became to be diverse with growth of various tree species (Choung et al., 2004; Lee et al., 2004).

Most areas burned by forest fires have been restored artificially in South Korea. However, vegetation can recover naturally the burned areas in South Korea, where most mountains are forested. The natural recovery can occur more easily in the forested area than in the naked area such as North Korea. Therefore, the restoration plan by natural reforestation was proposed as one of the ecological restoration strategies of the burned areas following the massive forest fire in 2000 (Research Cooperation for Eastern Fire Damage, 2000). After heated debates on restoration methods, both the artificial reforestation and natural reforestation methods were applied to the burned areas (Lee et al., 2004). In the artificial reforestation, dead trees and twigs are removed prior to afforestation of burned area. Such works are additional disturbance that negatively affects living organisms in the burned areas (Kwon et al., 2013b). Therefore, disturbance intensity of the artificial reforestation is greater than that of the natural reforestation, which was found across communities of various arthropods (Kwon et al., 2011b; Lee et al., 2012; Kwon et al., 2013b). No studies on the impact of restoration methods of burned forests on insects are reported excluding the studies stated above. Ants play a key role in improving the productivity of soil as ecosystem engineers (Folgarait, 1998) and they also play a number of important roles in ecosystem as seed dispersals, scavengers and predators (Hölldobler and Willson, 1990). Ants sensitively respond to environmental changes due to their sedentary habits, so they are widely used as indicator organisms to study influences of various environmental changes (Agosti et al., 2000).

The purpose of this study is to compare the recovery process of ant fauna between the artificial reforestation and the natural reforestation after a forest fire. Ant communities were investigated at three survey sites (artificial reforestation site, natural reforestation site, and unburned forest site) in a burned forested area for eight years. Understory vegetation such as shrubs and grasses grow as trees are burned. Forests turn into open habitats such as grasslands and shrub lands after fire. Therefore, species preferring open habitat would increase after forest fire, whereas species preferring forest would decrease. However, as the burned forests have been increasingly recovered by vegetation, ant assemblages would gradually change to become similar with the pre-fire state. These predictions were examined in the present study.

Materials and Methods

Ant survey

This study was conducted in Gangleung area where a forest fire burned pine forest with an area of 430 ha in April 2004 (Kwon et al., 2013b). Three survey sites were selected within the study area; artificial reforestation (AR) site that was burned, clear-cut, and artificially reforested, natural reforestation (NR) site that was recovered naturally after fire, and unburned forest (UN) site (Fig. 1). In April 2006, seedlings of *Liriodendron tulipifera* were planted at the AR site. The fire was crown fire burning all vegetations, and the pre-fire vegetation in the burned area was pine forest. The sites are located at N38°18~19’, E129°01’. The average annual temperature in the study area is 12.9℃, and annual rainfall was 1650 mm in 2005 (Kwon et al., 2013b). Crown coverage was 80% in the UN site, whereas it was 0% at the AR and NR sites. Coverage of understory vegetation was about 90% and 100% at the AR site and NR site, respectively. Dominant plant species in the understory vegetation were *Lespedeza bicolor*, *Rubus phoenicolasius* at the burned sites (AR and NR), whereas they were *Rhus trichocarpa*, *Quercus dentata*, *Smilax china* at the UN site.

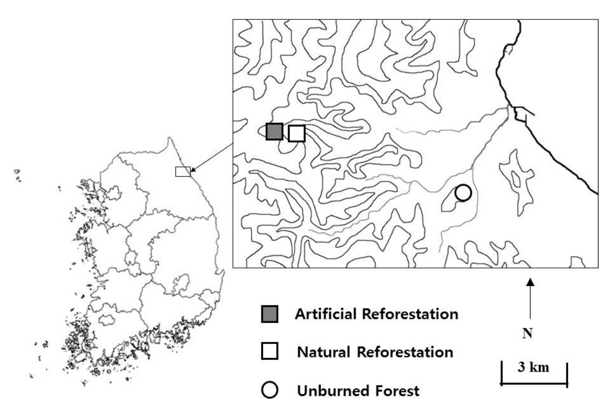

Fig. 1. Map of the study sites in the Gangleung area.

