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Effect of Patch Size and Habitat Variables on Small Rodents Population in Urban Woods

Hyun-Ju Cho[1], Eun-Jae Lee[2] and Shin-Jae Rhim[3*]

[1]*Department of Landscape Architecture, Daegu University, Kyungsan, South Korea*
[2]*Urban Planning Research Group, Daejeon Sejong Research Institute, Daejeon, South Korea*
[3]*School of Bioresource and Bioscience, Chung-Ang University, Ansung, South Korea*

ABSTRACT

This study was conducted to investigate the relationships between patch size and habitat variables in the context of small rodent populations in the urban woods of the Daejeon metropolitan area in South Korea. The forested patches included in this study ranged from 2.1 to 1934.1 ha in size. Six species of small rodents were captured during this study. The number of small rodent species and the total number of captured individuals were correlated with patch size. We focused on the patch size and preferred habitat variables of two dominant small rodents, *Apodemus agrarius* and *A. peninsulae*, and found that the numbers of captured individuals of both species were highly related to the patch size. We determined that understory coverage and the volume of coarse woody debris were the habitat variables associated with the *A. agrarius* population, while the corresponding variables associated with *A. peninsulae* population were suboverstory coverage, understory coverage, and the volume of coarse woody debris as preferred habitat variables. We found that patch size and habitat variables had major direct effects on small rodent populations. Investigations of biodiversity in urban areas are necessary and should be considered in urban planning for the conservation of biodiversity.

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Authors' Contribution
EJL and SJR designed the study and wrote the manuscript. HJC and EJL performed field work and analyzed the data.

Key words
***Apodemus agrarius, A. peninsulae*, Coarse woody debris, Forested patch, Understory coverage**

INTRODUCTION

Habitat fragmentation, which involves the reduction of continuous vegetation into small islands, is one of major factors contributing to the loss of biodiversity around the worldwide (Soulé and Orians, 2001; Johnson and Karels, 2016), and is considered a threat to the conservation of wildlife (Ogogo et al., 2013). Moreover, fragmentation of natural habitats causes changes in the vegetation cover, temperature, and moisture levels in habitat fragments (Laakkonen et al., 2001). In this process, original habitats are converted into new anthropogenic patches and reduced to series of small forested woodlots (Hinsley et al., 1996; Estavillo et al., 2013; Lee and Rhim, 2017). A thorough understanding of the influence of habitat fragmentation on biodiversity is an important theoretical and conservation priority (Lawrence et al., 2018).

The reduction of natural vegetation and the formation of fragmented patches through urbanization are the main causes behind the decrease in wildlife population in urban areas (Forman, 2014). When the patch size is reduced, the remnant area becomes isolated, leading to a decrease in animal populations (Foley et al., 2005). In urban areas, anthropogenic activities include expansion of existing settlements via construction of buildings and roads, which reduce large vegetative areas to small and fragmented patches (Park and Lee, 2000). Despite the importance of animal ecology studies for the conservation of wildlife and their habitats in urbanized areas studies on the influence of urbanization on small rodents within fragmented urban areas are relatively scare.

The effects of habitat fragmentation on small rodents are variable. Some species decline in abundance in smaller size and more isolated patches (Pardini et al., 2005). The reduced population sizes in fragmented patches might lead to demographic stochasticity, inbreeding depression, and edge effects, increasing the risk of a population collapse (Frankham et al., 2002; Püttker et al., 2008). Population density is one of the most essential parameters affecting the dynamics of small rodent populations (Efford, 2004).

In South Korea, human activities over the past several decades have resulted in substantial loss and fragmentation of forested territory (Lee et al., 2017). Forest fragmentation, especially major disturbances in the urban woods, are likely to be influenced mammal populations. In this regard, although the mall rodents, *Apodemus agrarius* and *A. peninsulae* are largely widespread across South Korea. However, very little is known about their ecological status and survivability in fragmented patches of urban woods (Lee, 2020).

* Corresponding author: sjrhim@cau.ac.kr
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The developed and urbanized areas in the Daejeon metropolitan area provide a good opportunity to investigate the effect of patch size and habitat variables on small rodents in urban woods. Thus, the purpose of this study was to investigate the influence of vegetation fragmentation on the abundance of small rodent species in the urban woods of the Daejeon metropolitan area. The effects of abiotic and biotic factors on the small rodents were analyzed in an effort to gain insight as to the effects of patch size and habitat variables. We hypothesize that (1) small rodent species' abundance differs in accordance with patch size, and (2) small rodents have preferred habitat variables in urban woods.

