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Ecological Role of Mountain Ridges in and around Gwangneung Royal Tomb Forest in Central Korea

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We assessed the ecological structure and function of mountain ridges connected to a reserve area, Gwangneung Royal Tomb Forest (GRTF), in central Korea. This site has been strictly preserved since the 15th century. Our objectives were to 1) investigate the interactions between and the influence of a protected old-growth forest on its surrounding forests, and 2) suggest management strategies for forests outside that reserve area. Three ridges were surveyed and divided into two categories -- A and B ridges covered with secondary forests connected to GRTF, and the C ridge, covered with primary forests and plantations within GRTF (from core zone to managed zone). The ridge forests had a characteristic lobe shape. We found no significant decline in species richness (peninsular effect) with distance from GRTF for any tree-layer or herbaceous-layer species on Ridges A or B. However, when only the species that appeared in primary forests on the C ridge were considered, the richness of tree- and herbaceous-layer species was significantly decreased there. This meant that the neighboring forests of GRTF could serve as a buffer zone. Differences were obvious between the two categorized forests in their species composition, species richness, basal area, and regeneration patterns. DCA ordination of quadrats on Ridges A and B showed that Axis 1 was significantly correlated with distance from GRTF, indicating that this protected area affects regeneration within neighboring forests. Thus, reserves are important not only to the conservation of biodiversity, but also to the ecological management of surrounding forests.

Keywords: biodiversity conservation, landscape structure, mountain ridge, nature reserve, peninsular effect, source patch

The fragmentation of natural forests and decrease in wildlife habitat are severe problems when conserving biodiversity (Harris, 1984; Wilcove et al., 1986). Among conservation strategies is the utilization of nature reserve areas that can provide important information currently lacking in our knowledge base of ecosystems (Cooperrider et al., 1999). Management of such areas requires one to consider interactions between interior and exterior of the reserve. The latter region can offer an extended source habitat for interior species that have a home range larger than what the boundaries of a reserve offer, as well as a degraded habitat for edge species.

These ecological interactions are influenced by the structure of the landscape (Farina, 2000; Lü et al., 2003), which affects both animals (Anderson and Danielson, 1997; Brown et al., 1999; Helzer and Jelinski, 1999; Hong et al., 2004) and plants (Burel and Baudry, 1990; Riffell and Gutzwiller, 1996; Moilanen and Hanski, 1998; López-Barrera et al., 2005; Song et al., 2005). This structural effect differs between those two kingdoms. For example, it is possible for animals to move through an unsuitable habitat because their travel corridor does not have to be of high quality. However, for plants, corridor and habitat are closely related, and unsuitable sites for colonization cannot act as corridors. Those detrimental areas, which crisscross plant habitats, can cause severe problems for connectivity, especially for species with short dispersal ranges. Interior species generally have weaker dispersal ability and require better conditions for habitat fitness. Therefore, it is important for those connecting areas to contain the required habitats as source patches, particularly for interior species.

Many investigations have focused on plant dispersal ability and distribution in landscape mosaics. These study sites can be categorized into three main groups: hedgerow (Burel and Baudry, 1990; Corbit et al., 1999), riparian (Curry and Slater, 1986; Nilsson et al., 1994; Cho, 1995), and the boundaries between old and new forests (Matlack, 1994a; Brunet and von Oheimb, 1998; Bossuyt et al., 1999; López-Barrera et al., 2005). Historically hedgerows and riparian zones, related to corridors, have been considered the most important elements in habitat management and conservation of species diversity (Burel and Baudry, 1990; Forman, 1995; Farina, 2000).

Korea has few hedgerows or lowland forests, but most mountainous regions remain forested. Especially in urban areas, forests are typically found on mountain ridges, sites that can be used for wildlife habitat and as corridors between urban and suburban areas. Similar to the characteristics of peninsulas, these mountain forests end on the tip and are usually surrounded by populated regions. However, on the landscape scale, little research has been conducted on the role of ridge forests and the effects of peninsulas near reserve areas. The peninsular effect is defined as a progressive decrease in species diversity from the base to the tip of the peninsula (Simpson, 1964; Cook, 1969; Wiggins, 1999). This effect has been used to explain the relatively poor diversity of animals on peninsulas (Cook, 1969; Wiggins, 1999; Choi, 2004) and riparian strip forests (Tubelis et al., 2007), as well as diversity in tree species (Milne and Forman, 1986).

