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Effect of Mosaic Vegetation Structure on Pine Seed Predation by Forest Animals in Agricultural Landscape

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농촌경관내의 삼림동물에 의한 소나무종자 포식에 미치는 모자이크형 식생구조의 영향

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ABSTRACT

All landscapes are mosaics of habitat patches of different types. Therefore, there are always edged between habitat patches in a landscape. Forest animal has an important role in vegetation development and maintenance by seed dispersal around forest. Movement of animals depends on the spatially heterogeneous structure and pattern of vegetation landscapes because each animal has special habitats in a landscape. Especially, forest edge with high permeability and prey density is one of the important habitats to the animals. Therefore, understanding the ecological characteristics of the forest edges as a corridor connecting mosaic vegetation patches is necessary to establish the strategies for the nature conservation and sustainable vegetation management.

Under this idea, we examined the animal influenced on pine seeds as one of the method of monitoring the animal activity in mosaic vegetation. Man-made mosaic vegetations including open, edge and inner forests were carefully selected in the rural landscape. We carried out predation test on pine seeds during one year. A result was that damages on seed was more significant at forest edge than inner and open forest. Pine seed on seedbeds was mainly attacked by squirrels and mice than birds. Pine seed was damaged by squirrels in different types of vegetation by seasons. Rate of seed predation at forest edge was, in special, higher than that of other sites. According to this results, it is suggested that the relationship between animal behavior and spatial vegetation structure relating to human impact such as the distance from settlement to vegetation appeares to be in the rural vegetation landscape.

Key words: Agricultural landscape, Animal influence, Corridor, Edge effect, Mosaic vegetation, *Pinus densiflora* seed

INTRODUCTION

All landscapes are mosaics of habitat patches of different types. Therefore, there are always edged between habitat patches in a landscape (Forman and Godron 1986). Mosaic vegetation has an important role of constituting spatially different habitat patches in all landscapes (Andrén and Angelstam 1988). Moreover, it is generally one of the factors determining the structure and functioning of animal and plant populations and communities (Johnston 1995, Fitzgibbon 1997).

Spatially heterogeneous vegetation patches consist of "habitat edges" (e.g. Odum 1971) between patches and matrix characterized by different quality, size, and shape (Forman and Moore 1992). The habitat edges may be associated with a higher diversity of plants and animals, traditionally called an "edge effect" (Andrén 1992). In recent, rural vegetation landscape characterizing these landscape elements is faced on the habitat fragmentation and degradation due to the unbalances of natural and anthropogenic factors (Hong *et al.* 1993, Murcia 1995). Therefore, it is necessary to study ecological functions between the fragmented habitats and local biota for the effective adjunct to planning for conservation in fragmented landscape (Noss 1983, Soul and Gilpin 1991).

To understand the effect of habitat fragmentation as well as the effect of different landscape (vegetation) mosaic on prey-predator interaction, it is important to explore the interaction among organisms living in different habitat patches in the landscape (Forman and Godron 1986, Kozakiewicz *et al.* 1993).

Forest animals have important roles in vegetation development and maintenance by dispersal of seed around forest (Rim and Shidei 1975, Houle 1992, Ida and Nakagoshi 1996). Activity of the animals is significantly related to vegetation pattern and structures in and around landscape boundaries (e.g. Andrén 1992, Hanssen *et al.* 1995). Moreover, in the case of rural vegetation, the animal activity is specially related to landscape factor such as patch size and the distance from village to vegetation as well as vegetation quality (Andrén and Angelstam 1988). Therefore, quantitative data to show loss of seeds and to indicate the relative importance of the factors for seedling establishment should be considered to understand the animal activity on spatial mosaic vegetation structure.

To understand the mosaic landscapes and ecological process associated with vegetation development and animal activity, animal influence on pine seeds in varied mosaic vegetations, i.e. forest edge, open and inner forests that made by human activity, were studied. We also examined the animal influence on pine seeds as one of the method of monitoring the animal activity in mosaic vegetation.

METHODS

Study area and survey

Animal influences on the pine seeds on the forest floor were studied in the pine-dominated vegetation at Yanghwa-ri, Kyeryong-myon in Chungcheongnam-do from June 1995 to July 1996. Vegetation of this region is mainly covered with secondary pine (*Pinus densiflora*) forest (Hong *et al.* 1993) as in Korea generally (Lee and Lee 1991). A place remote from village is mixed with deciduous oak forest such as *Quercus acutissima* and *Q. mongolica*. We carefully selected two pine forest plots (each 200×50 m^2) with mosaic vegetations that composed of cutting area and graveyard with different distance from human settlement (Fig. 1).