MATERIALS AND METHODS

This study was carried out from May to June 2020 in the urban woods of Daejeon Metropolitan City (36°17′–27′N, 127°17′–28′E) in South Korea. The annual mean precipitation in this area is 1943 mm and annual mean temperature is 12.6°C. The metropolitan area of Daejoen encompasses 540 km^2, of which 286 km^2 is vegetated (Lee and Rhim, 2017). We sampled the abundance of small rodents and studied their habitat variables at 35 sites in the urban woods. The study sites had areas ranging from 2.1 to 1934.1 ha (Table I). Many study sites were located in mixed forests dominated by the pitch pine (*Pinus rigida*), Japanese red pine (*P. densiflora*), Mongolian oak (*Quercus mongolica*), and false acacia (*Robinia pseudoacacia*) (Lee, 2020).

In each patch of urban wood, we selected an 80×80 m size study plot, which was divided into a grid pattern consisting of a 20×20 m arrays for live trapping and habitat variable surveying. Habitat variables at each trap station were measured within circles with a radius of 5 m. In each circle, we recorded the number of standing trees, shrubs, woody seedlings, snags, and downed trees. We also measured the volume of coarse woody debris on stand. Within these circles, we classified the vertical layer into the understory (0–2 m), midstory (2–8 m), suboverstory (8–20 m), and overstory (20–30 m) regions. Based on the percentage of cover in each vertical layer, the vegetation coverage was categorized as 0 (percent coverage= 0%), 1 (1%–33%), 2(34%–66%), and 3 (67%–100%). Rock coverage on the ground was measured using the same categories (Rhim et al., 2012).

We trapped small rodents in each study plot on three consecutive nights during May and June in 2020. Each study plot (80×80 m) contained 25 (5×5 array) trap stations spaced at intervals 20 m apart. A Sherman live trap (7.62×8.89×22.86 cm, LFA trap) was installed at each station. During the trapping sessions, we recorded the trap location, rodent species, if the individuals were new or recaptured, and their individual identities. All captured small rodents were toe-clipped for individual identification and immediately released in the capture station (Kang et al., 2013).

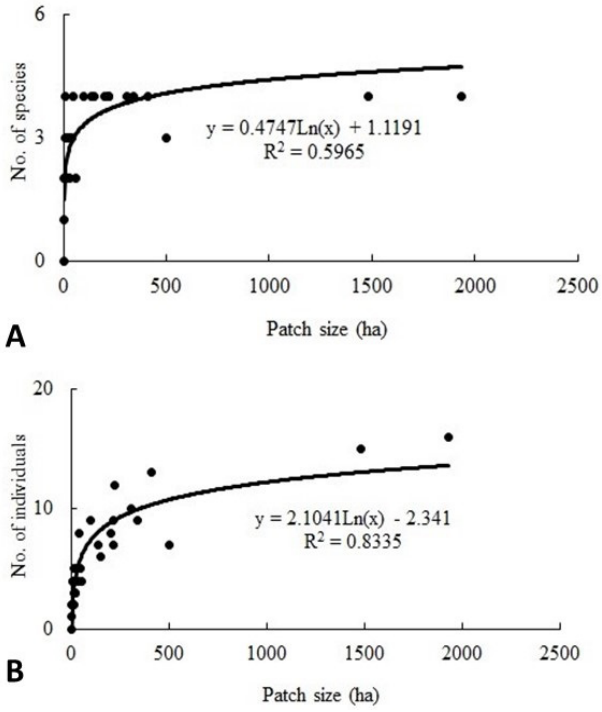

Fig. 1. Relationship between the number of small rodent species and patch size (A) and between the total number of captured individuals and patch size (B) in the urban woods of Daejeon, Korea from May to June 2020; number were obtained with a simple regression analysis.

Statistical analyses were performed using the SPSS statistical package for Windows. Simple regression analysis was used to examine the relationships between patch size and the variables of interest (number of species and individuals). Moreover, multiple correlation analyses were used to examine the preferred habitat variables of *A. agrarius* and *A. peninsulae*.

RESULTS

Six small rodent species were captured in 35 patches of urban woods in the Daejeon metropolitan area in South Korea. The total number of captured small rodents was 201 individuals. *A. agrarius* was the numerically dominant species with 77 captured individuals (38.3% of the total sample), while 64 individuals of *A. peninsulae* were also captured. The total number of small rodents

caught at each study site during the study period ranged from 0 to 16 (Table I). Moreover, *Myodes regulus, Tamias sibiricus, Rattus norvegicus,* and *Mus musculus* were the other species captured during the study period. However, the numbers of captured individuals of these four species were low in this study.

