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# Distribution Status and Characteristics of Exotic Plants in the Gwangreung Forest, Korea

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**ABSTRACT**: To find out the status and characteristics of exotic plants in the Gwangreung Forest, a representative forest ecosystem in central Korea, we surveyed the species composition, coverage, and habitat illuminance of exotic plant species in a set of quadrats established along roads and trails in and around the Gwangreung Forest and buffer zone areas. In 1932, only five species of exotic plants were found along paths and roads in the Gwangreung Forest. However, the number of species in the forest has dramatically increased since 2000, when *Ambrosia artemisiifolia* L. and *A. trifida* L. were first recorded, and in 2007, 38 species of exotic plants were recorded. Among the 11 families, 23 genera and 25 species of exotic plants recorded in the quadrats, Compositae was the most common family (11 species), and perennial herbs, 42%, were the most frequently occurring life type, followed by annual herbs (31%) and biennial herbs (19%). Plants of North American origin comprised 48% of exotic species identified in our surveys. Exotics were found most frequently in quadrats along roads in the forest, followed by the buffer zones and hiking trails. The number of species and individuals of exotic plants decreased as we moved deeper into the forest, but *Aster pilosus* Willd. and *Erigeron annuus* (L.) Pers. were identified along hiking trails in the interior, and appeared to be capable of spreading further and more rapidly into the forest than other species.

***Key words***: Alien plants, Distribution status, Gwangreung forest, Naturalized plant

## INTRODUCTION

As travel and trade among countries becomes increasingly common, the risk of international transmission of harmful exotic plants that can cause problems like disturbance of ecosystems becomes more likely. Alien plants are spreading rapidly to islands, cities, and rural areas alike due to the rapid progress of industrialization and globalization. The uncontrolled spread of exotic plants is a concern throughout the world. Prevention of the introduction of foreign species and the need for management of existing exotics have been discussed at the EN Environment Development Conference held in Rio, Brazil in 1992, the Biological Diversity Convention in 1995, and other conferences, and research on the characteristics of invasive species and the effects and management of alien plants is being conducted throughout the world. The introduction of exotic plants into natural habitats is recognized as one of the greatest factors leading to loss of biodiversity (Mooney 1999, Meiners et al. 2001, Levine et al. 2003).

In Korea, the Ministry of Environment has published a report on "Research on the Effects of Alien Plants on Ecosystems and Their Management" each year since 2000, and research and surveys of the distribution, status and ecological characteristics of exotic plants has been ongoing in Korea since 1980 (Lim et al. 1980, Suh et al. 1997, Seon et al. 1992, Park 1994, Seo et al. 2000, Kang et al. 2002, Yang 2003, Shin et al. 2004).

The exact date of introduction of exotic plants that survive and propagate without human intervention cannot be precisely identified for each species in Korea. However, exotic plants can be classified as earlier exotic plants - plants that were in Korea before the second half of the 19th century and for which survey data are generally insufficient, pre-war exotics - those introduced from the second half of the 19th century until the Korean War, or new exotic plants that have entered Korea since the 1960s (Kim et al. 2000). JW Pallibin, from Russia, published the first record of exotic plants in Korea, and subsequently Lee and Kim (1961) identified 65 species of exotic plants from the Americas and another 12 exotic plants in Korea. Additional species were subsequently identified by Lee and Oh (1974), and Lim and Jeon (1980), and by 1995, 218 alien plant species had been identified in Korea (Goh et al. 1995). However, the number continues to increase (Goh et al. 2003); 280 species of exotic plants are known to be present in the nation at the time of writing, of which 6 species, *Ambrosia artemisiifolia* L., *Ambrosia trifida* L., *Eupatorium rugosum* Houtt., *Paspalum distichum* var.

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*indutum* Shinners, *Paspalum distichum* L., and *Solanum carolinense* L., are classifed as harmful alien plants.