Our study objectives were to 1) investigate the interactions between and the influence of a nature reserve area on its surrounding forests, and 2) suggest management strate-

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gies for the area outside a forest reserve. We hypothesized that the landscape patch and vegetation structure differ between the interior and exterior of a reserve area, but that there are gradual changes in vegetation associated with distance from that area.

METHODS

Study Sites

This study was conducted at the Gwangneung Royal Tomb Forest (GRTF) and on neighboring forests in central Korea (127° 10′ E, 37° 45′ N). GRTF occurs in a basin at an elevation of 100 to 600 m. The site has been strictly preserved since 1468 as the tomb forest of King Sejo, the 7th king of the Joseon Dynasty. Currently, 2,240 ha of forest land belonging to Korea Forest Service is protected as an experimental forest by the Forest Law, and another 346 ha is designated as Natural Monument No. 11 for protecting the habitat of the White-bellied Woodpecker. A 140-ha forested area containing those royal tombs is set aside as an historic site by the Korea Cultural Heritage Administration. However, pressures of development have steadily increased since the 20th century. Currently, nearly half of GRTF is covered by plantations, and only the other half remains natural (Lim et al., 2003, Cho et al., 2007). Plantations crisscross two core zones (Peak Soribong and Mt. Jukyupsan) (Figure 1). Portions of forests outside GRTF have been clear-cut for timber and then re-planted with seedlings or else regenerated naturally.

Figure 1. Location of study areas.

Quercus serrata and *Carpinus laxiflora* dominate the natural forests within GRTF (Lim et al., 2003, Cho et al., 2007). Some reserve areas are managed as experimental forests. All of the neighboring forests are secondary forests, having been regenerated since the 1960s to 1970s. Corings indicate that many of those plantations are now 40 to 50 years old. Naturally regenerated forests are dominated by *Quercus* spp. and *Pinus densiflora*, whereas the artificially regenerated areas are planted with *Pinus koraiensis, P. rigida, Larix leptolepis, Castanea crenata,* and *Robinia pseudoacacia*.

We surveyed three ridges (A, B, and C). From the GRTF boundary, Ridge A extends southwest to Chonghakri and Ridge B south to Toegyewon. Ridge C, within GRTF, is in the core zone between Mt. Jukyupsan and "Gwangneung/Kwangnung" (the royal tomb), but also contains some plantations. The southern tip of Ridge C is partly surrounded by agricultural lands (Figure 1). Ridge B is crossed twice by roads, the first being unpaved, the other, a tunnel. The tips of Ridges A and B are utilized for suburban growth. Thus, GRTF is challenged not only by damage from plantations within, but also by increasing pressure from real estate development outside.

Landscape Analysis

Landscape analysis was conducted on the three ridges and surrounding forests. Patches were categorized by canopy tree types and land-use types. Determination of patch boundaries was based on a forest type map (1:25,000 scale) constructed with aerial photography (Korea Forest Research Institute, 1992). ArcView (ESRI, ver. 3.1) software was applied to analyze the landscape structure. Patton's diversity was used to examine the shape pattern of patches (Forman, 1995; Rim and Hong, 1999), with a larger value meaning a more complex shape. A value of one (1) corresponds to a perfect circle. Patton's diversity was calculated by the following formula:

$$D = \frac{Perimeter}{2\pi\sqrt{(area)}}$$

Patch types were determined according to median values for some extremely distorted patches.

The peninsular effect was investigated at Ridges A and B to understand the ecological role of forests outside GRTF. Such effects may appear in areas characterized by lobe shapes. The forests of Ridges A and B are lobed (Figure 1), and are surrounded by paved roads. Our quadrats on those ridges were 400 m apart and ran outward from the GRTF boundary.

Species richness in the tree and herbaceous layers was evaluated with 10 m×10 m quadrats. This particular investigation was somewhat complicated because deforestation was more or less extensive. Thus, any peninsular effect detected could be attributed to this human activity or to "natural" phenomenon. To solve for this possible discrepancy, two cases were analyzed: all quadrats or only those with natural vegetation, the latter sites being dominated by *Quercus* spp. and *P. densiflora*. To get a better correlation with other environmental factors, we used two modes of distance: one from the base (boundary of GRTF) to each quadrat, and the other as distance transformed by square root.

Vegetation Analysis

For the vegetation study, 20 quadrats (10 m × 10 m) for tree layer were set up on each ridge. Quadrats were 400 m apart on Ridges A and B and 300 m apart on Ridge C, and quadrats were marked by GPS (Garmin GPS 12XL). All plants in the tree layer that were larger than 2.5 cm DBH (diameter at breast height) were recorded by species name and DBH. Plants in the herbaceous layer also were recorded by species name and coverage.