Table I. Patch size, species population, and total captured number of small rodents in the urban woods of Daejeon, Korea from May to June 2020.

No.	Study site	Size (ha)	No. of species	No. of individuals
1	Wolpyeong park	501.0	3	7
2	Doan park	151.0	4	6
3	Keonyang university hospital	11.0	3	4
4	Daejeong elementary school	9.1	2	2
5	Gasuwon park	308.7	4	10
6	Daeshin high school	11.1	2	2
7	Byeondong park	2.6	2	2
8	Namsun park	12.2	2	2
9	Daejeon national cemetery	1934.1	4	16
10	Sajeong park	1482.0	4	15
11	Humansia apartment	25.6	2	3
12	Panamdong north	34.0	3	4
13	Panamdong south	4.1	1	1
14	Daejeon/woosong university	9.5	4	4
15	Daejeon university	18.1	2	2
16	Woosong university	46.6	4	5
17	Yongjeon park	15.3	3	5
18	Hannam university	8.8	2	2
19	Ojeong farm market	2.1	0	0
20	Hoedeok park	31.5	3	5
21	National research institute of cultural heritage	413.0	4	13
22	Maebong park	41.5	3	8
23	Bokyong horse racing course	220.0	4	9
24	Chungnam national university	101.4	4	9
25	Seongdusan park	26.2	2	4
26	Eulmigi park	58.2	2	4
27	Cheongbyeoksan park	19.9	2	3
28	Kwanpyeongdong	16.7	3	4
29	Saesomang church	24.5	3	4
30	Yeojin buddhism museum	18.9	2	3
31	Hyemyeong temple	223.0	4	12
32	Yongho public cemetery	203.0	4	8
33	Obongsan	344.0	4	9
34	Jangan reservoir	137.0	4	7
35	Songlim temple	218.0	4	7

The correlation between the number of small rodent species and the patch size in Daejeon was assessed using a regression equation (y= 0.4747 Ln(x)+1.1191). The coefficient of determination (R^2) for the regression was 0.5965. The number of captured small rodents was correlated with patch size in this study (regression equation, y = 2.1041 Ln(x) - 2.341, R^2 = 0.8335, Fig. 1).

To understand the relationship between patch size and the number of captured individuals of small rodents, the simple regression was used. The numbers of captured *A. agrarius* (regression equation, y= 0.6957 Ln(x) - 0.4659, R^2= 0.7108) and *A. peninsulae* (regression equation, y= 0.6118 Ln(x) - 0.3209, R^2= 0.5373) individuals were correlated with patch size (Fig. 2).

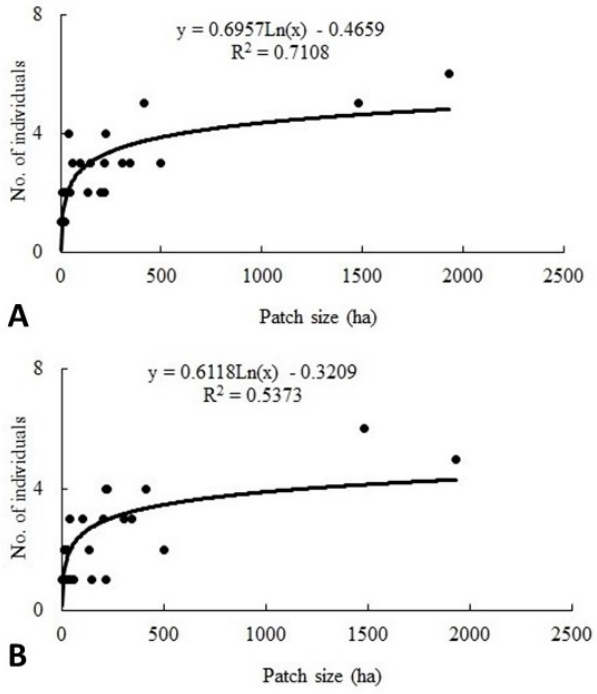

Fig. 2. Relationship between the number of captured small rodents and patch size in the urban woods of Daejeon, Korea from May to June 2020; numbers were obtained with the simple regression analysis. (A) *A. agrarius*; (B) *A. peninsulae*.