One was composed of two-year abandoned cut-off plot (cut-off plot, COP) for Korean pine (*Pinus koraiensis*) plantation (Approx. 2.5 km distant from the nearest village). Except for open site after cut-off, other part including inner forest was partly mixed with *Quercus* species in tree layer. Phanerophytes such as Genus *Robinia*, *Smilax*, *Rosa*, *Juniperus* and young *Quercus* spp. are intruded in shrub and herb layers under the tall pines. Open site was partly covered with *Pueraria thunbergiana*, *Robinia pseu-*

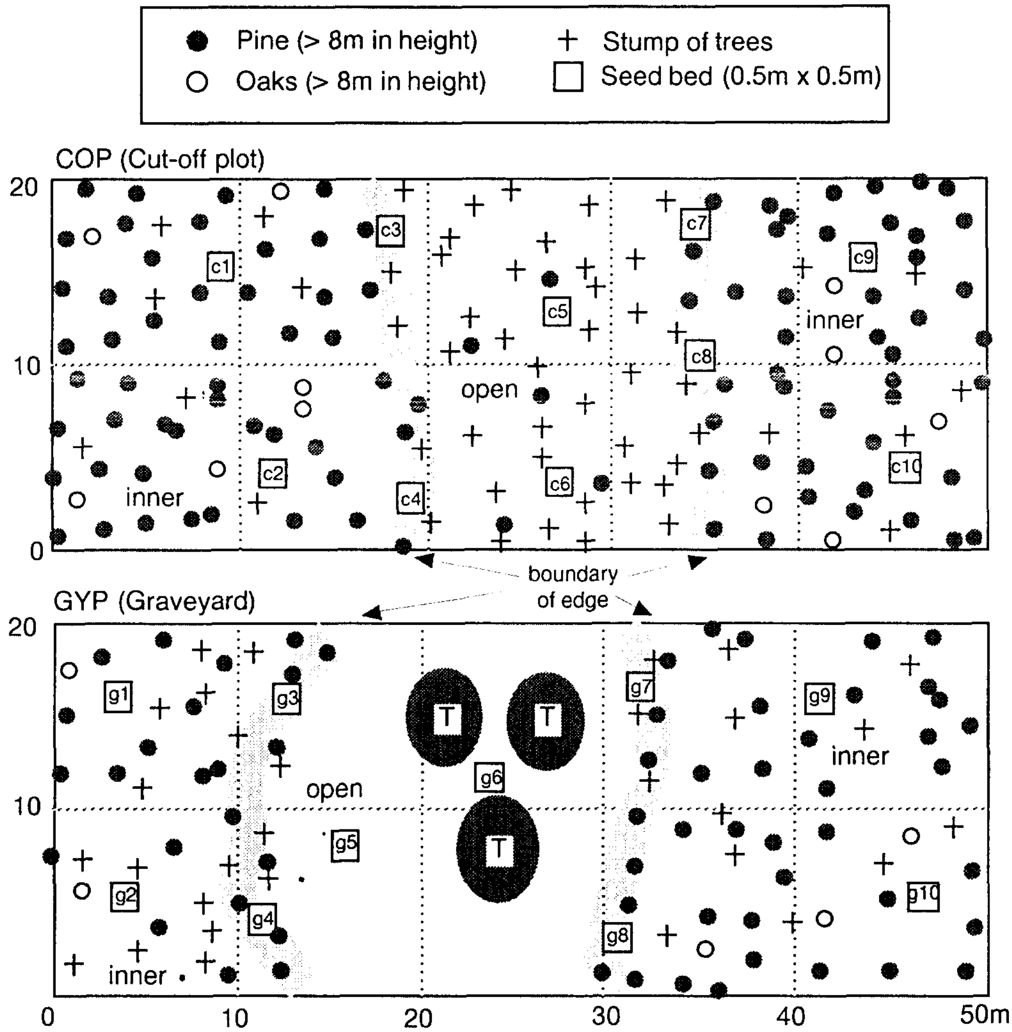

Fig. 1. Vegetation types composed of varied mosaic vegetations (20×50m² per plot). COP is composed of cutting area as a open forest. Three mounded tombs (T) as a open forest are belonged to GYP. Each number in box means the number of seedbed to check animal influence. Seedbeds 1, 2, 9, 10 : inner forests, Seedbeds 3, 4, 7, 8: forest edge, Seedbeds 5, 6: open forest in both plot.

doacacia and *Lespedeza* spp. which often occurring at disturbed area.

The other was a managed forest with graveyard (graveyard plot, GYP) near farm village (Approx. 200 m distant from the nearest village). Making graveyard is one of the traditional forest-use in agricultural landscape (Hong and Nakagoshi 1996). For the construction, people cut the owned forest and make an open area and then buried. The grass (*Zoysia japonica*) is planted on and around the mound for protection of soil erosion and for aesthetic landscape. People periodically manage and pluck up weed from the graveyard. Vegetation of graveyard is, therefore, always poor (Table 1). In the present study, we set up the boundary zones including the edges on both sides of a boundary line at each site according to the case of forest-edge-field boundaries (Forman and Godron 1986).

