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Differences in Mammal Abundance of Post-Fire Silvicultural Management Stands Within the South Korean Pine Forest

[1]Eun-Jae Lee and [2]Shin-Jae Rhim
[1]Urban Planning Research Group, Daejeon Development Institute,
302-280 Daejeon, Korea
[2]School of Bioresource and Bioscience, Chung-Ang University, 456-756 Ansung, Korea

Abstract: Researchers examined difference in the abundance of mammals in post-fire silvicultural management stands within a pine forest in Samcheok, Gangwon province, South Korea, from 2008-2010. Researchers recorded the tracks of 12 mammal species, amur hedgehogs (*Erinaceus amurensis*), Japanese moles (*Mogera wogura*), raccoon dogs (*Nyctereutes procyonoides*), Siberian weasels (*Mustela sibirica*), European badgers (*Meles meles*), Bengal cats (*Prionailurus bengalensis*), wild boars (*Sus scrofa*), roe deer (*Caproelus pygargus*), water deer (*Hydropotes inermis*), Korean hares (*Lepus coreanus*), red squirrels (*Sciurus vulgaris*) and Siberian chipmunks (*Tamias sibiricus*). There were significant differences in the number of species and tracks linked to mammals among unburned, post-burned Japanese red pine planted and post-burned untreated stands. Of the 12 mammal species analyzed, six species were related to habitat variables in a stepwise approach with repeated measures. Long-term ecological research is needed to understand post-fire pine forest management.

Key words: Abundance, forest fire, mammals, pine forest, Korea

INTRODUCTION

Biotic and abiotic disturbances lead to extensive changes in the forest structure and composition. A variety of disturbance factors including herbivory, pathogens, human impact, weather events, climate change and fire have affected the formation, maintenance and function of forests (Abrams, 1992; Land and Rieske, 2006). These changes influence stand succession (Batista and Platt, 2003).

Fire is a key ecological process in many ecosystems (Andersen *et al*., 2003; Lindenmayer *et al*., 2008). Fires affect habitat components in many ways including the burning of woody vegetation, changes in the moisture and nutrient content of the forest floor seed production and more (Van Lear and Harlow, 2000). Fire reduces standing dead herbaceous vegetation and litter accumulation that can suppress herbaceous vegetation growth (Hulbert, 1988). The combination of overstory removal and burning may initiate earlier growth and greater production as a result of warmer soil temperatures, increased nitrogen availability and increased surface light intensity (Svejcar and Browning, 1988; Masters *et al*., 1993). Effects of fire on wildlife habitat are variable (Lanham *et al*., 2002). Changes in habitat following a forest fire strongly influence mammal population changes (Wilson and Carey, 2000; Converse *et al*., 2006). Species resilience or sensitivity to changes in the habitat may be linked to the degree of habitat specialization such that habitat generalists are less affected by changes than habitat specialists (Howell *et al*., 2000).

Some ecologists have suggested that landscape fires should be considered biological in nature, much like herbivory (Bond and Keeley, 2005) or decomposition (Pyne, 2007). A complex fire regime can create habitat complexities for wildlife by facilitating the development of different patches of regenerating vegetation following fires. Such habitat complexity provides a diversity of microclimates, resources and shelter from predators. The contrasting requirements of different species and communities within fire-prone landscapes make it difficult for those managing fire regimes of biodiversity conservation (Bowman and Murphy, 2010).

Since, post-fire changes in mammal communities are generally linked to vegetation structure and composition (Ojeda, 1989) fire events may result in strong changes in population as well as in the community structure of mammals (Whelan, 1995). There have been several large-scale pine forest fires in South Korea since the late 1990s. Extensive post-fire silvicultural management practices that lead to regeneration such as the removal of snags, downed trees, woody debris and the planting of Japanese red pine (*Pinus densiflora*) have been implemented in most of the burned areas (Lee, 2011).

Corresponding Author: Shin-Jae Rhim, School of Bioresource and Bioscience, Chung-Ang University, 456-756 Ansung, Korea

However, information regarding the impact of fire and post-fire management activities on mammal species in Korea is still lacking. In this study, researchers studied mammal abundance in pine forest stands impacted by different post-fire silvicultural management practices and a control stand in South Korea.