Detrended Correspondence Analysis ordination (DCA; Jongman et al., 1995) was carried out with importance values for tree-layer plants (mean of relative density and relative basal area in each quadrat), using DECORAN (Ver. 4.1). Correlations were examined between axis scores for sample ordination and environmental factors.

Environmental Factors

Leaf area index (LAI), slope, elevation, and soil hardness values for trails and slopes were assessed as environmental factors for each quadrat, except on Ridge C. LAI was measured with an LAI-2000 Plant Canopy Analyzer (LI-COR, Inc.; software ver. 2.14). Soil hardness was obtained with a soil penetrometer (Lang).

Statistical Analysis

Univariate analysis was used for evaluating the patches. The peninsular effect was examined by linear regression analysis, and correlations were identified according to Pearson correlation analysis. Characteristics were compared among ridges by GLM. SAS software (release 6.12) was used in all statistical processes.

RESULTS

Landscape Structure

GRTF comprises two large deciduous forests (in the areas of Peak Soribong and Mt. Jukyupsan) and one managed plantation. Two natural deciduous forests (core zones Peak Soribong and Mt. Jukyupsan) of GRTF were disconnected by several building facilities, and a paved road. In contrast, quadrats on Ridge A were mostly covered with mixed forests, while Ridge B was covered primarily with deciduous vegetation except for scattered plantations. There was no direct disconnection due to a paved road on Ridges A and B, although the latter was disconnected by an unpaved road and was crossed by a tunnel underneath (Figure 1).

The landscape structure (Table 1) was configured so that the analyzed space was divided into two categories -- areas inside or outside of GRTF. Deciduous forest accounted for the highest percentage within the reserve area while mixed forest was the primary vegetation type, with scattered plantations, outside. Although significant differences were not physically apparent, natural forests and naturally regenerated patches generally had higher Patton's diversity, except for the *P. densiflora* forests in plantations. Patches managed by humans had lower values.

In terms of vegetation cover type, deciduous forests occupied larger areas than mixed forests (about 4 times) in the reserve while outside, mixed forests covered greater areas than the deciduous forests (about 2 times). More deciduous and mixed forest patches were located outside of GRTF (Table 1).

Peninsular Effect

The peninsular effect was tested with species richness for tree-layer and herbaceous-layer species within 10 m×10 m quadrats. When all quadrats or only natural quadrats (i.e., those excluding plantations) were analyzed per two modes of distance, neither species type showed any peninsular effect. However, diversity was significantly decreased when only species that were present in the core-zone quadrats of Ridge C were considered (Figure 2). Likewise, there was a significant decline when only natural quadrats were analyzed for tree-layer species with two distance modes. Finally, there were significant decreases, in all cases, for herbaceous-layer species in the two distance modes.

DCA Ordination

The result of our DCA ordination, which was carried out with importance values for tree-layer species, is shown in Figure 3. Two large groups appeared in the sample ordination -- quadrats on Ridges A and B (left) and those on Ridge C (right). In addition, quadrats dominated by *Pinus koraiensis* and *P. banksiana* were separated and formed a small group without distinct ridges. This demonstrated the many differences in community structure between Ridges A/B and Ridge C. Quadrats were separated even when their dominant species were the same due to the difference in forest origin.

DCA ordination was carried out again only for quadrats on Ridges A and B (Figure 4), and the relationship between ordination axis scores and environmental factors was analyzed (Table 2). Axes 1 and 3 are presented in Figure 4 because LAI was correlated only with Axis 3. Axis 1 was highly significantly correlated ($p<0.001$) with distance, square root distance, and elevation. Quadrats in plantations of pitch pine (*Pinus rigida*) and natural forests dominated by red pine (*Pinus densiflora*) had high Axis 1 values, while those made of Korean pine (*Pinus koraiensis*) plantations and natural forests dominated by oak species had low Axis 1 values.

LAI was affected by the composition of the canopy trees. Quadrats dominated by conifers, such as *P. rigida* and *P. densiflora* with lower LAI values, were located at a lower position on Axis 3. Broadleaf trees with higher LAI, however, were found at a higher position on that axis (Figure 4). Positioning was independent of distance from GRTF (Table 3) but dependent on tree canopy. Our evaluation of environ-

Table 1. Configuration of landscape structure of inside and outside of Gwangneung Royal Tomb Forest (GRTF) area and measurements of patch characteristics of each patch composing the landscape.