Experimental design for seed predation monitoring

To trace seeds sown on the ground, the following method was devised (Rim and Shidei 1975). The pine seed was glued the thin thread with emulsion of polyvinylacrylate (PVC). Seed-beds (0.5×0.5 m^2) of dispersed 100 pine seeds were randomly set up at forest floor in each plot (Fig. 1). With these seeds, monthly changes of seed population were checked. Wire traps were used to catch the animals responsible for eating pine seeds. Pine seeds were fed to the animals caught to identify the clues for the animal agents. Germination rate was checked near the seed-beds by placing quadrats (1×1m^2) ; open (outside), edge and inner forests at each plot. In germination test, wire-net was used to protect pine seeds from predators. Before setting up seed-beds, the seedling distribution from the center of open area to inside was checked by belt-transect method. Damage rate due to each predator was obtained from the hulls of seeds (Rim and Shidei 1975).

RESULTS AND DISCUSSION

Vegetation structure and germination rate of pine seed

Table 1 shows the difference of germination rate from forest inside to open area in both plots. Compared to COP, the coverage of vegetation in GYP was low. It was due to human activity on forest surrounding graveyard. People periodically manage the graveyard and forest. Vegetation management such as weeding, cutting-twig and harvesting litter are often occur. Therefore, all coverage of vegetation in GYP is poor than COP that had abandoned since clear-cutting of pine. Open area in GYP is covered with the grass *Zoysia japonica* for protecting soil erosion in graveyard, therefore, coverage of the herb layer was relatively high. Moreover, there is no trees having shadow, so that open area is sunny and dry during seasons.

Table 1. Germination rate under different vegetation types of two plots. Each seed-bed was located under the litter

Vegetation types	Mean coverage of vegetation(%)* Tree	Subtree	Shrub	Herb	Germination rate(%)
COP					
inner	80	75	60	45	35.5
edge	60	85	80	55	56.8
open	5	0	15	60	59.1
GYP					
inner	65	50	30	25	55.7
edge	45	40	10	5	40.4
open	0	0	0	45	15.5

* Original cover scale is based on the coverage of Braun-Blanquet (1964).

These structures of vegetation affect the germination rate of pine seed. More seedlings were found in forest edge of both plots (56.8 and 40.4%) and inner forest of GYP (55.7%) being keep away from direct sun light. On the other hand, germination rates of inner forest of COP and open area of GYP were lower than other areas (35.5 and 15.5%). In the case of inner forest in COP, accumulated litter and closed canopy were main reasons for low germination of pine. However, low germination rate of open area in GYP was due to soil dry by heat and soil erosion by heavy rain after dry season.

Light conditions in the forest and soil temperature is important factors for germination, establishment and growth of seedling and sapling (Grime 1979, Canham *et al.* 1990). The excessive portions of these factors are, however, sometimes be resulted in failure

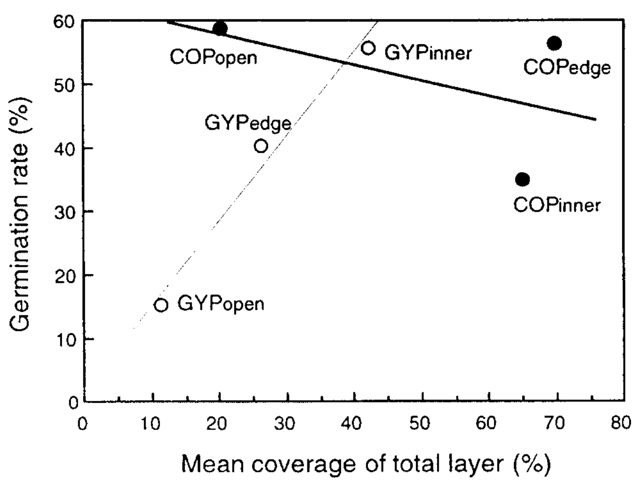

Fig. 2. The relationships between germination rates and the mean coverages of total vegetation layer in each sites. COP(closed circle, thick line) : r=−0.501 ($p<0.05$), GYP(open circle, thin line):r=0.987 ($p<0.01$).

performance at the early germination phase. According to Houle (1992), the litter layer with moist condition and canopy shadow avoided from direct sun light are reasonably necessary to germinate, specially in pine seed, at the initial stage of seedling establishment. The relationships between germination rate and vegetation coverage represent the "safe-site" need for successful germination of pine seed (Fig. 2). Open site of GYP was the worst place to perform germination of pine seed than the inner forest of COP. Germination rates of edge of GYP and open site of COP where forest management continued were high germination rate. Considering germination of pine seed, two forest types, forest edge in COP and inner forest in GYP, are similar "safe-sites" (e.g. Grime 1979) for successful performance of seed germination.

After successful germination performance, many mortal factors are till left. Fig. 3 shows the distribution of the germinated current-year seedling of pine on the seedbeds with wire-net protecting predators. In the case of COP, seedling number was regularly increased toward open forest from inner forest.