The Gwangreung Forest is part of the original forest surrounding the 1468 tomb of King Seju, the 7th king of the Chosun dynasty, and has been preserved from external interference for > 540 years. Therefore, it is a good representative of the original central Korean forest habitat. The forest includes at least 924 species of plants, including prized plants like *Cypripedium japonicum* Thunb. and *Fraxinus densata*, and 2,881 species of animals including 20 species designated as Korean Natural Treasures, such as *Dryocopus javensis* (the Korean woodpecker) and *Callipogon relictus* Semenov, making the forest a place of rich biological diversity. The purpose of our research was to lay the groundwork for ecological management of exotic plants in the Gwangreung Forest by surveying the status and characteristics of exotic plants and examining the distribution of exotics in different areas of the forest, and to provide basic data for the preservation of biodiversity in the Gwangreung Forest.

## STUDY AREA

We conducted surveys from May to October, 2007 along roads that pass through the Gwangreung Forest and nearby buffer zones, and on hiking trails within the Gwangreung Forest. The forest extends through Soheul eup and Naechon myeon in Pocheon gun, Jinjeop eup and Byeolnaem myeon in Namyangju city, and Minlak dong and Nakyang dong of Uijeongbu city in Gyeonggi province, and includes Sori Peak (536.8 m asl) in the center, Cheonchim Mountain in the southern end and Yongam Mountain (489.6 m asl) in the west. The forest stretches about 4 km east-west and about 6 km north-south. We surveyed 12 locations along a 4.5 km segment of road that passes through Gwangreung Forest from the 3-way junction to Jikdong ri and around residential areas, restaurants and temples near the buffer zones within Gwangreung Forest, and 9 locations in the adjacent area. We also surveyed three sections of hiking trails within Gwangreung Forest: hiking trail Ⅰ is the segment from the foreign botanical garden entrance to Sori Peak, hiking trail Ⅱ is the segment from the Sori Peak outlook post to the Forest Workforce Development Institute, and hiking trail Ⅲ is the segment from Jukyeop Mountain to Neungnae dong.

## METHODS

We surveyed roads in the Gwangreung Forest on foot and recording all exotic plants observed from the 3-way junction within the Gwangreung forest to the Forest Production and Technology Research Institute. We also established 5 × 5 m quadrats at intervals (0 m, 10 m 30 m, 50 m, 80 m, 100 m) in a line perpendicular to the road from 12 locations in the forest. Additional quadrats were established at 9 locations along roads in the Gwangreung Forest buffer zones perpendicular to the road at 0-m, 10-m 30-m, 50-m, 80-m, and 100-m intervals, and quadrats were placed at 1-km intervals along the Gwangreung forest hiking trails. We recorded all plant species in each quadrat at each location, and recorded the coverage, number of exotic plant species, and the intensity of incident light (illuminance) for each quadrat.