The Surveys on ants were conducted by pitfall traps. Plastic cups (diameter 9.5 cm, depth 6.5 cm) were used to install 20 traps at each survey site. Ten were buried in a straight line every 5 m and other ten were buried parallel 10 m away. Approximately 1/3 automobile antifreeze (automobile antifreeze, SK Energy, Super A, Seoul, South Korea) was added in each trap for the preservation solution. Pitfall traps were installed in late May and returned 10 to 15 days later. Total of 480 pitfall traps (160 traps per site) were used for 8 years. The returned traps were filled with 100% ethyl alcohol and preserved in the laboratory. Ants were identified by the Korean ant key of Kwon et al. (2012). During the surveys, soils (about 2 L) were sampled at five points of each site. These soil samples were analyzed by the Forest Soil Laboratory of the Korea Forest Research Institute from 2005 to 2011, or by the Korea Forestry Promotion Institute in 2012. The results of the soil analysis are listed in the appendix (Table S4).

Data analysis

Ants collected by pitfall traps could be collected excessively when ant colonies were located near the trap, which would cause distortion of abundance for collected ant species. Therefore, abundance of each ant species in this study was represented as trap catch frequency (%) (Table S1-3). This value has the same meaning as the probability of collecting a certain species by one trap at a specific location (Kwon et al., 2014a), and represents more the number of colonies than that of individuals. This is because this value deals only with whether the corresponding species exist around the trap. Ordination analysis of ant communities was conducted by Non-metric Multidimensional Scaling (NMS) using the abundance. NMS analysis was conducted using PC-ORD ver. 6.0 (MjM Software, Gleneden Beach, Oregon, USA). The disturbance index values of ant communities were calculated by the following equation of Kwon (2014) using the disturbance index values (DIV, indicator value for AR sites) of ant species that were estimated in the eastern coastal burned areas (Table 10 in Kwon et al., 2013a);

$$Disturbance = \frac{\sum_{i=1}^{n} x_i \times y_{ij}}{\sum_{i=1}^{n} y_{ij}}$$

where, x_i: the disturbance index value of species i (indicator value for AR site) y_{ij} : the abundance (trap catch frequency, %) of species i in site j. Simple regression model was made with the disturbance index value as the dependent variable and the year as the independent variable for each site. One-way ANOVA was used to compare values between groups with Neumann-Keuls multiple range test. Regression analysis and other statistical analysis were conducted using STATISTICA ver 8.0 (Statsoft, Inc., Tulsa, Oklahoma, USA).

Results and Discussion

A total of 6,443 ants belonging to 24 species were collected in this study (Table 1). *Nylanderia flavipes* was the first numerical dominant species which accounted for 31% of the total. Abundance of ant species was different between sites depending on their preferring habitats. The forest preferring species occurred more at the UN and NR sites, whereas the open habitat preferring species occurred more at the AR site. The former species were *Nylanderia flavipes*, *Pheidole fervida*, *Pristomyrmex pungens*, *Aphaenogaster japonica*, and *Lasius spathepus*, whereas the latter species were *Formica japonica*, *Camponotus japonica*, *Prenolepis* sp. *Tetramorium caespitum*, and *Lasius* spp. (*japonicus*+*alienus*). A species that most preferred forests was *Aphaenogaster japonica*, of which most individuals (56 of the 57) were collected at the UN site, with one at the NR site and none at the AR site. In Hongcheon, A, japonica was abundant in a larch forest, whereas this species was absent in a nearly located clear-cut forest (Kwon et al., 2011a). After a forest disturbance (heavy branch drop due to insect pest or/and heavy rain), this species declined drastically in abundance in the Gwangneung forest, whereas *Formica japonica* was increased (Kwon et al., 2014b). Therefore, it is likely that *A. japonica* is highly vulnerable to various types of forest disturbance. *Camponotus kiusuensis* and *Plagiolepis flavescens* were most abundant at NR site. Species richness was highest in the UN site followed by NR and AR sites, indicating the more disturbance the less richness. Therefore, forest fire and clearing prior to afforestation additively lowered the diversity of ant assemblages. However, abundance (number of individuals) was much higher at the AR site than the NR and UN sites because the open habitat preferring species such as *Camponotus japonicus*,