On the contrary, that of GYP was shown an irregular pattern of seedling distribution. Open forest having three tombs in GYP was not safe-site for seed germination of pine because of excessive sun light inducing high soil temperature. Inner forests in GYP

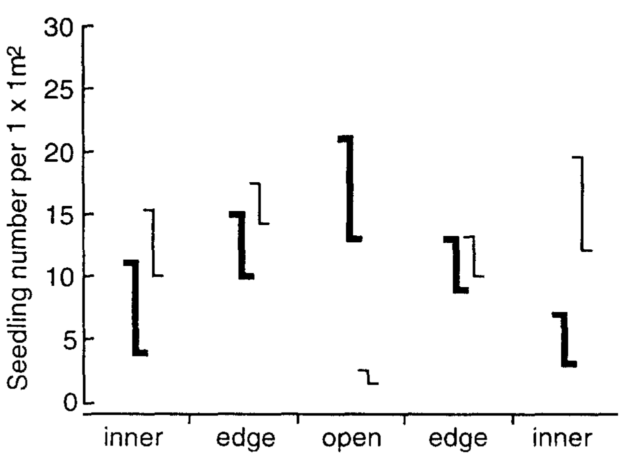

Fig. 3. The current-year pine seedling distribution of two study plots. Each bar shows the maximum and minimun number of seedlings. Thick line : COP, Thin line : GYP.

periodically controlled by human being were also shown more seedling number than other forests in COP. Therefore, we can guess that seed hunting by forest animals is more active at four forest types, open and edge sites in COP and inner and edge sites in GYP, where seedling density of pine was high (Harper 1977).

Animal activity on seed predation

Seed predators take seeds before or after dispersal (Gashwiler 1970). The long-lived mammals and birds are usually taken seeds before or after dispersal. A post-dispersal predator finds seeds in a pattern determined by the dispersal system and leaf residue with a pattern determined by his behavioral characteristics of choice and search. Predation on seeds before dispersal has some obvious advantages to the predators; he has jumped a queue of seed feeders most of which wait for seed to fall to the ground. However, pre-dispersal predation demands a degree of specialization, in particular the ability to fly or to climb (Harper 1977).

Seed of *Pinus densiflora* is wind-dispersed, therefore most seed falls close to the parent plant. However, forest animals are controlled the seed population size at the pre- and post-dispersal stages by cache (Rim and Shidei 1975). Animal effects and their behavioural characteristics are significantly related to the patterns of regeneration and vegetation development of pine forest. Consequently, it can be extended to changing landscape structure (Verboom and van Apeldoorn 1990).

Fig. 4 and 5 show the monthly dynamics of predation rate by forest animals and insects. In this study, predation by field mice (Genus *Apodemus* and *Micromys*) was added to other animal affects such as Genus *Sciurus* (e.g. *Sciurus vulgaris*) and Genus *Tamias* (e.g. *Tamias sibiricus*) because the trace of field mice seems to be less visible than that of squirrels. Mice are small, and work at night, and prefer fallen seeds to cones and fruits on the trees (Rim and Shidei 1975). The subject of animal

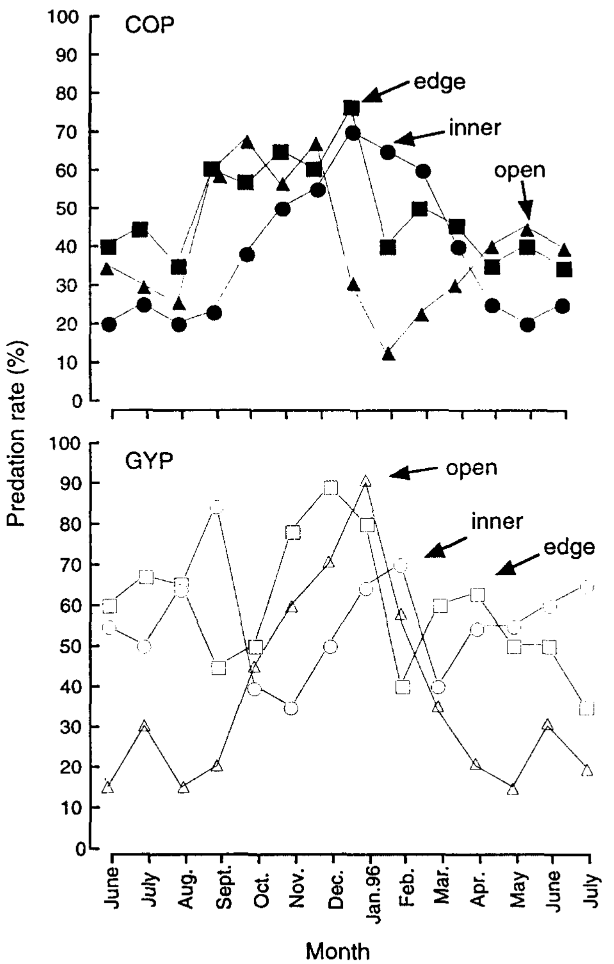

Fig. 4. Predation rates of pine seed due to squirrels and field mice.

