Journal of Animal and Veterinary Advances 12 (7): 846-851, 2013
ISSN: 1680-5593

Population Dynamics of Small Mammals in a Natural Deciduous Stand and a Japanese Larch *Larix leptolepis* Plantation Stand

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Abstract: The population dynamics of small mammals were studied using live trappings conducted in natural deciduous and Japanese larch *Larix leptolepis* plantation stands on Mt. Gariwang, Gangwon Province, South Korea. Foliage profiles, diameter at breast height distribution of standing trees, stand structure attributes and characteristics of downed trees were found to differ between natural deciduous and Japanese larch plantation stands. Differences in both species richness and abundance of small mammals were observed in the study area. Moreover, the number of captured individuals, age structure and sex ratio changed over the course of the trapping sessions. An understanding of relationship between habitat characteristics and small mammal population dynamics is required for sustainable forest management. Future research should therefore focus on a long-term study of small mammal populations in various habitat patterns.

Key words: Age structure, live trapping, sex ratio, small mammals, population dynamics

INTRODUCTION

The ecological value of small mammals in ecosystem is based on their important structural and functional roles (Taylor *et al*., 2012). For example as prey they support wide diversity of snakes, raptors and carnivores (Habtamu and Bekele, 2012). Moreover, small mammals are themselves predators and dispersers of seeds and fungi (Kirkland, 1990; Bermejo *et al*., 1998; Rhim *et al*., 2012).

Monitoring of biological issues is an important element of managing forest ecosystems (Pearce and Venier, 2005); most studies of small mammal dynamics have shown that forest management practices can alter species composition and abundance (Hansson, 1999; Ecke *et al*., 2002). Small mammals respond rapidly to environmental changes and are therefore used as indicator species in environmental quality assessment and studies of ecological processes (Aplin *et al*., 2003; Avenant, 2011). Higher density forest stands provide important thermal protection, security and cover for small mammals (Hagar *et al*., 1996; Sullivan *et al*., 2001) and these patterns of habitat usage by small mammals are strongly influenced by habitat structure and other variables (Ecke *et al*., 2002; Kang *et al*., 2013). Generally, wildlife responds to characteristics of forest stands other than stand age (Hayes *et al*., 1997) it may be possible to accelerate the development of some of these habitat attributes in young forest stands (Sullivan *et al*., 2001).

Forests are threatened by developments such as urban expansion and the construction of roads and buildings with forest-dwelling wildlife suffering adverse impacts such as forest loss and fragmentation (Rhim and Lee, 2001). The relationship between small mammals and habitat variables such as coarse woody debris and stand structure has been explored in a number of studies. Some of these studies have shown the distribution of woody debris and snags to be important to small mammals (Mills, 1995; Bowman *et al*., 2000; Rhim and Lee, 2001). Other studies have determined that small mammals are dependent on gaps in the canopy, understory coverage, snags, fallen trees, coarse woody debris, litter and humus, all of which vary according to specific forest ecosystems (Carey and Harrington, 2001; Pearce and Venier, 2005).

Globally, forest management practices have altered the structure of forests. It has recently become widely accepted that forest stands should be managed sustainably on the basis of ecological principles (Lindenmayer *et al*., 2000) with management practices perpetuating the inherent structural characteristics of forest ecosystems and contributing to the conservation of biodiversity (Kohm and Franklin, 1997). However, much of forest management has been based on commodity-oriented objectives and a less than adequate scientific evaluation of alternative management possibilities (Carey and Curtis, 1996).

In particular, trees have been planted on a large scale since the 1960s. In South Korea, Japanese larch

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Larix leptolepis is a dominant plantation tree with hundreds of thousands of hectares of Japanese larch plantations in early seral stages (1-40 years of age) established across the country. In constrast, natural forests are dominated by oak (*Quercus* sp.) and have a relatively low standing volume (Korea Forest Service, 2012). However, few studies have been carried out on the relationships between habitats and small mammals in South Korea.