Landscape element	Area (ha)		%*	Perimeter (km)		No. Patch	%**	Patton's diversity (median)
	Sum	Mean (±S.E.)		Sum	Mean (±S.E.)			
Gwangneung Royal Tomb Forest area								
Vegetation attribute								
Deciduous forest	1367.0	195.3(443.6)	50.7	98.6	14.1(30.3)	7	7.3	1.578
Mixed forest	336.9	24.1(27.0)	12.5	38.7	2.8(2.4)	14	14.6	1.546
Coniferous plantations								
Red pine	206.8	34.5(42.8)	7.7	22.4	3.7(3.8)	6	6.3	1.827
Korean pine	387.6	13.8(18.1)	14.4	58.8	2.1(2.0)	28	29.1	1.462
Japanese larch	61.1	5.6(3.8)	2.3	13.1	1.2(.05)	11	11.4	1.312
Pitch pine	92.2	7.1(5.6)	3.4	18.4	1.4(0.8)	13	13.5	1.439
Other	180.9	20.1(30.5)	6.7	23.7	2.6(3.3)	9	9.4	1.459
Deciduous plantation	6.3	3.2(0.2)	0.2	1.5	0.8(0.1)	2	2.1	1.198
Subtotal	2638.8		97.9	275.1		90	93.7	
Other land-use								
Inhabited and exploited area	57.1	9.5(10.1)	2.1	9.2	1.5(1.0)	6	6.3	1.506
Subtotal	57.1			9.2		6		
GRTF Total	2695.8		100.0	284.3		96	100	
Outside of Gwangneung Royal Tomb Forest area								
Vegetation attribute								
Deciduous forest	442.2	19.2(27.8)	19.6	54.4	2.4(2.2)	23	21.9	1.618
Mixed forest	925.6	37.0(79.9)	41.0	103.4	4.1(6.7)	25	23.8	1.652
Coniferous plantations								
Korean pine	481.3	20.6(33.0)	21.3	58.1	2.4(2.5)	24	2.8	1.413
Japanese larch	185.2	30.9(47.1)	8.2	18.1	3.0(3.5)	6	5.7	1.479
Pitch pine	116.6	10.6(11.3)	5.2	18.4	1.7(1.4)	11	10.4	1.245
Deciduous plantation	2.5	-	0.1	0.6	-	1	1.0	1.160
Subtotal	2153.4		95.4	253.1		90	85.8	
Other land-use								
Cropland	55.6	5.1(5.4)	2.5	13.3	1.2(0.9)	11	10.4	1.412
Graveyard	35.9	17.9(5.7)	1.6	4.3	2.1(1.0)	2	1.9	1.409
Inhabited and exploited area	12.0	6.0(0.2)	0.5	2.5	1.3(0.2)	2	1.9	1.450
Subtotal	103.5		4.6	20.1		15	14.2	
Outside of GRTF Total	2256.9		100.0	273.2		105	100.0	

%*, a percentage of certain element per total area; %**, a percentage of certain patch number per total number of patch

mental factors showed that soil hardness of the trail (SHT) was significantly correlated with distance from GRTF.

DISCUSSION

Landscape Structure of GRTF and Its Neighboring Forest

Human activity clearly influences patch shape (Hammett, 1992). Here, GRTF and the neighboring forest patches differed from each other in their shape and degree of human impact. For example, patches of human origin, i.e., plantations, had lower mean Patton's diversity than those that arose naturally. Therefore, human impact decreased the complexity of the boundary. Such complex boundaries enhance the interactions that occur across boundary patches (Forman, 1995) so that the loss of complexity may weaken ecological interactions.

The high percentage of mixed forest outside of GRTF seemed to be related to the successional stages within the plantation. Those mixed forests, where *Quercus* spp. and *P. densiflora* coexisted, generally appear at the early stages of succession in the temperate climate zones of Korea. In many cases, *Quercus* spp. regenerate in *P. rigida* plantations.

Peninsular Effect

The peninsular effect can be manifested in lobe shapes (Forman and Godron, 1986; Milne and Forman, 1986), as was evident with Ridges A and B here. We tested that effect only with species that appeared in the core zone. These included not only interior but also some edge species. In the