as predator (also as destroyer) of conifer seeds has an important meaning (Yoo and Kim 1987). For example, mice of the Genus *Peromyscus* have long been recognized as the main consumer (Donald 1960) in Douglas-fir region of northwestern California. Birds also are the main mortal factor of pine seeds on the forest floor in clear-cut area of *Pseudotsuga-Tsuga* community in western Oregon (Gashwiler 1970). There are some studies on the relationship between activity of small mammals and the regeneration of Japanese deciduous broad-leaved forests specially regarding dispersal and disappearance of acorns and nuts by acorn-feeding rodents such as field mice (Kikuzawa 1988, Ida and Nakagoshi 1996). Genus *Sciurus* is one of the representative mammal preferring fallen seeds and cones on the pine trees (Miyaki 1987). In study area, there are many traces eaten cones by *Sciurus* around tall pine trees. Genus *Tamias*, post-dispersal predator, as well as Genus *Sciurus* also prefer hard cones and seed of pine as well as acorn and walnut (Tamura and Shibasaki 1996). In this study, damage on pine seed is mainly by *Sciurus*, and they attack pine trees by group. Although we could not quantify the population size of squirrels in this area, we could find many *Sciurus* attacking cones on the pine trees in the forest.

According to Rim and Shidei (1975), *Tamias* usually attack cones on trees and eat the seeds even before the cones are mature, and leave a large number of young cones. Moreover, sometimes they pick the cones and eat on the forest floor. In the study area, cache sites with many acorns hoarded by *Tamias* could be found near the tree of *Quercus* species. Seed of pine also had found in the same cache sites.

Rim and Shidei (1975) also reported that the predation on pine seed is due to dove (*Streptopelia orientalis* Lat.). A negligible quantity of predation by birds could be found in the present study although the hull of injured seed was different to the result of Rim and Shidei (1975). However, high predation rates in winter (Nov. to Jan.) were perhaps the activity of the dove often appearing at rural forest, because the mammals such as squirrels have a hibernation in this season. As a whole, a predation rate was higher by squirrels and mice than insects in both plots (Figs. 4 & 5).

In addition, the whole trend in the monthly dynamics of predation rate between animals and insects was reversed in winter (Fig. 5). A few damages due to soil insects were observed from the early spring to fall, and this damage was not detected in winter. Total predation rates in open forest of GYP were higher in winter than other seasons. It is due to human who manage the forest and passing through the road to village in the season. Stopping human ac-

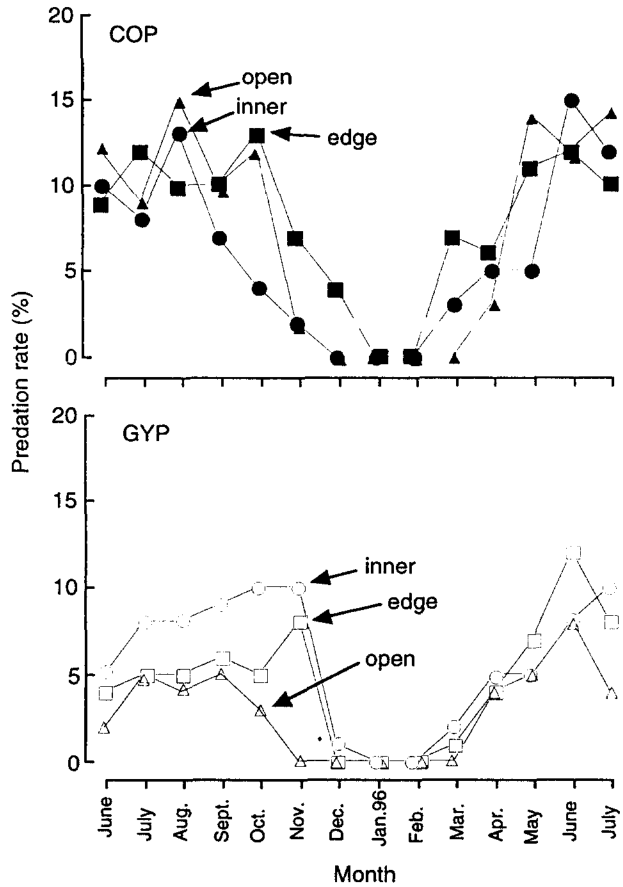

Fig. 5. Predation rates of pine seed due to insects.

tivity, therefore, may act as a trigger of animal movement. Animal activity and predation rate in GYP more nearly located from the village (Approx. 200 m distant from the nearest village) are may interrelated with human influence. In recent, the alien Northern pitch pine (*Pinus rigida* Mill.) and Korean pine (*Pinus karaiensis* Sieb. et Zucc.) were commonly planted near human settlement of rural region. Moreover, the animals can easily find many edible seeds such as chestnut, maize and other grains near village. In fact, dispersal and abundance of Genus *Sciurus* (e. g. *Sciurus vulgaris*) edible for seeds and young cone of these plantations had been increased in proportion to extending area of these plantations and human settlement in the whole Korea (Yoo and Kim 1987).