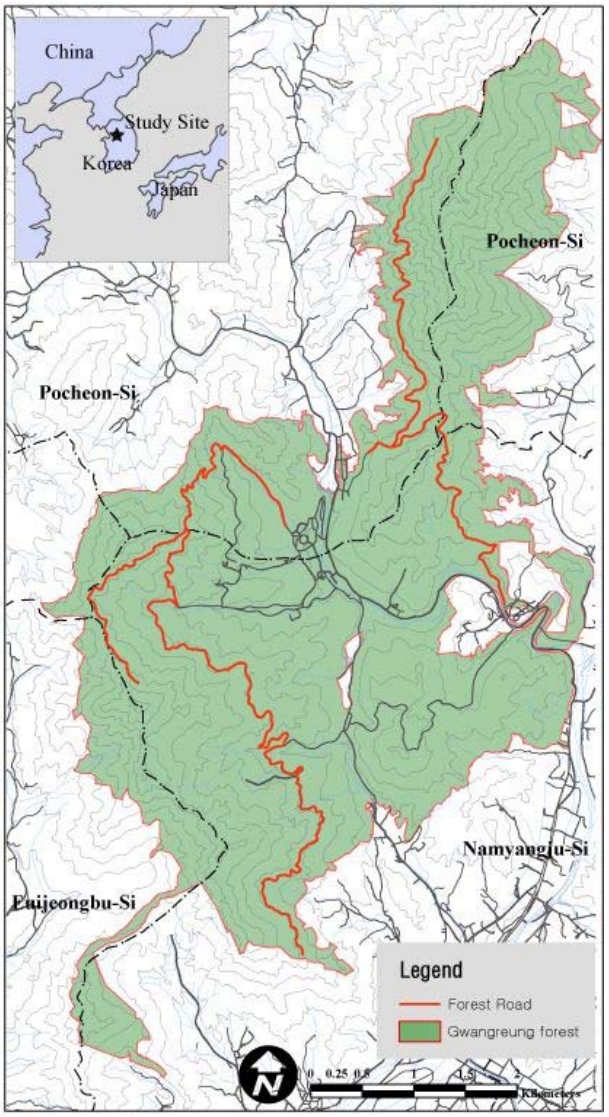


Fig. 1. Map showing the study area.
●: roads, ①~⑨: buffer zones, Ⅰ, Ⅱ, Ⅲ: hiking trails.

## RESULTS AND DISCUSSION

### Exotic Plants along Gwangreung Forest Roads

A 1932 survey recorded the presence of 5 species of exotic

plants on the sides of roads through Gwangreung forest: *Fallopia convolvulus* (L.) A. Lö, *Rumex acetosella* L., *Thlaspi arvense* L., *Carduus crispus* L. and *Taraxacum officinale* Weber, and all of these species except *Fallopia convolvulus* (L.) A. Lö were reproducing in Gwangreung Forest. Subsequently, *Poa pratensis* L., *Rumex acetosella* L., *Thlaspi arvense* L., *Robinia pseudoacacia* L., *Trifolium pratense* L., *Trifolium repens* L., *Ailanthus altissima (*Mill.) Swingle, *Abutilon theophrasti* Medicus, *Carduus crispus* L., *Erigeron annuus* (L.) Pers., *Conyza canadensis* (L.) Cronquist and *Taraxacum officinale* Weber have been recorded in the forest since 1980, and *Ambrosia artemisiifolia* L. and *Ambrosia trifida* L., which are harmful alien plants, were first recorded in the Gwangreung Forest buffer zones in the 2000s. We discovered one individual of *Eupatorium rugosum* Houtt near the river in our field survey, but did not observe this species in the quadrats. An additional 21 species that were first recorded in the area in 2000 were not observed along roads in the forest over the last 3～4 years, including *Lolium multiflorum* Lamarck, *Poa compressa* L., *Panicum virgatim* L., *Fallopia convolvulus* (L.) A. Lö, *Persicaria orientalis* (L.) Spach, *Chenopodium glaucum* L., *Brassica juncea* (L.) Czern., *Sisymbrium altissimum* L., *Trifolium campestre* Schreb., *Viola papilionacea* Pursh, *Datura stramonium* var. *chalybea* Koch., *Lindernia dubia* (L.) Pennell., *Veronica arvensis* L., *Anthemis cotula* L., *Aster subulatus* var. *sandwicensis* A.G. Jones, *Centaurea cyanus* L., *Verbesina alternifolia* Britton, *Coreop-*

Table 1. List of exotic plant recorded along roads in the Gwangreung Forest and the surrounding area