MATERIALS AND METHODS

Study area: The study area was located in the pine forest area (37°13'N, 128°18'E) of Samcheok, Gangwon province, South Korea. The elevation range was 300-500 m, the mean annual temperature was 11.8°C and the mean annual precipitation was 1,793 mm. The dominant tree species in the study area were Japanese red pine (*Pinus densiflora*), Mongolian oak (*Quercus mongolica*) and cork oak (*Q. variabilis*) (Lee *et al*., 2008). Human disturbances during the Korean war (1950-1953) including cutting and forest fires, led to the planting of Japanese red pines in this area. Prior to the forest fire, the forest in the study area was about 50 years old (Lee, 2011).

In April 2000, a fire burned thousands of hectares of pine forest in the study area. Researchers selected three types of plots for the study: unburned stands, post-burned Japanese red pine planted stands and post-burned untreated stands. All trees were damaged and dead in both of the burned stands. The forest conditions of the unburned and burned stands were similar prior to the fire. Furthermore, the stands did not receive different silvicultural treatment due to inherent differences impacting whether or not they were burned and whether or not they were logged after burning.

The experimental design was a random-block design with replicate blocks of unburned and burned stands that were subjected to different post-fire silvicultural management practices at each of the three locations (blocks) in the study area. These nine study sites were selected according to operational scale, proximity and reasonable grouping into blocks based on location and elevation. Study sites within a block of each other were spatially segregated in order to enhance statistical independence. In a block, the three study sites were 1.0-2.5 km apart.

Field survey: Researchers identified a sample area that was 1 km long and 50 m wide along the nine study sites. In August 2009, researchers measured five variables describing stand structure attributes, two variables describing downed tree characteristics and woody seedlings at 100 random sampling points in each study site. Researchers used a 5.56 m radius circle (0.01 ha) as the vegetation plot and recorded the number of standing trees, the diameter of trees >6 cm diameter at breast height, the estimated percentage of canopy cover, the estimated percentage of underground shrubs <50 cm off the ground, the volume of downed coarse woody debris, the number of downed trees on the ground and the number of woody seedlings (Rhim and Lee, 2007).

Researchers counted mammal trails for amur hedgehogs (*Erinaceus amurensis*), Japanese moles (*Mogera wogura*), raccoon dogs (*Nyctereutes procyonoides*), Siberian weasels (*Mustela sibirica*), European badgers (*Meles meles*), Bengal cats (*Prionailurus bengalensis*), wild boars (*Sus scrofa*), roe deer (*Caproelus pygargus*), water deer (*Hydropotes inermis*), Korean hares (*Lepus coreanus*), red squirrels (*Sciurus vulgaris*) and Siberian chipmunks (*Tamias sibiricus*). Researchers counted the fresh tracks in each transect. Censuses were performed on the study stands from April 2008 to October 2010 at 2-3 months intervals. A total of 13 field censuses were performed in each stand during the study period.

Data analysis: Reserachers examined the stand structure attributes, downed tree characteristics and woody seedling variables through randomized-block Analysis of the Variables (ANOVA) (Zar, 1984). Researchers used the number of tracks recorded per sampling day in each transect as an index of mammal abundance. Researchers excluded repeat counts of the same track at crossing transects (Rhim and Lee, 2007). The abundance of mammal tracks was analyzed by repeated measures ANOVA with three managed and three replicate stands for each management type and 13 measurements taken over time. Duncan's Multiple Range Test (DMRT) was used in post-hoc comparisons of the mean values.

Researchers analyzed the effect of habitat structure on mammal track counts using a stepwise approach. Stepwise multiple regression analysis was used to determine which variables resulted in the greatest amount of variation in species abundance. The first variable entered into the stepwise model accounts for the greatest variability. A variable may be removed if the variables are appropriately correlated. A variable was selected for the model if the $p<0.10$. After initially employing the stepwise procedure to identify significant variables, researchers analyzed each overall model again using multiple regression analysis.

RESULTS

With the exception of the number of standing trees, all measured variables for stand structure attributes, downed tree characteristics and woody seedlings were significantly different (randomized-block ANOVA, $F_{2,4}$ =

Table 1: Stand structure attributes, downed tree characteristics and woody seedling counts in post-fire silvicultural management stands in the South Korean pine forest as well as the results of a randomized-block ANOVA (*p<0.05, **p<0.01)