Spatial heterogeneous vegetation structure and animal activity

The size and abundance of animal populations are mutually related to the size, quality, and isolation rate of each vegetation patch (Forman and Godron 1986, van Dorp and Opdam 1987, Fitzgibbon 1977). Fig. 6 shows that predation rate is related to patch structure with different vegetation types. Edge and inner forest of GYP were highly influenced by animals than that of COP. Open sites of COP with the highest germination rate (Figs. 2 & 3) shown the lowest predation rate. It means that germination rate is not completely decisive to predation rate ($r=-0.452$, $p>0.05$). It is suggested that the movement of animals in relation to predation-prey interaction is also depended on the vegetation types (Verboom and van Apeldoorn 1990). In other words, predator activity on prey is related with vegetation type, that is, spatial pattern, to help animals moving through forest space (Fig. 7).

Vegetation structure and spatial pattern of forest edge as an ecological barrier (i.e. corridor) connecting or dissecting different vegetation types is important to the activity and conservation of forest animals (Hansen and di Castri 1992). Therefore, the builing corridor as heterogeneously connected veg-

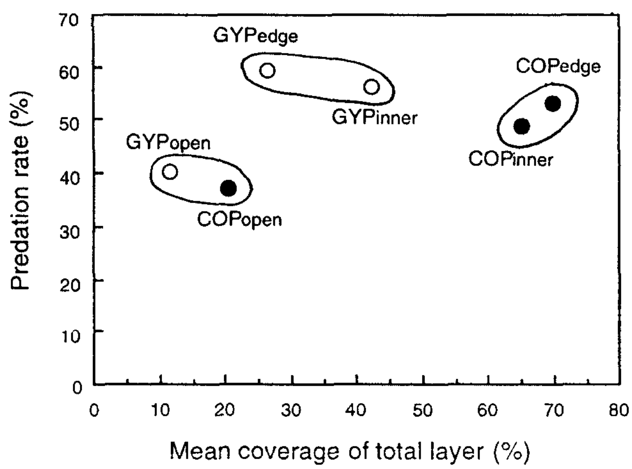

Fig. 6. The relationship between predation rate and the mean coverage of total vegetation layer in each sites. Total regression : r=0.230 (non significant).

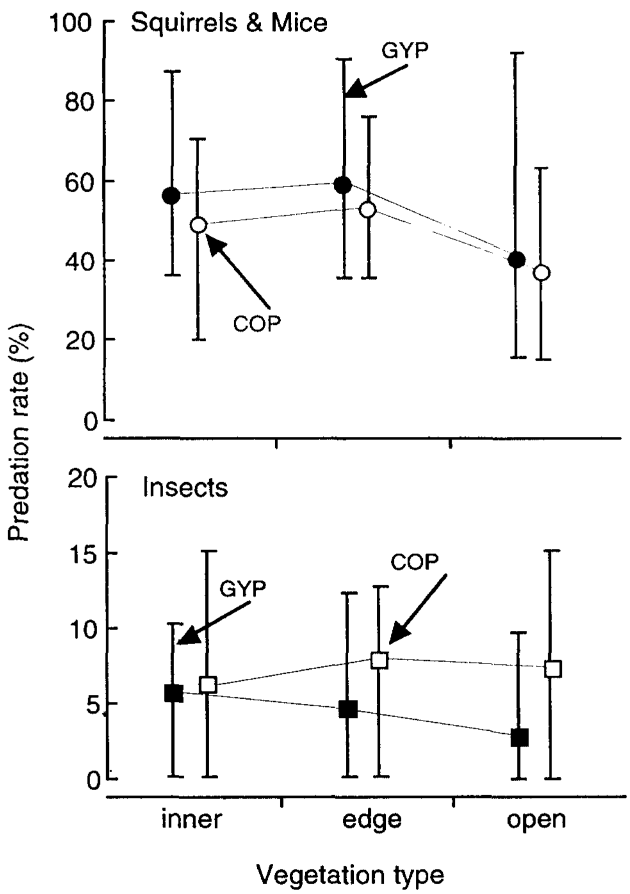

Fig. 7. Changes in predation rates due to forest animals such as mice, squirrels and insects in different vegetation types in both plot. Each vertical bar shows the maximum and minimun value of rate. Point is the mean value.

etation types that any animals can passing through habitats are needed for forest management and nature conservation strategies (Soulé and Gilpin 1991). A largescaled graveyard such as open site in GYP is, however, sometimes may act as a "hard edge" (or hard barrier, e.g. Andrén 1992) which some animal migration can be restricted because there is no shelter and habitat geometry for movement of the animals. In addition, closed structure of inner forest in COP also is one of the restrict factor to some animal movement in mosaic vegetation because of no permeability. In the present study, we could not correctly recognize that how size of graveyard as a corridor effect on animal movement is. However, it is important to understand the edge effect in fragmented forest for establishment of implication for habitat conservation of local biota (Ranny *et al.* 1991, Murcia 1995).