| Family | Scientific name | G.T[1)] | 1932[2)] | 1984[3)] | 1994[4)] | 01 | 03 | 04 | 05 | 06 | 07[5)] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gramineae | *Bromus tectorum* L. | a～b | | | | ● | ● | | ● | ● | |
| | *Dactylis glomerata* L. | p | | | | ● | ● | ● | ● | ● | ● |
| | *Festuca arundinacea* Schreb. | p | | | | ● | ● | | ● | ● | ● |
| | *Lolium multiflorum* Lamarck | a | | | | ● | ● | | | | |
| | *Poa compressa* L. | p | | | | | | ● | | | |
| | *Poa pratensis* L. | p | | ● | ● | ● | ● | ● | ● | | ● |
| | *Panicum dichotomiflorum* Michx. | a | | | | | ● | | ● | | ● |
| | *Panicum virgatim* L. | a | | | | | ● | | | | |
| Commelinaceae | *Tradescantia reflexa* Raf. | p | | | | | ● | | | | ● |
| Polygonaceae | *Fallopia convolvulus* (L.) A.Lö | a | ● | | | | ● | | | | |
| | *Persicaria orientalis* (L.) Spach | a | | | ● | ● | ● | | | | |
| | *Rumex acetosella* L. | p | ● | | ● | ● | ● | ● | ● | ● | ● |
| | *Rumex crispus* L. | p | | ● | | ● | ● | ● | ● | ● | ● |
| | *Rumex obtusifolius* L. | p | | | | ● | ● | ● | ● | ● | ● |
| Chenopodiaceae | *Chenopodium album L.* | a | | | | ● | ● | ● | ● | ● | |
| | *Chenopodium ficifolium* Smith | a | | ● | | ● | ● | ● | | | |
| | *Chenopodium glaucum* L. | a | | ● | | ● | ● | | | | |
| Amaranthaceae | *Amaranthus patulus* Bertol. | a | | | | | ● | | | ● | ● |
| Phytolaccaceae | *Phytolacca americana* L. | p | | | | ● | ● | | ● | ● | ● |
| Caryophyllaceae | *Silene armeria* L. | b | | | | ● | ● | ● | ● | | ● |
| Cruciferae | *Barbarea vulgaris* R.Br. | b | | | | ● | ● | | ● | ● | ● |
| | *Brassica juncea* (L.) Czern. | b | | | | | ● | | | | |
| | *Lepidium apetalum* Willd. | b | | | | | | ● | ● | ● | ● |
| | *Lepidium virginicum* L. | b | | | | ● | ● | ● | ● | ● | ● |
| | *Sisymbrium altissimum* L. | b | | | | ● | ● | | | | |
| | *Thlaspi arvense* L. | b | ● | ● | ● | ● | ● | | ● | | |
| Rosaceae | *Potentilla supina* L. | a-b | | | | ● | ● | ● | ● | ● | ● |
| Leguminosae | *Amorpha fruticosa* L. | t | | | | | | ● | ● | ● | ● |
| | *Medicago sativa* L. | p | | | | | ● | ● | ● | ● | |
| | *Robinia pseudoacacia* L. | t | | ● | | ● | ● | ● | ● | ● | ● |
| | *Trifolium campestre* Schreb. | a | | | | | ● | | | | |
| | *Trifolium pratense* L. | p | | ● | | ● | ● | ● | ● | ● | ● |
| | *Trifolium repens* L. | p | | ● | | ● | ● | ● | ● | ● | ● |