Table 1. Number of ants collected at the three study sites in Gangleung burned forest for 7 years from 2005. Abbreviation (Ab.) was used for representation of each species in Fig. 2. Sites, AR: artificial reforestation, NR: natural reforestation, and UN: unburned forest. DI: disturbance index value of each species that was provided by Kwon et al. (2013)

Species	Ab.	DI	Site			Total	%
			AR	NR	UN		
Aphaenogaster japonica	Aj	0		1	56	57	0.89
Camponotus japonicus	Cj	55	483	29	20	532	8.29
Camponotus kiusuensis	Ck	2	7	11	1	19	0.30
Camponotus sp.	C		1			1	0.02
Crematogaster matsumurai	Cm	1		4	11	15	0.23
Crematogaster osakensis	Co	26		1	17	18	0.28
Crematogaster vagulae	Cv	0			4	4	0.06
Formica japonica	Fj	82	642	35	12	689	10.73
Lasius sp.	L				45	45	0.70
Lasius spathepus	Ls	0		122	168	290	4.52
Lasius spp. *(japonicus+alienus)*	Lja	53	530	20	56	606	9.44
Lasius talpa	Lt	0			1	1	0.02
Myrmica carinata	Mc	5	8	72	85	165	2.57
Nylanderia flavipes	Nf	25	403	756	854	2013	31.36
Pachycondyla javana	Paj	39	132	367	102	601	9.36
Pheidole fervida	Pf	9	5	60	52	117	1.82
Plagiolepis flavescens	Plf	0		54	25	79	1.23
Ponera scabra	Ps	2		1	1	2	0.03
Prenolepis sp.	P	36	84	14	3	101	1.57
Pristomyrmex pungens	Pp	45	187	220	281	688	10.72
Solenopsis japonica	Sj	13	1		2	3	0.05
Strumigenys lewisi	Sl	1	1	1	1	3	0.05
Tetramorium caespitum	Tc	56	329	30	9	368	5.73
Vollenhovia emeryi	Ve	3			2	2	0.03
Number of species			14	18	23	24	
Number of individuals			2813	1798	1808	6443	

Formica japonica, *Lasius* spp., and *Tetramorium caespitum* were much more abundant at the AR site (Table 1).

The NMS ordination of ant assemblages is shown in Fig. 2. Two dimensional axes explained 89.6% of total variation, with the stress value of 9.725. Ant assemblages were clustered according to the sites. Even though the NR site is closer to the UN site (about 200 m) than the AR site (6 km, Fig. 1), the ant community at the NR is more similar to that of the UN site than that of AR site (Fig. 2). Ant species that were abundant at each site are located in the ordination space of each site. In the ordination space of AR site, *Formica japonica*, *Camponotus japonica*, *Prenolepis* sp. *Tetramorium caespitum*, and *Lasius* spp. (*japonicus*+*alienus*) that prefer open habitats appeared. In the space of UN site, *Aphaenogaster japonica* and *Crematogaster osakensis* that were collected mainly at this site appear in the center of the space, with *Vollenhovia emeryi* and *Lasius talpa* that usually live in the litter layer or soil layer (Kwon et al., 2012). In the space of the NR site, *Camponotus kiusuensis* and *Lasius spathepus* are distributed, and in its vicinity, *Plagiolepis flavescens*, *Myrmica carinata*, and *Pachycondyla javana* are distributed. *Myrmica* species occur commonly in both forests and open habitats (Shin et al., 2008), and *Myrmica carinata* also displayed such wide occurrence. This species was mainly collected at the UN and NR sites, but it also occurred in small