CONCLUSION

Edge effects are the result of the interaction between two adjacent ecosystem (landscape) boundaries (i.e. Hansen and di Castri 1992). Therefore, edges may affect the organisms in a forest fragment by causing changes in the biotic and abiotic conditions (Murcia 1995). Landscape structure affects the intensity of edge effects by reducing the amount of incident light that reaches the understory vegetation (Forman and Godron 1986). In human-influenced forest, therefore, the intensity of edge effects is resulted by human activity on the vegetation landscape structure. In present study, we tried to reveal the edge-effect on the relationship between vegetation structure and animal activity using monitoring of seed predator. The mosaic vegetation structure, although we only measured the coverage of understory vegetation and the germination performance of seed by vegetation types, also affects the spatial difference of animal activity between each vegetation type.

The structure of a forest edge adjacent to cultivation or a pasture can be understood by visualizing a cross section through the edge, that is, saum, mantel, and canopy trees (Ranney *et al.* 1981, Forman and Godron 1986). Shape and dispersal pattern as well as the width of graveyard as the complexed landscape element may have decisive roles to determine the intensity of edge effect and the differences of species composition and abundance in the agricultural landscape in Korea. The size of graveyard and the intensity of landscape management as one of the human disturbance keeping the ecological characteristics, therefore, must be considered for conservation strategy of agricultural landscape system in future Korea (Hong and Nakagoshi 1996).

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적 요

모든 경관은 서로 다른 형태의 서식처 patch들로 구성된 모자이크형태를 갖추고 있다. 따라서 경관내에서 서로 인접하는 서식처 patch들 사이에는 항상 주변부가 형성되고 있다. 산림동물은 산림주변에 종자를 산포함으로서 식생의 발달과 유지에 중요한 역할을 하고 있다. 식생경관내의 동물들은 서로 다른 서식처 특성을 갖고 있기 때문에 이러한 동물의 활동은 공간적으로 불균질한 식생경관의 구조와 유형에 의존한다. 특히 높은 투과성과 먹이 밀도를 갖는 숲 주변부는 중요한 동물서식처의 하나이다. 따라서, 모자이크한 식생 patch들 사이를 연결하는 생태통로(corridor)로서의 숲 주변부의 생태적 특성을 이해하는 것은 자연생태계 보호와 지속 가능한 식생관리를 위한 전략을 수립하는데 필요하다. 이러한 개념하에서, 저자들은 모자이크형 식생내에서 동물의 활동을 추적하는 한 방법으로서 소나무 종자에 미치는 동물의 영향을 조사하였다. 우선 조사지로서 개방지, 주변지, 그리고 숲으로 구성된 인위적인 모자이크 식생형태를 농촌의 소나무 우접 식생경관에서 선별하였다. 각 조사구역내에 100개의 소나무종자를 실로 고정시킨 모판($0.5\times0.5m^2$)을 고루 설치하여 1995년 6월부터 1996년 7월까지 일년 동안 매달 한 차례씩 포식테스트를 실시하였다. 그 결과, 종자피해는 숲 내부와 개방지보다도 숲 주변부에서 높게 나타났다. 모판의 소나무종자는 주로 청설모와 다람쥐에 의해 피해를 받았으며, 조류에 의한 피해도 있었으나 그 정도는 매우 미비하였다. 소나무종자에 대한 이들의 공격은 계절별로 또는 식생형태에 따라 차이가 있었다. 숲 주변지에서의 포식률은 다른 식생형태에서 보다도 높게 나타났다. 끝으로, 본 연구결과는 주거지역으로부터 식생까지의 거리와 같은 경관에 대한 인위적 피압요인과 더불어 인간활동으로 파생된 공간적인 식생구조와 동물의 행동사이에는 상호관계가 있음을 간접적으로 제시하고 있다.

LITERATURE CITED

Andrén, H. 1992. Corvid density and nest predation in relation to forest fragmentation. A landscape perspective. Ecology 73: 794-804.

Andrén, H. & P. Angelstam. 1988. Elevated predation rates as an edge effect in habitat islands: experimental evidence. Ecology 69: 544-7.

Braun-Blanquet, J. 1964. Pflanzensoziologie. Grundz e der Vegetationskunde. Springer-Verlag, Berlin.

Canham, C.D., J.S. Denslow, W.J. Platt, J.R. Runkle, T.A. Spies & P.S. White. 1990. Light regimes beneath closed canopies and tree-fall gaps in temperate and tropical forests. Can. J. For. Res. 20: 620-631.

Donald, C.H. 1960. The interrelationships of logging, birds, and timber regeneration in the Douglas-fir region of Northwestern California. Ecology 41: 116-125.