In the study, researchers investigated a wide spectrum of habitat variables to analyze small mammal communities. Researchers studied the dynamics of small mammals in both natural deciduous and Japanese larch plantation stands to understand the relationship between habitat structure and small mammals.

MATERIALS AND METHODS

The study was undertaken in natural deciduous and Japanese larch plantation stands located in the national forest of Mt. Gariwang, Pyeongchang, Gangwon Province, between 37°25' and 37°30'N and 128°27' and 128°33'E. Mt. Gariwang covers an area of approximately 40.3 km^2. The altitude of the study area ranges between 800 m and 1,100 masl. The dominant tree species in the natural deciduous stand are Mongolian oak *Quercus mongolica*, Amur linden *Tilia amurensis* and Korean ash *Fraxinus rhynchophylla*. The Japanese larch stand was planted in the early 1970s. For the trapping and habitat surveys, researchers selected two 100×100 m study plots, one from each stand type and divided each plot into a grid pattern consisting of a 15×15 m array (Kang *et al*., 2013).

Circles measuring 5.64 m in diameter were established at each trapping station (Lee *et al*., 2008) within which recorded stand characteristics: species and Diameter at Breast Height (DBH) for each tree and snag, number of downed trees, volume of downed trees and volume of coarse woody debris. Researchers also categorized the vertical layers within the circles into overstory (20-30 m), sub-overstory (8-20 m), mid-story (2-8 m), understory (1-2 m) and ground (0-1 m) (Kang *et al*., 2013). Coverage was classified into the following four categories on the basis of the percentage of cover in each vertical layer, according to the method described by Rhim and Lee (2001): 0 (percentage coverage = 0%), 1 (1-33%), 2 (34-66%) and 3 (67-100%).

Researchers used a capture-mark-release technique to trap small mammals in each study plot for 3 consecutive nights in May, July and September 2013. The trapping grids (100×100 m) contained 49 (7×7 array) trap stations (Sherman live trap) at 15 m intervals. Traps were baited with peanuts and checked each morning (Lee *et al*., 2012). For each trapped mammal, researchers recorded species, sex, weight and reproductive condition. Toe-clippings were used for individual identification and individuals were immediately released in the same area where they had been captured (Lee *et al*., 2008).

Wilcoxon rank sum test and t-test were used to analyze stand structure by comparing the number of standing trees, basal area, vegetation coverage (overstory, sub-overstory, mid-story, understory and ground), number of downed trees and volume of downed trees (Lee *et al*., 2012).

RESULTS

Foliage profiles differed between the natural deciduous and Japanese larch plantation stands. Sub-overstory (8-20 m) (t-test, $t = 6.35$, $p = 0.001$) and mid-story (2-8 m) ($t = 3.42$, $p = 0.001$) vegetation coverage was higher in the natural deciduous stand than in the Japanese larch plantation stand. However, overstory (20-30 m) ($t = 2.5$, $p = 0.01$) and ground (0-1 m) ($t = 15.19$, $p = 0.001$) vegetation coverage was higher in the Japanese larch plantation stand (Fig. 1 and Table 1). A total of 900 trees were recorded in the natural deciduous stand. The number of standing trees was higher in the natural deciduous stand than in the Japanese larch plantation stand ($t = 4.83$, $p = 0.001$). Moreover, there were more