Table 1. Continued

| Family | Scientific name | G.T[1] | 1932[2] | 1984[3] | 1994[4] | 01 | 03 | 04 | 05 | 06 | 07[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Geraniaceae | *Geranium carolinianum* L. | a-b | | | | ● | ● | | ● | | ● |
| Simaroubaceae | *Ailanthus altissima (*Mill.) Swingle | t | | ● | | ● | ● | ● | ● | ● | ● |
| Euphorbiaceae | *Euphorbia supina* Raf. | a | | | | ● | ● | | ● | ● | ● |
| Malvaceae | *Abutilon theophrasti* Medicus | a | | ● | | ● | ● | | | ● | |
| Violaceae | *Viola papilionacea* Pursh | p | | | | | ● | | | | |
| Onagraceae | *Oenothera biennis* L. | b | | | | ● | ● | | | ● | ● |
| Convolvulaceae | *Cuscuta pentagona* Engelm. | a | | | | | ● | | ● | ● | |
| Boraginaceae | *Symphytum officinale* L. | p | | | | | | ● | ● | | ● |
| Solanaceae | *Datura stramonium* var. *chalybea* Koch. | a | | | | | ● | | | | |
| Scrophulariaceae | *Lindernia dubia* (L.) Pennell | a | | | | | ● | | | | |
| | *Veronica arvensis* L. | a | | | | ● | ● | | | | |
| Plantaginaceae | *Plantago lanceolata* L. | b, p | | | | | | ● | | ● | |
| Compositae | *Ambrosia artemisiifolia* L. | a | | | | ● | ● | ● | ● | ● | ● |
| | *Ambrosia trifida* L. | a | | | | | ● | ● | ● | ● | ● |
| | *Anthemis cotula* L. | a | | | | ● | ● | | | | |
| | *Aster pilosus* Willd. | p | | | | ● | ● | ● | | ● | ● |
| | *Aster subulatus* var. *sandwicensis* A.G.Jones | a | | | | | ● | | | | |
| | *Bidens frondosa* L. | a | | | | ● | ● | | ● | ● | ● |
| | *Carduus crispus* L. | b | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | *Centaurea cyanus* L. | a-b | | | | ● | ● | | | | |
| | *Verbesina alternifolia* Britton | p | | | | | ● | | | | |
| | *Coreopsis lanceolata* L. | p | | | | | ● | ● | ● | ● | |
| | *Coreopsis tinctoria* Nutt. | a | | | | ● | ● | | | | |
| | *Cosmos bipinnatus* Cav. | a | | | | | ● | ● | ● | ● | ● |
| | *Erechtites hieracifolia* Raf. | a | | | | ● | ● | | ● | ● | ● |
| | *Erigeron annuus* (L.) Pers. | b | | ● | ● | ● | ● | ● | ● | ● | ● |
| | *Conyza canadensis* (L.) Cronquist | b | | ● | ● | ● | ● | ● | ● | ● | ● |
| | *Erigeron strigosus* Muhl. | a-b | | | | ● | ● | ● | | | |
| | *Conyza sumatrensis* E.Walker | b | | | | | ● | | | | |
| | *Eupatorium rugosum* Houtt. | p | | | | | | | ● | | |
| | *Galinsoga ciliata* (Raf.) S.F.Blake | a | | | | ● | ● | | ● | ● | ● |
| | *Helianthus tuberosus* L. | p | | | | ● | ● | ● | | | |
| | *Lactuca scariola* L. | a-b | | | | | ● | ● | ● | ● | ● |
| | *Rudbeckia laciniata* var. *hortensis* Bail. | p | | | | | ● | | ● | ● | ● |
| | *Senecio vulgaris L.* | a | | | | ● | ● | | ● | ● | |
| | *Taraxacum laevigatum* DC. | p | | | | | ● | ● | ● | ● | ● |
| | *Taraxacum officinale* Weber | p | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | *Xanthium canadense* Mill. | a | | | | ● | ● | | | | |
| 22 family | 72 species | | 5 | 14 | 8 | 44 | 65 | 33 | 42 | 40 | 38 |

[1] a: annuals, b: biennuals, a-b: annualbiennuals, p: perennials, t: trees.

[2] Nakai, T. 1932. Gwangreung Test Forest, Chosun Governing Authority.

[3] Nam-Suk Lee, Women's, 1984. Sori Peak Plants Status and Life Types, Korean Journal of Ecology 7: 33-59.

[4] 59 Forestry Research Institute, 1994. Gwangreung Test Forest (Appendix 3. Gwangreung Test Forest Fauna and Flora Distribution List).

[5] 2001, 2003～2006: Survey Data of Korea National Arboretu.

*sis tinctoria* Nutt., *Conyza sumatrensis* E. Walker, *Helianthus tuberosus* L. and *Xanthium canadense* Mill. Among these, 13 species of annual herbs may have become locally extinct due to competition, or alternatively, they may simply have not been discovered or properly identified by survey personnel. In 2002, 65 species were recorded, which reflects an increase of 11 species from the previous year. An additional 44 species presumably entered the area as a result of accidental introduction in soil or sand during construction associated with the expansion of the 3-way junction road within the Gwangreung Forest in 2002, but no new species have been recorded more recently.

### Life Type and Place of Origin of Exotic Plants in the Gwangreung Forest

Of the exotics found in the Gwangreung Forest, 138 species (50.9 %) were annual herbs, 57 species (21.0%) were biennial herbs, 73 species (26.9%) were perennial herbs, and 3 species (1.1%) were trees (Park et al. 2002). We identified 25 species of exotic plants in the surveyed areas, including 8 species (31%) of annual herbs, 5 species (19%) of biennial herbs, 11 species (42%) of perennial herbs, and 2 species (8%) of trees (Fig. 2). Perennial herbs, particularly those with stalks or rhizome nodes that fall easily and regenerate into new plant bodies after falling, are particularly difficult to eradicate, so the observation that perennial herbs comprise the largest component of the exotic plant flora in the forest indicates that it is important that forest managers employ effective methods to eliminate invasive perennials.