Multiple correlation analysis was used to examine the habitat variables and eh abundance of small rodent species. We determined that understory coverage and a certain volume of coarse woody debris were the preferred habitat variables of *A. agrarius*. Similarly, *A. peninsulae*'s preferences correlated with suboverstory coverage, understory coverage, and the volume of coarse woody debris (Table II).

Table II. Preferred habitat variables of *A. agrarius* and *A. peninsulae* in the urban woods of Daejeon, Korea from May to June 2020; numbers obtained with the multiple correlation analysis.

Habitat variables	Apodemus agrarius	*Apodemus peninsulae*
Overstory coverage	-0.14	0.21
Suboverstory coverage	-0.16	0.29*
Midstory coverage	0.11	0.15
Understory coverage	0.33*	0.26*
Rock coverage	-0.01	-0.01
No. of standing trees	-0.12	0.11
No. of shrubs	-0.02	0.14
No. of woody seedlings	-0.08	0.16
No. of snags	-0.02	0.01
No. of downed trees	-0.01	0.03
Volume of coarse woody debris	0.36*	0.35*

*, $p < 0.05$

DISCUSSION

The continuous worldwide changes in land use have changed the landscapes and threatened the survivor of wild flora and fauna (Wang et al., 2019). Urbanization creates various environmental gradients that can influence on small rodents. Especially, patch size and heterogeneity of fragmented habitats were the two major predictors of small rodents in an urbanized landscape (Tews et al., 2004; Stevens and Tello, 2009).

This study showed considerable differences in the abundance of small rodents in urban woods. Many previous studies have demonstrated that local rodent populations persist longer in larger patches of suitable habitats than in small patches (Stacy and Taper, 1991; Capizzi et al., 2003; Jorge, 2008). Although small rodents may be able to survive in small fragments, habitat fragmentation nevertheless poses an increased risk of extinction for mammals such as small rodents, whose population density has continued to remain small (Laakkonen et al., 2001). We found that patch size had a significant direct effect on small rodent populations. This finding indicates that patch size influences small rodent species' abundance, since small patches do not have sufficient resources to support a large number of small rodents (Wang et al., 2020).

Most previous studies (Rhim et al., 2012; Lee et al., 2020) have suggested that the amount of plant cover and woody debris in forest floor influence the habitat preferences of small rodents. The results of our study have shown that suboverstory and understory coverages, and the volume of coarse woody debris are preferred by small rodents across urban woods in the Daejeon metropolitan area. Understory coverage and coarse woody debris were main variables explaining the presence of *A. agrarius* and *A. peninsulae*. The characteristics of favorable urban woods for small rodents include dense understory coverage and a high amount of coarse woody debris, since these conditions may be related to the availability of a large amount of food, a moister microclimate, and greater shelter for the mammals (Umetsu and Pardini, 2007). Thus, maintenance of habitat cover in urban woods is likely to facilitate the preservation of small rodent populations.

The *A. agrarius* and *A. peninsuale* species are known to be generalists with respect to habitat requirements and were captured in different patches. The population sizes of these two types of mammals exceed 70% of the total population size of small rodents in South Korea (Lee et al., 2017). However, forest-dwelling species such as *M. regulus* and *T. sibiricus* showed low abundance. Habitat loss and fragmentation could generate an edge effect. The negative effects of habitat edges are particularly severe in the small remaining patches (Wang et al., 2020). The low population sizes of these forest-dwelling species might be attributable to the negative edge effects of fragmented urban woods (Bowman et al., 2002). The populations of *R. norvegicus* and *M. musculus* are related to human settlements. These mammals prefer human houses, restaurants, and buildings (Yoon, 1992). Since our study sites were vegetative patches, these mammals might have shown in low population density at these sites.

Our study yielded no information about the predation on small rodents at the study sites. Many mammalian predators and predatory birds really eat small rodents (Bolger et al., 1997). Stray cat may also be important predators of small rodents in urban woods (Lee et al., 2017). Our assessments also did not yield data on the movement ability of small rodents, and the spatial context of the patches, such as isolation and proximity, were not dealt with in this study. Future studies should consider these factors for the conservation of the mammals and their habitats.

Nevertheless, this study could elucidate the effects of fragmented patch characteristics on small rodents in urban woods. We found that patch size and habitat variables had a major direct effect on the populations of small rodents. These results may add to the growing body of research on the effects of habitat fragmentation. Investigations of biodiversity in urban areas are necessary and should be considered during urban planning for the conservation of species and their habitats. As human activities and disturbances continue, it is vital to focus on ways to reduce the negative effects of human development on mammals

in urban woods.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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