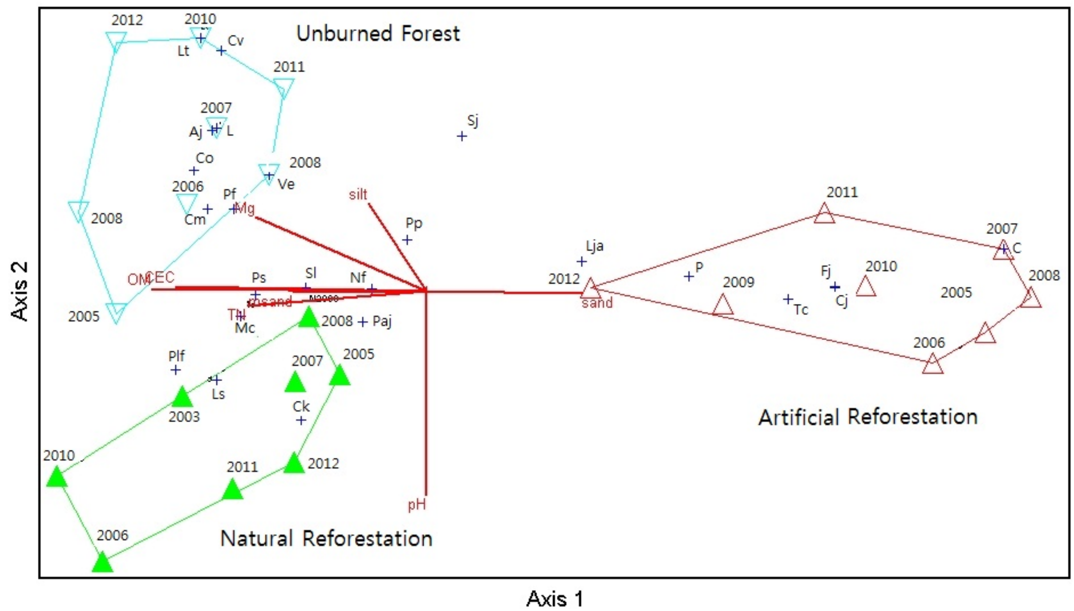

Fig. 2. Results of Non-metric Multidimensional Scaling (NMS) analysis on ant communities at the 3 sites in the Gangleung area. Full name of ant species are shown in Table 1. OM: organic matter, CEC: cation exchange capacity, and TN: total nitrogen.

numbers at the AR site, showing the wide range of its habitat. There was a clear correlation between ant assemblages and soil factors. Ordination of sand with larger particles is in the direction of the AR site, while ordination of silt is in the direction of the UN site. More loss of soil had happened due to little surface cover at the AR site so that proportion of sand increased as small particles such as silt and mid sand reduced. Ordination of organic matters and cation exchange capacity (CEC) that represent the nutrition of soil were in the direction of the UN and NR sites, and thus, it seems likely that loss of soil nutrition was most severe in the AR site. Such result is similar to that of the results obtained in three burned forested areas of the eastern coastal region in South Korea (Kwon et al., 2013b). However, it is dubious that ant assemblages might respond to the change of soil composition. However, ant assemblages might respond sensitively to changes in the crown layer or litter layer due to disturbance caused by forest fires or additional artificial disturbance (clear-cutting and removal of surface-cover, etc) that occurred after forest fires (Kwon et al., 2013b, 2014b). At the AR site, therefore, the crown layer was disappeared and the litter layer was reduced so ants reacted to this environmental change and their assemblages changed, while at the NR site, where there were still dead trees and the litter layer was maintained, vegetation rapidly recovered so species

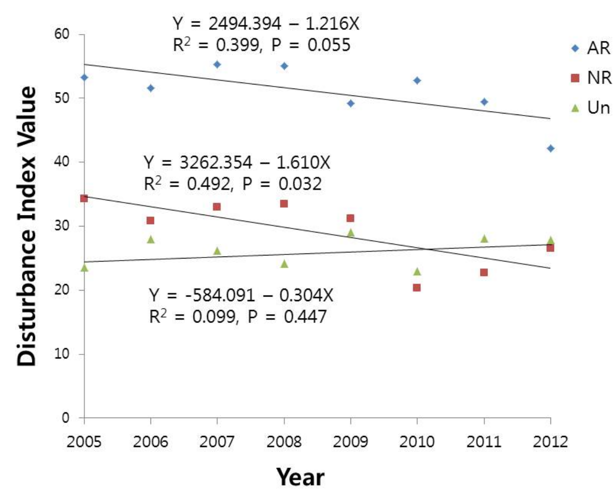

Fig. 3. Change of Disturbance Index Value of ant communities at the three sites in the Gangleung area. AR: artificial reforestation site, NR: natural reforestation site, and UN: Unburned forest.

that prefer forests remained to maintain closer ant assemblages with the UN site.