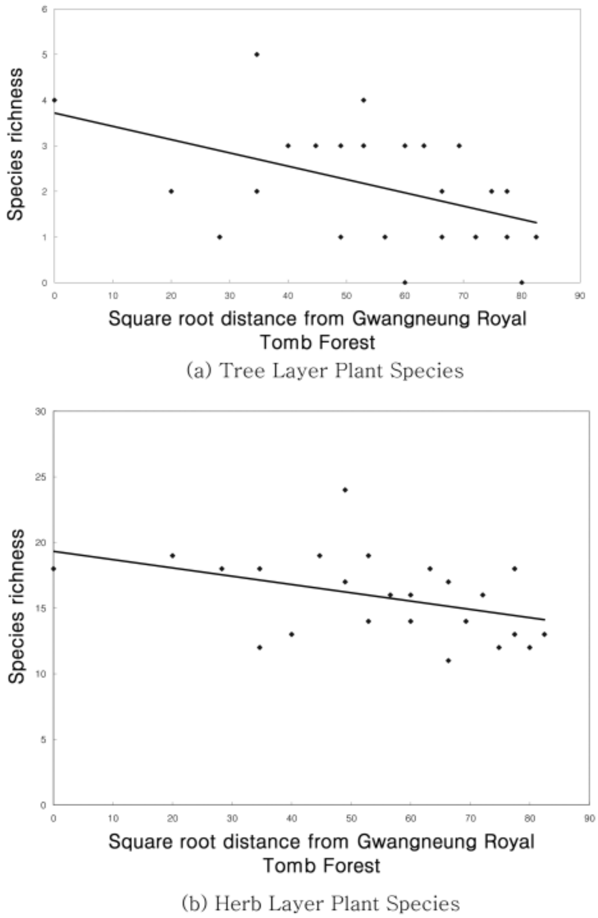

Figure 2. Richness of species appearing in C1–C11 quadrats for natural sites on A/B ridges as function of square root distance from Gwangneung Royal Tomb Forest. (a) tree-layer species, (b) herb-layer species. Regression equations: (a) Richness=3.70-0.029(Distance)$^{1/2}$, r^2=0.21, p=0.023. (b) Richness=18.51-0.054(Distance)$^{1/2}$, r^2=0.16 p=0.0490.

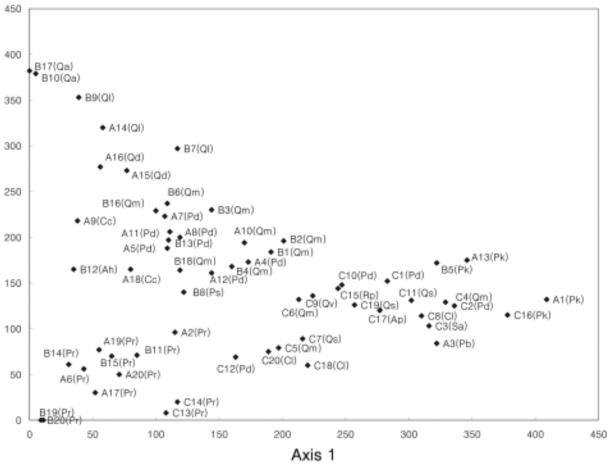

Figure 3. DCA ordination for all numbered quadrats. Eigenvalues were 0.65 for Axis 1 and 0.57 for Axis 2. Acronyms in parentheses indicate tree species with highest importance value within quadrat. Ah: *Alnus hirsuta*, Ap: *Acer pseudo-sieboldianum,* Cc: *Castanea crenata,* Cl: *Carpinus laxiflora,* Pb: *Pinus banksiana,* Pd: *Pinus densiflora,* Pk: *Pinus koraiensis,* Pr: *Pinus rigida,* Ps: *Prunus sargentii,* Rp: *Robinia pseudoacacia,* Qa: *Quercus acutissima,* Qd: *Quercus dentata,* Ql: *Quercus aliena,* Qm: *Quercus mongolica,* Qs: *Quercus serrata,* Qv: *Quercus variabilis,* Sa: *Sorbus alnifolia.*

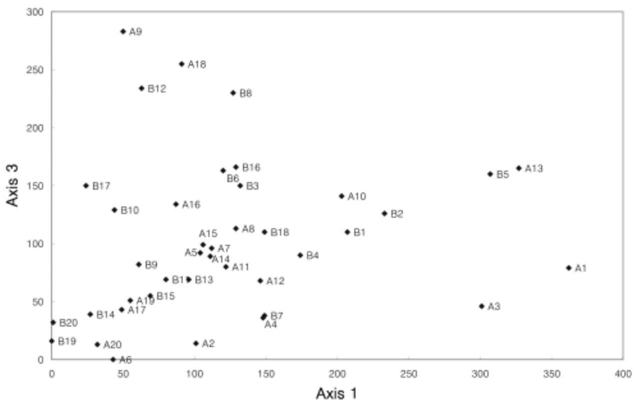

Figure 4. DCA ordination for numbered A/B ridge quadrats. Eigenvalues were 0.66 for Axis 1 and 0.34 for Axis 3.

case of the former, their species richness showed a more rapid decline.