The most common place of origin of exotic plants in Korea is Europe (112 species, or 41.3%), followed by North America (64 species, or 10.7%) and Eurasia (24 species or 8.9%) (Park et al. 2002). For the 25 exotics identified in the survey area, however, North America was the most common place of origin, followed by Europe, Eurasia, China, and Central and South America (Fig. 3). In the case of Gaya Mountain, the characteristics were quite different, showing 43% from Europe and 29% from North America (Lim and Hwang 2006).

### Frequency of Occurrence and Distribution Characteristics of Exotic plants

Twenty-five species of exotic plants in 23 genera and 11 families were recorded in the quadrats in the survey area. The family Compositae (11 species) was the most common, followed by Leguminosae (3 species), Gramineae (2 species), Polygonaceae (2 species), Amaranthaceae, and Phytolaccaceae. Compositae, which comprised 43% of the exotic species recorded, have an advantage over other species in scattering seeds, are also the most prevalent exotic plants in Jejudo (Yang et al. 2003).

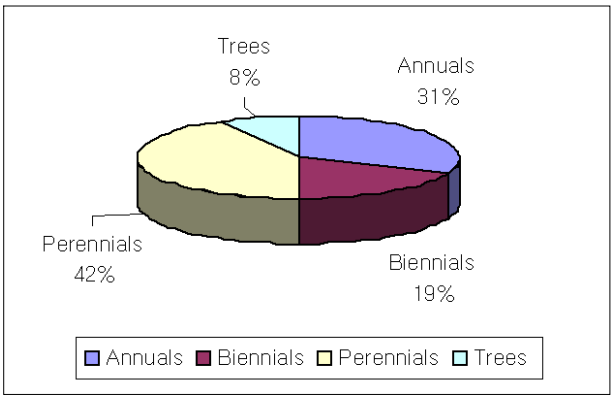


Fig. 2. Growth type

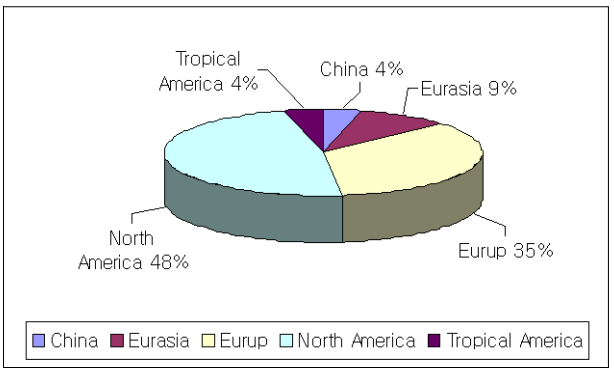


Fig. 3. Region of origin

Twenty-one of the species found along the roads in Gwangreung Forest were represented by large numbers of individuals that comprised comparatively large portions of the species recorded in the quadrats. The same was true of 19 species in the Gwangreung Forest buffer zone and 10 species on the Gwangreung Forest hiking trails.

Exotic plants were most frequently recorded in quadrats placed along the Gwangreung Forest road in areas that experience frequent artificial disturbances, resulting in the influx of various species including *Erigeron annuus* (L.) Pers. and *Ambrosia artemisiifolia* L., and in a bare area near Gwangreung Forest that was confirmed to form a pure colony of *Ambrosia trifida* L., *Erigeron annuus* (L.) Pers. and *Aster pilosus* Willd. *Ambrosia trifida* L., which forms a large colony near the Gwangreung Forest cultivation complex, not only suppresses the growth of native plants but also produces highly allergenic pollen, so long-term monitoring and removal of this plant is particularly important. The quadrats around the hiking trails in the Gwangreung Forest contained a relatively small number of exotic plants compared to other quadrats.