As expected, the DIV of ant assemblages tended to gradually decrease at the AR and NR sites (Fig. 3); however, the linear change did not occur at the UN site (P = 0.446). Comparing DIV by sites, the AR site was highest at 51.08 ± 1.51 (SE, standard error) and NR site was 29.04 ± 1.86, while the UN site was relatively lower at 26.25 ± 0.83. There was a significant difference of DIV between the AR site and other sites (Neumann-Keuls multiple range test, $P < 0.05$), but there was no significant difference between the NR site and UN site ($P > 0.05$). In the beginning of the survey, the DIV for the NR site was slightly higher compared to the UR site, but it became almost equivalent after 2009. On the regression model of Fig. 3, the DIV of the AR site is expected to become similar with the mean value of the UN site by circa 2029. This is the 25 year after the forest fire. Kwon et al. (2013a) reported that it takes only 16 years in the Gosung burned area. Pines (*Pinus densiflora*) were planted in the Goseong burned area and they grew fast. However, the planted trees (*Liriodendron tulipifera*) in the AR site grew very slowly, so the tree height was only 50-80 cm in 2012. Thus, the recovery process of ant assemblages in the AR site was highly influenced by growth of planted trees.

Results of this study showed that the ant assemblage of the AR site was much different from that of the UN site, while the assemblage of the NR site was relatively similar to that of the UN site. This finding represents that the artificial recovery of burned forest would influence more greatly on forest-dwelling organisms than the natural recovery would do. When evaluating the recovery speed of ant assemblages using the value of DIV, in the case of natural recovery, it is restored nearly to its original state in five to six years after forest fire. However, in the case of artificial recovery, it is expected that it will take approximately 25 years to be restored to its original state. Also, there is a high relationship between the growth speed of planted tree species and the recovery speed of ant assemblages, so it is important to select a proper tree species with optimum growth for the restoration of the insect fauna. Although artificial reforestation is the mainstream for restoring burned forests currently in South Korea, vegetation usually restored rapidly in the burned forests even if trees were not planted. The ongoing afforestation program of burned forests is related with the rigid afforestation policy of the Forest Service in South Korea. The rapid recovery and more diversity in the NR site suggest enlargement of the natural recovery program of the burned forests.

Acknowledgement

I thank Dr. Y-K Park for his field works. This study was conducted as a part of a research project of Korea Forest Research Institute (Ecological monitoring of burned forests and development of recovery technology, FE0500-1997-01).

Literature Cited

Agosti, D., Majer, J.D., Alonso, L.E., Schultz, T.R., 2000. Ants: standard methods for measuring and monitoring biodiversity, Washington: Smithsonian Institution.

Choung, Y.S., Lee, B.C., Cho, J.H., Lee, K-S, Jang, I-S., Kim, S-H., Hong, S-K., Jung, H-C., Choung, H-L., 2004. Forest responses to the large-scale east coast fires in Korea. Ecol. Res. 19, 43-54.

Folgarait, P.J., 1998. Ant biodiversity and its relationship to ecosystem functioning: a review. Biodiv. Conserv. 7, 1221-1244.

Gibb, H., Pettersson, R.B., Hjältén, J., Hilszczanski, J., Ball, J.P, Johansson, T., Atlegrim, O., Danell, K., 2006. Conservation-oriented forestry and early successional saproxylic beetles: Responses of functional groups to manipulated dead wood substrates. Biol. Conserv. 129, 437-450.

Hölldobler, B., Willson, E.O., 1990. The ants. The Belknap Press of Harvard University Press, Massachusetts.

Kwon, T-S., 2014. An empirical test of influence of global warming and forest disturbance on ant fauna at Gwangneung LTER site, South Korea. J. Asia-Pacific Biodiv. 7, 252-257.

Kwon, T-S., Kim, S-S., Lee, C.M., Jung, S.J., Sung, J.H., 2012. Korean ant atlas (2006-2009). Research Note 459. Korea Forest Research Institute, KDHL Pub. Co., Seoul.

Kwon, T-S., Lee, C.M., Chun, J.H., Sung, J.H., Kim, S.K., 2011a. Ants in Hongneung forest. Research Note 412, Korea Forest Research Institute, Seoul.