There is some evidence for a peninsular effect in woody plants on a large scale (Milne and Forman, 1986). If such an effect does appear on the fine scale, e.g., in a landscape, it may be related to a loss of interior species (Forman and Godron, 1986). Peninsular effects that occur on mountains differ from those found in ordinary forests. Mountains are very diverse in their physical and chemical environments and microclimate when elevation, slope, and aspect are considered. The three-dimensional element also is important in mountain ecosystems (Forman, 1995; Hong et al., 2004). Therefore, diverse habitats can coexist in relatively small areas and form various natural patches. In addition, mountains generally have horizontal belts of a particular vegetation type, which can be used as travel corridors (Forman, 1995). It is very easy for plants and animals to move horizontally along ridges with similar environmental factors.

Table 2. Correlation coefficients between DCA ordination axis scores of A and B ridge quadrats and the environmental factors.

Environmental factors	Axis 1	Axis 2	Axis 3
Distance	-0.579***	-0.197^{NS}	-0.042^{NS}
Square root of distance	-0.614***	-0.132^{NS}	-0.012^{NS}
LAI	0.197^{NS}	0.179^{NS}	0.320*
Elevation	0.648***	0.299^{NS}	0.068^{NS}
Soil hardness of trail (SHT)	-0.389*	-0.310^{NS}	-0.097^{NS}
Soil hardness of slope (SHS)	-0.221*	-0.400*	-0.018^{NS}

*: p<0.05, ***: p<0.001, ^{NS}: not significant

Table 3. Correlation coefficients between environmental factors of A and B ridges: Distance = distance from the boundary of GRTF, LAI = leaf area index, SHT = soil hardness of trail, SHS = soil hardness of slope.

	Distance	$(Distance)^{1/2}$	LAI	Elevation	SHT
$(Distance)^{1/2}$	0.965***	-			
LAI	-0.306^{NS}	-0.220^{NS}	-		
Elevation	-0.850***	-0.831***	0.271^{NS}	-	
SHT	0.592***	0.538***	-0.267^{NS}	-0.605***	-
SHS	-0.064^{NS}	-0.066^{NS}	0.336^{NS}	-0.094^{NS}	0.352^{NS}

***: $p<0.001$, ^{NS}: not significant

In young forests, herbaceous-layer and tree-layer species are not significantly correlated (Gilliam et al., 1995). Because the neighboring forests of GRTF are relatively young (40 to 50 yr), the interactions between tree layer and herbaceous layer may be loose. Thus, the decrease in species richness may also be related to limits on their dispersal ability because many herbaceous plants have very low migration rates (1 to 2 m yr^{-1}) and generally are dispersed by animals (Matlack, 1994a; Bossuyt et al., 1999).

Environmental Factors Affecting Vegetation Structure

The structure of vegetation in the neighboring forests was very closely related to elevation and distance from GRTF. Areas outside of that reserve were either secondary forests or plantations, and almost all were even-aged (40 to 50 yr). However, the secondary forests closer to GRTF were composed primarily of oak species while those farther away were more or less entirely red pine. Previously, You et al. (1995) also showed that forests closer to GRTF have a higher percentage of tree species typical of later successional stages. Thus, the regeneration of those forests has been closely related to their proximity to GRTF.

Soil hardness of trails on mountain ridges is usually a function of the intensity of human visitation; higher values toward the tip of a ridge indicate that the vegetation structure is influenced more by humans there. Illumination is an important factor that affects plants in the herbaceous layer (Messier et al., 1998); light intensity at the forest floor is related to the composition of the tree canopy. However, a correlation between LAI and canopy-layer composition may not demonstrate a cause-and-effect relationship.

Here, quadrats closer to GRTF were at higher elevations. Even though both distance from GRTF and elevation affected the type of vegetation, we think that the differences in elevation among quadrats in the neighboring forests were not great enough (<300 m) to affect community structure.

Ecological Interactions Between GRTF and Its Neighborhood Forest

The important factors for dispersal of plant species are dispersal modes and environmental differences between old-growth and regenerated forests (e.g., successional stages, microclimate, canopy tree species). Mode influences the rate of dispersal (Matlack, 1994a; Brunet and von Oheimb, 1998; Bossuyt et al., 1999), while environment determines colonization (Gilliam et al., 1995). Most species that need conservation are specialists. In terms of canopy trees, GRTF and its neighboring forests were connected by broadleaf tree patches (deciduous or *Pinus-Quercus* mixed forest). This connectivity was advantageous to the dispersal of plants in the herbaceous layer. However, community attributes were very different inside and outside of GRTF. From DCA ordination, we found a distinction between internal and external quadrat positioning even though those quadrats were dominated by the same species (Figure 3). It is also important to note the gradual changes in forest structure that occurred with distance from GRTF (Figure 4; Table 2). We interpreted this to mean that the neighboring forests were influenced by the reserve, which implies that an urban forest, connected to such an area, can be affected by it.