The exotic plants most frequently recorded in quadrats in the study areas other than hiking trails were *Erigeron annuus* (L.) Pers.,

Table 2. Frequency of exotic plants in the quadrats

| | | Appearance frequency (quadrates) | | |
|---|---|---|---|---|
| | | 9 locations in buffer zones (40 quadrates) | 12 locations in paths and roadsides (39 quadrates) | Hiking trails I, II, III (24 quadrates) |
| Gramineae | *Dactylis glomerata* L. | 2 | 2 | 1 |
| | *Poa pratensis* L. | · | 2 | · |
| Commelinaceae | *Tradescantia reflexa* Raf. | · | 1 | · |
| Polygonaceae | *Rumex crispus* L. | 1 | 3 | · |
| | *Rumex obtusifolius* L. | · | 1 | · |
| Amaranthaceae | *Amaranthus patulus* Bertol. | 1 | · | · |
| Phytolaccaceae | *Phytolacca americana* L. | 1 | · | · |
| Caryophyllaceae | *Silene armeria* L. | · | 1 | · |
| Rosaceae | *Potentilla supina* L. | 1 | 1 | · |
| Leguminosae | *Amorpha fruticosa* L. | · | 1 | · |
| | *Robinia pseudoacacia* L. | 2 | 1 | · |
| | *Trifolium repens* L. | 3 | 2 | · |
| Simaroubaceae | *Ailanthus altissima (*Mill.) Swingle | 2 | · | 1 |
| Onagraceae | *Oenothera biennis* L. | 2 | 2 | 1 |
| Compositae | *Ambrosia artemisiifolia* L. | 11 | 9 | · |
| | *Ambrosia trifida* L. | 4 | 2 | · |
| | *Aster pilosus* Willd. | 9 | 8 | 13 |
| | *Bidens frondosa* L. | 5 | 4 | 1 |
| | *Carduus crispus* L. | · | 1 | 1 |
| | *Erechtites hieracifolia* Raf. | 6 | 2 | 1 |
| | *Erigeron annuus* (L.) Pers. | 21 | 17 | 7 |
| | *Conyza canadensis* (L.) Cronquist | 9 | 5 | 3 |
| | *Galinsoga ciliata* (Raf.) S.F.Blake | 1 | 5 | · |
| | *Helianthus tuberosus* L. | 2 | · | · |
| | *Taraxacum officinale* Weber | 5 | 2 | 2 |
| 11 families | 25 species | 19 species | 21 species | 10 species |

*Ambrosia artemisiifolia* L., *Aster pilosus* Willd. and *Conyza canadensis* (L.) Cronquist, and the exotic plants most frequently recorded along the hiking trails were *Aster pilosus* Willd., and *Erigeron annuus* (L.) (Table 2). In the interior of tbe Gwangreung Forest, we recorded relatively few species of exotic plants; however, *Aster pilosus* Willd., *Erigeron annuus* (L.) Pers. and *Taraxacum officinale* Weber etc were found in bare areas around the hiking trails. Since these plants, mostly perennial herbs, are unlikely to die out on their own and may be difficult to eradicate, active management of these invasions is required. Introduced exotic plants may induce changes in natural ecology, especially when they outcompete native plants due to their superior adaptability, seed production capability, and germination rates (Newsome and Noble 1986, Aber et al. 1991).

The exotic plants that had been introduced along roadsides in the Gwangreung Forest and nearby buffer zones were found up to ~100 m into the forest (Fig. 4). It appears that exotic plants may not be

able to spread further into the forest due either to ongoing removal operations along the roads or to the lower light conditions in the forest interior. However, while the frequency of observation of exotics and the numbers of exotic species were lower in quadrats in the forest interior, *Aster pilosus* Willd. and *Erigeron annuus* (L.) Pers. were found along hiking trails and appear to be able to colonize the forest interior rapidly compared to other species. Therefore, there is a real risk that these and other exotic plants are may continue to expand their distributions into open spaces within the Gwangreung Forest.