Kwon, T-S., Lee, C.M., Park, J., Kim, S-S., Chun, J.H., Sung, J.H., 2014a. Prediction of abundance of ants due to climate warming in South Korea. J. Asia-Pacific Biodiv. 7, 179-196.

Kwon, T-S., Lee, C.M., Sung, J.H., 2014b. Diversity decrease of ant (Formicidae, Hymenoptera) after a forest disturbance: different responses among functional guilds. Zool. Stud. 53, 37-47.

Kwon, T-S., Park, Y.K., Lee, C.M., 2011b. Influence of recovery method and fire intensity on coleopteran communities in burned forests. Korean J. Appl. Entomol. 50, 267-278.

Kwon, T-S., Park, Y.K., Lee, C.M., Lim, J.H., 2013a. Change of ant communities in the burned forests in Eastern Coastal area. Research Report 13-24. Korea Forest Research Institute, Seoul.

Kwon, T-S., Park, Y.K., Lim, J-H., Ryou, S.H., Lee, C.M., 2013b. Change of arthropod abundance in burned forests: different patterns according to functional guilds. J. Asia-Pacific Entomol. 16, 321-328.

Lain, E.J., Hanley, A., Burris, J.M., Burton, J., 2008. Response of vegetation and birds to severe wind disturbance and salvage log-

ging in a southern boreal forest. Forest Ecol. Manag. 256, 863-871.
Lee, C.M., Kwon, T-S., Park, Y.K., Kim, B-W., 2012. Influences of disturbance intensity on community structure, species ricnness and abundance of arthropod predators (Aranea, Carabidae, Staphylinidae, and Formicidae) in burned pine forest. Jour. Korean For. Soc. 101, 488-500.
Lee, M.B., Gang, Y.H., Lim, J.H., Shin, S-C., Yang, S-Y., Gong, J-S., Shim, W-B., Kim, J-C., Soe, S-A., Soe, J-W., Won, H-K., Byun, J-K., Kim, C-S., Lee, Y-Y., Bae, S-W., Lee, W-K., 2004. Restoration and rehabilitation of damaged forest on post-fire sites in Korea. Research Report 04-07. Korea Forest Research Institute, Seoul.
Nöske, N.M., Hilt, N., Werner, F.A., Brehm, G., Fieldler, K., Sipman, H.J.M., Gradstein, S.R., 2008. Disturbance effects on diversity of epiphytes and moths in a montane forest in Ecuador. Basic Appl. Ecol. 9, 4-12.
Research Cooperation for Eastern Fire Damage, 2000. Report II of eastern sea side burned region for establishment of health ecosystem and recovery of burned forests. Korea Forest Research Institute, National Institute of Environmental Research, Kwangwon University, and Baekdudaegan Civil Cooperation.
Shin, J.H., Lee, M.B., Lim, J.H., Lee, Y.K., Gu, G.S., Gang, Y.H., Won, M.S., Sung, J.H., Jo, J.H., Kwon, T-S., Kim, G.H., Yun, H.J., Lee, C.W., Lee, S.H., Ga, G.H., Park, H., Park, B.S., Park, J.H., Kim, S.D., Lee, E.J., Lee, W.S., Lee, E.J., Byun, H.G., Lee, J.E., Lee, G.S., Park, Y.K., Kim, S-S., Shin, S.E., Han, S.W., Lee, H.S., Gang, T.H., 2007. Change of ecosystem in the burned forests 1997~2006. Research Report 07~06. Seoul: Korea Forest Research Institute. 242pp.
Shin, J.H., Lim, J.H., Kwon, T-S., Yang, H.M., Chun, J.H., Lee, I.K., Yun, C.W., Park, C.Y., Jo, J.H., Choi,. M.S., Kim, Y.G., Ga, G.H., Park, B.B., Lee, S.W., Lee, Y.Y., Shin, J.S., Kim, S-S., Park, Y.S., Kim, B.W., Park, D.S., Jang, M.H., Park, S.J., Park, Y.K., Shin S.E., Kim, C.M., Lee, W.S., 2008. Forest eco-map for Eulsu-dong. Research Report 311. Korea Forest Research Institute, Seoul.