	Stands			
Variables	Unburned	Post-burned Japanese red pine planted	Post-burned untreated	$F_{2, 24}$
No. of standing trees/ha	437.68±79.390[a]	39.71±2.1400	391.35±42.670	2.31
Basal area (m^2/ha)	5.31±1.2400	0.46±0.1300	3.72±0.5400	5.13*
Canopy cover (%)	61.25±6.7800	-	15.39±0.2300	24.29**
Shrub cover (%)	34.29±5.1800	75.36±9.1200	52.05±7.3900	12.67**
Volume of downed cwd[b] (m^3/ha)	1.05±0.1200	3.21±0.6700	5.75±0.9800	15.21**
No. of downed trees/ha	154.31±34.230	34.36±10.620	491.67±69.380	23.28**
No. of woody seedlings/ha	2317.69±458.32	5753.39±689.21	4029.84±896.57	13.24**

[a]Mean±SE; [b]cwd = coarse woody debris

Table 2: Total number of mammal tracks within post-fire silvicultural management stands in the South Korean pine forest from April 2008 to October 2010

Tracks	No. of species	No. of tracks	Total
Unburned			137 tracks of 11 species
1	11	29	
2	10	48	
3	11	60	
Post-burned Japanese red pine planted			226 tracks of 7 species
1	7	91	
2	7	65	
3	5	70	
Post-burned untreated			145 tracks of 12 species
1	12	41	
2	11	50	
3	11	54	

5.13-24.29, p = 0.05-0.01) (Table 1). Basal area and canopy cover were higher for unburned stands compared to the burned stands (DMRT: p = 0.05). Shrub cover and the number of woody seedlings were higher in post-burned Japanese red pine planted stands (p = 0.05). In post-burned untreated stands, the volume of downed coarse woody debris and the number of downed trees were higher (p = 0.05).

Researchers had 117 total tracking days at nine study sites (13 tracking days per study site) during the sample period. Researchers recorded 507 tracks of 12 species of mammals from 2008-2010 (Table 2). The mean number of mammal species (repeated measures ANOVA, $F_{2, 24}$ = 16.12, p<0.01) and tracks ($F_{2, 24}$ = 22.60, p<0.01) per sampling day were significantly different among the stands (Table 3). The mean number of species was higher in post-burned untreated stands when compared to the other stands (p = 0.05). The mean number of tracks was higher in post-burned Japanese red pine planted stands (p = 0.05).

There were differences in the species present among the stands. Researchers also detected significant differences in the number of tracks per sampling day among unburned and post-fire silvicultural management stands for 9 of the 12 mammal species (Table 4). In unburned stands, mean track numbers for Amur hedgehogs, raccoon dogs, European badgers, wild boars, roe deer and red squirrels were >2 times greater than those found both burned stands. In post-burned untreated stands, the number of tracks identified for Siberian chipmunks was two times greater than that in unburned and post-burned Japanese red pine planted stands. The track density of water deer and Korean hares was >5 times that of the post-burned Japanese red pine planted stands. The most abundant species in the study area was water deer while the least abundant was siberian weasels.

Table 3: Mean number (±SE) of mammal species and tracks per sampling day (n = 13 tracking day/stand) according to censuses of post-fire silvicultural management stands in the South Korean pine forest from April 2008 to October 2010 as well as the results from repeated measures ANOVA (*p<0.05, **p<0.01)

	Stands			
Variables	Unburned	Post-burned Japanese red pine	Post-burned planted untreated	$F_{2, 24}$
No. of species	2.28±0.25	1.67±0.06	2.83±0.21	16.12**
No. of tracks	3.51±0.56	5.79±0.51	3.72±0.35	22.60**

Table 4: Mean number (±SE) of tracks per sampling day (n = 39 tracking day/stand) of 12 mammal species according to censuses of post-fire silvicultural management stands in the South Korean pine forest from April 2008 to October 2010 as well as the results from repeated measures ANOVA (*p<0.05, **p<0.01)

	Stands			
Species	Unburned	Post-burned Japanese red pine planted	Post-burned untreated	$F_{2, 24}$
Amur hedgehogs	0.18±0.04	-	0.05±0.02	26.31**
Japanese moles	0.23±0.05	-	0.17±0.04	25.29**
Raccoon dogs	0.30±0.09	0.07±0.01	0.20±0.05	188.66**
Siberian weasels	0.05±0.02	-	0.11±0.04	1.75
European badgers	0.25±0.03	-	0.08±0.02	14.83*
Bengal cats	0.01±0.01	0.08±0.02	0.11±0.04	1.42
Wild boars	0.56±0.04	-	0.14±0.03	34.07**
Roe deer	0.13±0.04	0.05±0.02	0.06±0.01	2.63
Water deer	0.27±0.05	3.74±0.08	0.25±0.04	103.73**
Korean hares	0.32±0.01	1.79±0.10	0.20±0.04	88.64**
Red squirrels	0.08±0.01	-	0.04±0.01	8.89*
Siberian chipmunks	1.13±0.18	0.06±0.01	2.31±0.31	92.01**