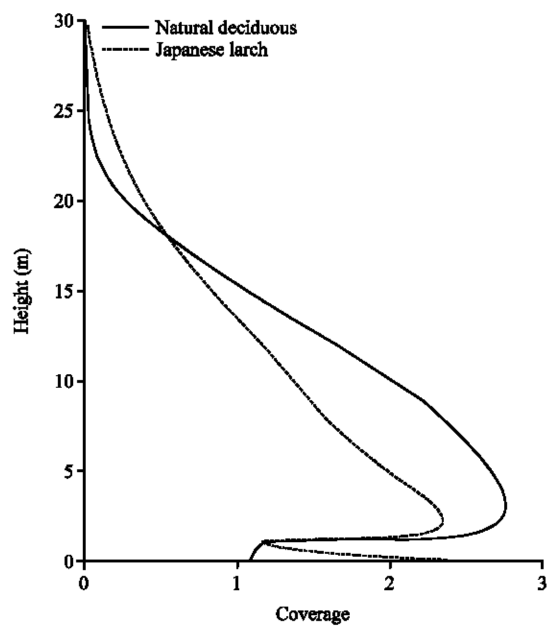

Fig. 1: Mean foliage profiles of the studied stands in the natural deciduous forest and Japanese larch *Larix leptolepis* plantation, Mt. Gariwang, Pyeongchang, Korea

Table 1: Summary of stand structure attributes (density, basal area and coverage) and characteristics of downed trees (volume and number of trees) for the studied stands in the natural deciduous forest and Japanese larch *Larix leptolepis* plantation, Mt. Gariwang, Pyeongchang, Korea. Results of the t-test are shown

	Stands			
Variables	Natural deciduous	Japanese larch	t-values	p-values
No. of standing trees/ha	894.89±122.45	627.25±128.91	4.83	0.001
Basal area (m^2/ha)	23.36±12.94	16.45±11.93	3.89	0.001
Coverage of overstory (20-30 m) vegetation	0.16±0.05	0.39±0.03	2.50	0.010
Coverage of sub-overstory (8-20 m) vegetation	2.34±0.82	1.57±0.06	6.35	0.001
Coverage of mid-story (2-8 m) vegetation	2.69±0.06	2.34±0.35	3.42	0.001
Coverage of understory (1-2 m) vegetation	1.21±0.16	1.16±0.09	0.75	0.450
Coverage of ground (0-1 m) vegetation	1.08±0.04	2.37±0.07	15.19	0.001
No. of downed trees/ha	776.98±197.08	573.01±126.86	3.46	0.001
Volume of downed trees (m^3/ha)	17.50±1.51	15.72±1.67	0.71	0.480

Table 2: Monthly changes in the number of captured individuals, age structure and sex ratio for the Asiatic chipmunk *Tamias sibiricus* in May, July and September 2013 for the studied stands in the natural deciduous forest and Japanese larch *Larix leptolepis* plantation, Mt. Gariwang, Pyeongchang, Korea

Variables	May	July	September	Total
Natural deciduous				
No. of mice (adults)	1 (1)	32 (29)	13 (11)	46 (40)
Sex ratio (male:female)	0:1	20:12	7:6	27:19
Japanese larch				
No. of mice (adults)	0 (0)	0 (0)	0 (0)	0 (0)
Sex ratio (male:female)	0:0	0:0	0:0	0:0

p = 0.001). There was no difference in basal area (t = -0.05, p = 0.96) and volume of downed trees (t = 0.71, p = 0.48) between the studied stands (Table 1).

Small trees were abundant in both stands, mostly of <20 cm (DBH). There were <20 trees of DBH >40 cm ha^{-1} in each studied stand. There were no difference in DBH distribution between the natural deciduous stand and Japanese larch plantation stand (Wilcoxon rank sum test, Z = -0.32, p = 0.75, Fig. 2).

During the study period, three species of small mammals, the Asiatic chipmunk *Tamias sibiricus*, Korean field mouse *Apodemus peninsulae* and Korean red-backed vole *Myodes regulus* were captured in the study area. A total of 141 captures of 87 individuals and 137 captures of 89 individuals were achieved in the natural deciduous stand and the Japanese larch plantation stand, respectively. The study revealed that small mammals have a higher species richness in the natural deciduous stand than in the Japanese larch plantation stand. However, small mammal abundance was similar for both stands. The number of small mammals captured differed according to the month in which the trapping session was conducted and it was higher in July both stands.