Implication for Nature Reserve Conservation

Urban expansion is a serious problem, especially in a country like South Korea with its high population density (Song et al., 2005). Most of the level lands have been developed or cultivated, so that the only natural forests remaining in metropolitan Seoul are located in mountainous areas. Likewise, the areas below the mid-slope of those mountains have been developed for housing. Forests on the ridge are the sole ones left, and the only trees not used for timber are those in urban and suburban parks. Trees in this forest act as corridors through which species migrate from old-growth forest (source habitat) to urban areas (sink habitat). To preserve the forest's role as corridor, it is essential to minimize the trimming and cutting of lower-layer plants (Forman, 1995). Cadenasso and Pickett (2000) have shown that these precautions can protect the access of interior herbivores traveling to the forest edge. Thus, forests near urban areas must be managed by keeping the landscape as natural as possible.

Ridge forests have several disadvantages as wildlife habitats. They cannot supply diverse habitat types, they have a large edge area, and their water supply is restricted. However, ridge forests can support habitat for edge species that move through to the interior. It is important to connect old-growth forests to urban and suburban forests, a role provided by ridge forests. The characteristics of edge areas include the steepness of biotic and abiotic changes across edges, and the abrupt structural and compositional changes between contrasting land covers (Matlack, 1994b). Lobe forests, which have similar conditions to old-growth forests, manifest gradual environmental changes from the base to the tip of the lobe. Such a shape is common in landscapes that are mountainous, such as in Korea. There, lobe forests can be used to expand natural areas outward toward old-growth forests, as well as utilized for corridors or buffer zones, especially in urban and/or suburban areas.

These contrasting attributes (connection versus discrete and gradual changes) are critical if we are to recognize the ecological interactions between the interior and exterior of GRTF. Neighborhood forests are supplied with seed from that reserve, and they can absorb the pressures of development and act as corridors through which species can be dispersed. Their similar species composition and structure are essential to the maintenance of these ecological interactions. Nevertheless, it becomes difficult to sustain those interactions when unsuitable forest practices, expansion of urban areas, and road construction interfere with this relationship. Management of GRTF's neighboring forests as natural areas is important. Moreover, these strategies can be applied to benefit other reserves or old-growth forests.

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LITERATURE CITED

Anderson GS, Danielson BJ (1997) The effects of landscape composition and physiognomy on metapopulation size: The role of corridors. Landsc Ecol 12: 261-271

Bossuyt B, Hermy M, Deckers J (1999) Migration of herbaceous plant species across ancient-recent forest ecotones in central Belgium. J Ecol 87: 628-638

Brown DR, Peles JD, Barrett GW (1999) Effects of landscape spatial structure on movement patterns of the hispid cotton rat (*Sigmodon hispidus*). Landsc Ecol 14: 53-65

Brunet J, von Oheimb G (1998) Migration of vascular plants to secondary woodlands in southern Sweden. J Ecol 86: 429-438

Burel F, Baudry J (1990) Hedgerow network patterns and processes in France, *In* IS Zonneveld, RTT Forman, eds, Changing Landscapes: An Ecological Perspective. Springer-Verlag, New York, pp 99-120

Cadenasso ML, Pickett STA (2000) Linking forest edge structure to edge function: Mediation of herbivore damage. J Ecol 88: 31-44

Cho DS (1995) A study on the distribution of streamside vegetation in Kyonganchon. Kor J Ecol 18: 55-62

Cho YC, Shin HC, Kim SS, Lee CS (2007) Dynamics and conservation of the Gwangneung National Forest in central Korea. J Plant Biol 50: 615-625

Choi SW (2004) Trends in butterfly species richness in response to the peninsular effect in South Korea. J Biogeogr 31: 587-592

Cook RE (1969) Variation in species density of North American birds. Syst Zool 18: 266-275

Cooperrider AY, Day S, Jacoby C (1999) The bioreserve strategy for conserving biodiversity, *In* RK Baydack, H Camp III, JB Haufler, eds, Practical Approaches to the Conservation of Biological Diversity. Island Press, Washington DC, pp 35-53