Of the 12 mammals species analyzed, six species exhibited one or more significant correlations with habitat variables according to the stepwise approach (Table 5). Canopy cover (Bonferroni test; Japanese moles, p = 0.001; raccoon dogs, p = 0.002) and basal area (Japanese moles, p = 0.005; raccoon dogs, p = 0.005) were the most

Table 5: Results of the stepwise approach for stand structure attributes, downed tree characteristics and woody seedling effects on mammals in the post-fire silvicultural management stands of the South Korean pine forest from April 2008 to October 2010

Species	First variables	Coefficient	Partial r^2	Second variable	Coefficient	Partial r^2	Model r^2	Model p
Japanese moles	Canopy	0.0021	0.74	Basal area	0.0254	0.41	0.76	0.001
Raccoon dogs	Canopy	0.0037	0.72	Basal area	0.0368	0.44	0.71	0.005
Wild boars	Shrub	0.0015	0.81	cwd[a]	0.0429	0.47	0.83	0.001
Water deer	Shrub	0.0049	0.69	Woody seedling	0.0624	0.51	0.73	0.005
Korean hares	Shrub	0.0068	0.57	-	-	-	-	-
Siberian chipmunks	Downed tree	0.0025	0.73	Shrub	0.0347	0.44	0.72	0.005

[a]cwd = coarse woody debris

sensitive variables with respect to the track density of Japanese moles and raccoon dogs. For these two species, the first variables yielded r^2>0.72 and the overall model yield r^2>0.71. Wild boars were most sensitive to shrub cover (p = 0.001) and the volume of coarse woody debris (p = 0.005). Shrub cover (p = 0.002) and the number of woody seedlings (p = 0.007) were sensitive variables for water deer. Korean hares were positively associated with shrub cover (p = 0.003). For Siberian chipmunks, the number of downed trees (p = 0.001) and shrub cover (p = 0.005) were sensitive variables.

DISCUSSION

Fires can result in the creation of new habitats that are made available to community species for potential immigration. Fire also create a sequence of microhabitats that represent a function of time following the fire (plant secondary succession) and are preferentially selected by different mammalian species (Fox, 1982, 1990). In the study area, the forest canopy was opened up after forest fire. Canopy conditions can also become more open due to the post-fire management practice of removing damaged trees. Post-fire silvicultural practices are expected to result in the immediate reduction of woody debris (Arno *et al*., 1995).

Changes in the vegetation structure due to post-fire silvicultural practices were predicted based on vegetation development in gaps and openings in the forest, providing spatial variability in microhabitats and resources (Homyack *et al*., 2004). Management and habitat variables influence the abundance of mammal tracks because each variable can be manipulated via silvicultural practices. Researchers found that canopy cover, basal area, shrub cover, volume of coarse woody debris, number of woody seedlings and number of downed trees were the habitat components most strongly related to mammal abundance.

Researchers identified marked variation in mammal species' response to habitat variables based on post-fire silvicultural management practices in the study area. Shrubs were linked to wild boars, water deer, Korean hares and siberian chipmunks (Table 5). Wild boars used the shrubs as resting sites (NPA, 1999). Korean hares preferred shrubs available in the form of young trees and saplings (Genoways, 1990). Water deer, Korean hares and Siberian chipmunks likely used the understory cover and small shrub stems as a cover from predation and as food (Yoon, 1994).

Compared to the burned stands, the unburned stand provided a more suitable habitat for mammal species. Only the water deer and the Korean hares preferred post-burned Japanese red pine planted stands. The results indicate that mammal abundance is influenced by post-fire silvicultural management practices. Forest managers can manipulate habitat variables using post-fire management practices.

CONCLUSION

Mammal species' response to fire and post-fire silvicultural practices is difficult to generalize. Successional processes will continue to modify these post-fire habitats. It must be understood that the mammal community is not responding to any temporal axis. Rather, the mammals are responding to vegetation succession which in and of itself may or may not be responding directly to time. There is a need to carefully assess the ecological effects of post-fire practices over a longer period of time.

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