However, the number of small mammals captured in each month was consistent between the stands (Z = -0.44, p = 0.66, Fig. 3). Asiatic chipmunks were only captured in the natural deciduous stand with a higher number of captures in July than in May and September combined. Most of the captured individuals were adults and a higher proportion was male (Table 2).

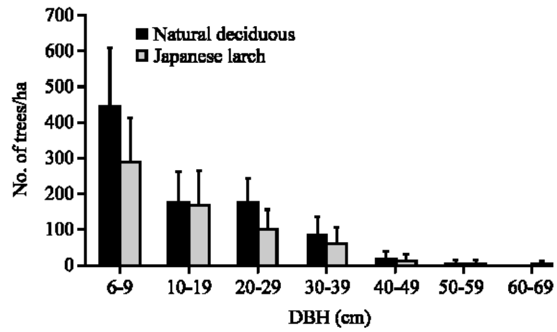

Fig. 2: Diameter at Breast Height (DBH) distributions of standing trees for the studied stands in the natural deciduous forest and Japanese larch *Larix leptolepis* plantation, Mt. Gariwang, Pyeongchang, Korea

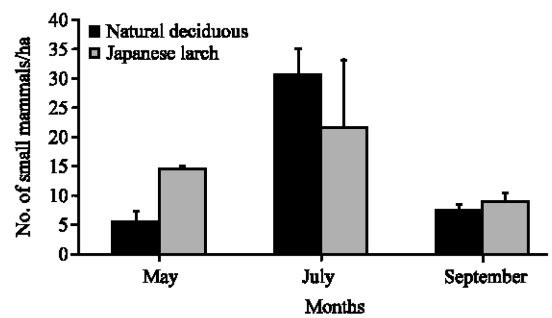

Fig. 3: Monthly changes in the number of small mammals captured in May, July and September 2013 in the studied stands in the natural deciduous forest and Japanese larch *Larix leptolepis* plantation, Mt. Gariwang, Pyeongchang, Korea

The total number of captured Korean field mice was similar for both stands. However, the month in which the number of captures peaked was different for the natural deciduous (July) and Japanese larch plantation (May) stands. In both stands, the number of adults and males was higher in all trapping sessions. In particular, over 80% of the captured Korean field mice were male (Table 3).

Table 3: Monthly changes in the number of captured individuals, age structure and sex ratio for the Korean field mouse *Apodemus peninsulae* in May, July and September 2013 for the studied stands in the natural deciduous forest and Japanese larch *Larix leptolepis* plantation, Mt. Gariwang, Pyeongchang, Korea

Variables	May	July	September	Total
Natural deciduous				
No. of mice (adults)	6 (6)	20 (14)	15 (13)	41 (33)
Sex ratio (male:females)	4:2	12:8	8:7	24:17
Japanese larch				
No. of mice (adults)	23 (22)	12 (12)	11 (8)	46 (42)
Sex ratio (male:female)	18:5	12:0	8:3	38:8

Table 4: Monthly changes in the number of captured individuals, age structure and sex ratio for the Korean red-backed vole *Myodes regulus* in May, July and September 2013 for the studied stands in the natural deciduous forest and Japanese larch *Larix leptolepis* plantation, Mt. Gariwang, Pyeongchang, Korea

Varibales	May	July	September	Total
Natural deciduous				
No. of mice (adults)	9 (9)	34 (10)	11 (8)	54 (27)
Sex ratio (male:female)	5:4	19:15	9:2	33:21
Japanese larch				
No. of mice (adults)	13 (12)	48 (22)	30 (29)	91 (63)
Sex ratio (male:female)	13:0	30:18	22:8	65:26

A higher number of Korean red-backed voles were captured in the Japanese larch plantation than in the natural deciduous stand. The number of juveniles captured was higher in July for both stands. For the natural deciduous stand, the total number of adults and juveniles captured was the same and the ratio of females to males was higher. In the Japanese larch plantation stand, a higher number of adults and males were recorded (Table 4).