Fitzgibbon, C.D. 1997. Small mammals in farm woodlands: the effects of habitat, isolation and surrounding land-use patterns. J. Appl. Ecol. 34: 530-539.

Forman, R.T.T. & M. Godron. 1986. Landscape Ecology. John Wiley & Sons, New York. 619 pp.

Forman, R.T.T. & P.N. Moore. 1992. Theoretical foundations for understanding boundaries in landscape mosaic. *In* Hansen, A.J. & F. di Castri (eds.). Landscape Boundaries, consequences for biotic diversity and ecological flows. Springer-Verlag, New York. pp. 236-258.

Gashwiler, J.S. 1970. Further study of conifer seed survival in a western Oregon clearcut. Ecology 51: 849-854.

Grime, J.P. 1979. Plant Strategies and Vegetation Processes. John Wiley & Sons. Chichester. 222 pp.

Hansen, A.J. & F. di Castri (eds.). 1992. Landscape Boundaries, consequences for biotic diversity and ecological flows. Springer-Verlag, New York. 452 pp.

Hanssen, L., L. Fahrig & G. Merriam (eds.). 1995.

Mosaic landscapes and ecological processes. Chapman & Hall, London. 356 pp.

Harper, J.L. 1977. Population Biology of Plants. Academic Press, London. 892 pp.

Hong, S.-K., N. Nakagoshi & K. Nehira. 1993. Trends of *Pinus densiflora* populations under the traditional regimes of forest management in the rural landscapes of Korea and Japan. Ann. Bot. (Roma). 51: 5-20.

Hong, S.-K. & N. Nakagoshi. 1996. Biomass changes of a human-influenced pine forest and forest management in agricultural landscape system. Korean J. Ecol. 19: 305-320.

Houle, G. 1992. Spatial relationship between seed and seedling abundance and mortality in a deciduous forest of north-eastern North America. J. Ecol. 80: 99-108.

Ida, H. & N. Nakagoshi. 1996. Gnawing damage by rodents to the seedlings of *Fagus crenata* and *Quercus mongolica* var. *grosseserrata* in a temperate *Sasa* grassland-deciduous forest series in southwestern Japan. Ecol. Res. 11: 97-103.

Johnston, C.A. 1995. Effects of animals on landscape pattern. *In* Hanssen, L., Fahrig, L., & G. Merriam (eds.), Mosaic Landscapes and Ecological Pro-
cesses. Chapman & Hall, London. pp. 57-80.

Kikuzawa, K. 1988. Dispersal of *Quercus mongolica* acorns in a broadleaved deciduous forest. 1. Disappearance. For. Ecol. Manag. 25: 1-8.

Kozakiewicz, M., Kozakiewicz, A., Lukowski, A. & T. Gortat. 1993. Use of space by bank voles (*Clethrionomys glareolus*) in a Polish farm landscape. Landscape Ecol. 8: 19-24.

Lee, W.-T. & C.-H. Lee. 1991. Plant sociological studies on the *Pinus densiflora* forest in Korea. Korean J. Ecol. 12: 257-284 (in Korean with English abstract).

Miyaki, M. 1987. Seed dispersal of the Korean pine, *Pinus koraiensis*, by the red squirrel, *Sciurus vulgaris*. Ecol. Res. 2: 147-157.

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. TREE 10: 58-62.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. BioScience 33: 700-706.

Odum, E.P. 1971. Fundamental of Ecology. Saunders, Philadelphia.

Ranney, J.W., Bruner, M.C. & J.B. Levenson. 1981. The importance of edge in the structure and dynamics of forest islands. *In* Burgess, R.L. & D.M. Sharpe (eds.), Forest Island Dynamics in Man-dominated Landscapes. Springer-Verlag, New York. pp. 67-95.

Rim, Y.-D. & T. Shidei. 1975. Animal influences on Japanese red pine seeds on the forest floor (II). Seed input and output of seedling with seed coat. Jpn. J. Ecol. 25: 141-148.

Soulé, M.E. & M.E. Gilpin. 1991. The theory of wildlife corridor capability. *In* Saunders, D. A. & R. J. Hobbs (eds.), Nature Conservation 2: The Role of Corridors. Surrey Beatty & Sons, pp. 3-8.

Tamura, N. & E. Shibasaki. 1996. Fate of walnut seed, *Juglans ailanthifolia*, hoarded by Japanese squirrels, *Sciurus lis*. Jour. For. Res. 1: 219-222.

van Dorp, D. and P. Opdam. 1987. Effects of patch size, isolation and regional abundance on forest bird communities. Landscape Ecol. 1: 59-73.

Verboom, B. & R. van Apeldoorn. 1990. Effects of habitat fragmentation on the red squirrel, *Sciurus vulgaris* L. Landscape Ecol. 4: 171-176.

Yoo, B.-H. & S.-W. Kim. 1987. Ecology and control of the squirrel, *Sciurus vulgaris coreae*. Res. Rep. For. Res. Inst. Korea 35: 130-138. (in Korean with English abstract)

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