Corbit M, Marks PL, Gardescu S (1999) Hedgerows as habitat corridors for forest herbs in central New York, USA. J Ecol 87: 220-232

Curry P, Slater FM (1986) A classification of river corridor vegetation from four catchments in Wales. J Biogeogr 13: 119-132

Farina A (2000) Landscape Ecology in Action. Kluwer Academic Publishers, Dordrecht

Forman RTT (1995) Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge

Forman RTT, Godron M (1986) Landscape Ecology. John Wiley & Sons, New York

Gilliam FS, Turrill NL, Adams MB (1995) Herbaceous-layer and overstory species in clear-cut and mature central Appalachian hardwood forests. Ecol Appl 5: 947-955

Hammett JE (1992) The shape of adaptation: Historical ecology of anthropogenic landscapes in the southeastern United States. Landsc Ecol 7: 121-135

Harris LD (1984) The Fragmented Forest. The University of Chicago Press, Chicago

Helzer CJ, Jelinski DE (1999) The relative importance of patch area and perimeter-area ratio to grassland breeding birds. Ecol Appl 9: 1448-1458

Hong SK, Kim S, Cho KH, Kim JE, Kang S, Lee D (2004) Ecotope mapping for landscape ecological assessment of habitat and ecosystem. Ecol Res 19: 131-139

Jongman RHG, ter Braak CJF, van Tongeren OFR (1995) Data Analysis in Community and Landscape Ecology. Cambridge University Press, Cambridge

Korea Forest Research Institute (1992) Forest Type Map. Seoul, Korea

Lim JW, Shin JH, Jin GZ, Chun JH, Oh JS (2003) Forest structure, site characteristics and carbon budget of the Gwangneung natural forest in Korea. Korean J Agric For Meteorol 5: 101-109

López-Barrera F, Newton A, Manson R (2005) Edge effects in a tropical montane forest mosaic: Experimental tests of post-dispersal acorn removal. Ecol Res 20: 31-40

Lü YH, Chen LD, Fu BJ, Liu SL (2003) A framework for evaluating the effectiveness of protected areas: The case of Wolong Biosphere Reserve. Landsc Urban Plan 63: 213-223

Matlack GR (1994a) Plant species migration in a mixed-history forest landscape in eastern North America. Ecology 75: 1491-1502

Matlack GR (1994b) Vegetation dynamics of the forest edge - trends in space and successional time. J Ecol 82: 113-123

Messier C, Parent S, Bergeron Y (1998) Effects of overstory and understory vegetation on the understory light environment in mixed boreal forests. J Veg Sci 9: 511-520

Milne BT, Forman RTT (1986) Peninsulas in Maine: Woody plant diversity, distance, and environmental patterns. Ecology 67: 967-974

Moilanen A, Hanski I (1998) Metapopulation dynamics: Effects of habitat quality and landscape structure. J Ecol 63: 151-162

Nilsson C, Ekblad A, Dynesius M, Backe S, Gardfjell M, Carlberg B, Hellqvist S, Jansson R (1994) A comparison of species richness and traits of riparian plants between a main river channel and its tributaries. J Ecol 82: 281-295

Riffell SK, Gutzwiller KJ (1996) Plant-species richness in corridor intersections: Is intersection shape influential? Landsc Ecol 11: 157-168

Rim YD, Hong SK (1999) Landscape ecological studies on structure and dynamics of plant populations on vegetation landscape patterns in rural regions: The effect of patch shape on the initial population structure of pine and oaks. Kor J Ecol 22: 71-79

Simpson GG (1964) Species density of North American recent mammals. Syst Zool 13: 57-73

Song IJ, Hong SK, Kim HO, Byun BS, Gin Y (2005) Pattern of landscape patches and invasion of naturalized plants in urban developed area of Seoul. Landsc Urban Plan 70: 205-219

Tubelis DP, Lindenmayer DB, Cowling A (2007) The peninsula effect on bird species in native eucalypt forests in a wood production landscape in Australia. J Zool 271: 11-18

Wiggins DA (1999) The peninsula effect on species diversity: A reassessment of the avifauna of Baja California. Ecography 22: 542-547

Wilcove DS, McLellan CH, Dobson AP (1986) Habitat fragmentation in the temperate zone, *In* ME Soule, ed, Conservation Biology. Sinauer Associates, Sunderland, MA, USA, pp 237-256

You YH, Gi KJ, Han DU, Kwak YS, Kim JH (1995) Succession and heterogeneity of plant community in Mt. Yongam, Kwangnung Experimental Forest. Kor J Ecol 18: 89-98