DISCUSSION

Biological and physical structures play major roles in the function and diversity of ecosystems. Forest stands are three-dimensional systems, the structure of which can be considered a product of both forest dynamics and biophysical processes (Spies, 1998); it is also controlled by forestry management and advancements in the knowledge of forest structure have highlighted its ecological importance (Kohm and Franklin, 1997). As forest stands age, trees die therefore creating gaps in the canopy layer. Small mammals use woody debris from fallen trees for nesting and foraging (Tallmon and Mills, 1994; Simon *et al*., 1998).

Heterogeneous environments are generally held to sustain higher species richness in forest ecosystems (Kerr and Packer, 1997). The foliage profile distribution is one component of forest structure that has important roles in stand microclimate, absorption of solar radiation and wildlife habitat (Spies, 1998). Moreover, coarse woody debris should increase habitat heterogeneity thereby increasing the availability of shelter and food and promoting reproduction (Ecke *et al*., 2002). Dead organic matter could therefore represent an important structural and functional element for small mammals within a forest ecosystem. However, its spatial distribution, quality and quantity can be greatly modified by human activities such as harvesting and management (Freedman *et al*., 1996). Downed logs and snags in an advanced stage of decay have the potential to provide microhabitats in which small mammals can nest and forage (Tallmon and Mills, 1994; Bowman *et al*., 2000). In the study, stand structure attributes and the characteristics of downed trees differed between the study areas. Moreover, the species richness and abundance of small mammals were both influenced by habitat structure.

Ground vegetation coverage was on average much higher in the Japanese larch plantation than in the natural deciduous stand. This characteristic has the potential to provide food and shelter for small mammals (Morris, 1997) good habitat conditions were in particular present for Korean red-backed voles (Lee *et al*., 2008). The overall high abundance of Korean red-backed voles in both study areas was mainly due to the high number of subadults which was closely related to the high rate of reproduction during summer. According to the study results, Asiatic chipmunk occurred in the natural deciduous stand but not in the Japanese larch plantation stand. This mammal is a forest dweller, in particular occurring in deciduous and mature coniferous forests (Won, 1967). Researchers found that standing and downed trees were more abundant in the natural deciduous stand than in the Japanese larch plantation stand and it is also possible that the effects of standing and downed trees on habitat structure and characteristics may influence Asiatic chipmunk.

Forest management based on ecological principles is required globally (Plochman, 1992). However, there is little experience of multipurpose forest ecosystem management for wildlife, water, fish and economic activities, for various forest types (Carey and Harrington, 2001). The conservation of biodiversity is a goal of forest management (Lindenmayer *et al*., 2000) and stand complexity would seem to be the most effective factor in promoting this (Hunter, 1996). The spatial arrangement and size of habitat patches are critical for some taxa; forest management practices should therefore aim to maintain spatial heterogeneity or complexity across the whole forest ecosystem (Cale and Hobbs, 1994).

There is a lack of information about the cumulative effects of habitat variables on small mammal populations which complicates the understanding of habitat availability through time (Pearce and Venier, 2005). Long-term ecological research into forest ecosystems is required in order to understand the population dynamics of small mammals in various habitat conditions.

CONCLUSION

Habitat characteristics were reflected in the diverse foliage profile and structural diversity of the study stands. Habitat preferences of the Asiatic chipmunk and Korean red-backed vole were significantly different between the stands. Population sizes of small mammals did not differ between the natural deciduous stand and Japanese larch plantation stand. In addition, there was a tendency towards a high abundance of adults in both stands.

SUGGESTIONS

Researchers suggest that future studies should focus not only on the differences in small mammal populations among forest types but also on the effects of forest type at different scales. The possible influences of the overall habitat quality of forest areas on small mammals should be the subject of further study.

ACKNOWLEDGEMENTS

This study was supported by the Korea Forest Research Institute, Republic of Korea (FE 0100-2011-01).

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