Fig. 5 displays the results of a Canonical Correspondence Analysis (CCA) of the grade of illuminance and the distribution of exotic plants by distance into the forest, and groups the plant species into three types. *Aster pilosus* Willd., *Erigeron annuus* (L.) Pers. and *Rumex crispus* L., the species that entered along hiking trails and are found inside the forest, were confirmed to inhabit areas of low illuminance, whereas *Ambrosia artemisiifolia* L., *Oenothera biennis* L., *Rumex obtusifolius* L. and *Poa pratensis* L. were found in sunny bare areas inside the forest, and *Taraxacum officinale* Weber, *Ambrosia trifida* L., *Galinsoga ciliata* (Raf.) S.F. Blake and *Potentilla supina* L. were found in sunny marginal places of the forest.

*Taraxacum officinale* Weber was observed at high densities in the vicinity of the exhibition center and along the roads rather than inside the forest, and *Ambrosia trifida* L., which forms colonies in bare areas near the temple of Bongsunsa, was also found in open spaces inside the forest in clusters of several individuals. The major methods for managing exotic plants include biological methods (using natural enemies), chemical methods (using herbicides), physical methods (direct removal) and institutional methods. Currently, the Korea National Arboretum is carrying out weeding operations along the roads and are blocking the spread of weeds into the forest to some extent; however the exotic plants appearing along hiking trails also need be removed. The method sused by the Ministry of Environment for eliminating *Ambrosia trifida* L., including pulling out the roots before mid-September when seeds form and disposing

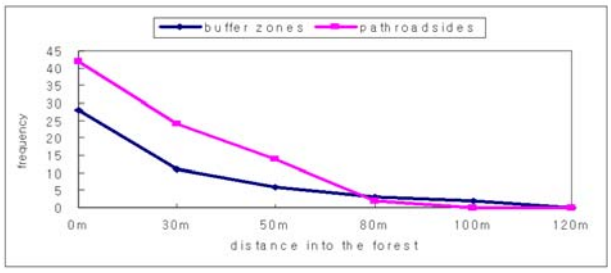


Fig. 4. Frequency of appearance of naturalized plants plotted against distance from the forest edge (Standard deviations; 0～80 m: 14.03 , 80～120 m: 1.33).

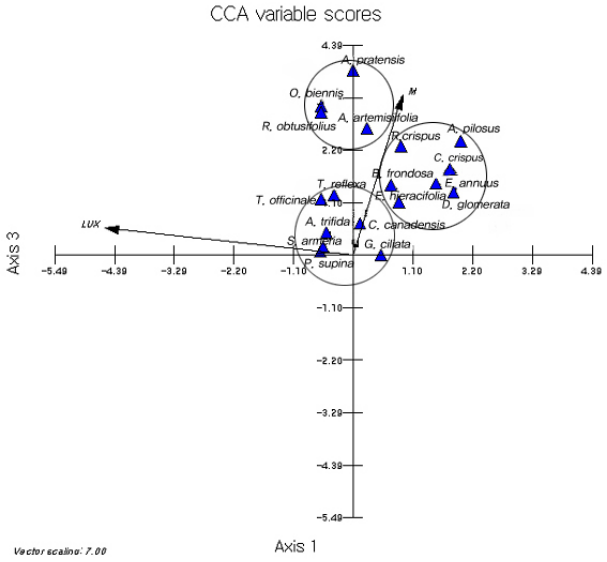


Fig. 5. Result of CCA (canonical correspondence analysis) for the illuminance and distance into the forest.

of the plant after drying, can be an effective method not only for *Ambrosia trifida* L. but also for perennial herbs like *Aster pilosus* Willd..

Both natural and artificial disturbance can be major factors affecting the ability of exotic plants to intrude into forest ecosystems (Deferrari and Naiman 1994), and since exotic plants may react more quickly to vegetation and soil disturbance than native plants (Mclntyre and Lavorel 1994), it is important to minimize disturbances such as the transportation of sand or other materials into the area by freight vehicles. Preventing or managing the invasion of landscapes by exotic plants is one of the most daunting challenges that conservationists face when attempting to preserve biodiversity in threatened ecosystems (Wilcove et al. 1998). Our results suggest that continued monitoring and active management of exotic plants will be critical for the preservation of biodiversity in the Gwangreung Forest.

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