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Seasonal Movements and Home Range Sizes of Korean Field Mouse *Apodemus peninsulae* in Unburned and Post-Fire Pine Planted Stands Within a Pine Forest

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Abstract: The seasonal movements and home ranges of Korean field mice *Apodemus peninsulae* in unburned and post-fire pine planted stands within a pine forest were studied via the radio-tracking of 56 mice for 12 months in South Korea. Seasonal movement distances were significantly longer in the post-fire pine planted stand than in the unburned stand in each season and did not differ between males and females over the 4 seasons. In both stands, the activity patterns and duration of movement also differed significantly over the 4 seasons. Home range sizes were largest in autumn and smallest in Winter. Seasonal home range sizes were significantly larger in the post-fire pine planted stand than in the unburned stand in each season. No differences in home range size between males and females were noted in either of the experimental stands. Post-fire silvicultural practices affect forest-floor small rodents in the early stages after the planting of pine seedlings. Studying space use patterns over longer time periods will provide a better sense of the long-term impacts of post-fire silvicultural practices on small rodents within pine forests.

Key words: *Apodemus peninsulae*, korean field mouse, seasonal movement, telemetry, pine forest

INTRODUCTION

Studies of habitat use by mammals are crucial for understanding the mechanisms relevant to their distribution and abundance. Habitat use has been regarded as a critical factor in community dynamics (Halle and Stenseth, 2000). Additionally, patterns of space use are fundamental to animal ecology (Skliba *et al*., 2009). Generally, home range size is regarded as one indicator of habitat quality (Hubbs and Boonstra, 1998). The dynamic nature of home ranges has been recognized as having important consequences for population dynamics and other aspects of an animal's ecology (Moorcroft *et al*., 2006; Wang and Grimm, 2007). Animal space use is physically limited due to structures imposed by the modalities of locomotion and by the medium through which locomotion takes place.

For small rodents, patterns of movement and home ranges frequently reflect variations in the availability of resources in space and time (Stapp, 1997; Vieira *et al*., 2005). Some variables that might potentially affect movement include habitat heterogeneity, moisture regimes, habitat quality, population density, sex, age and season (Ostfeld, 1990; Getz *et al*., 2005; Steinmann *et al*., 2005; Moorhouse and Macdonald, 2008). Moreover, most small rodents are known to prefer areas of high structural complexity (Rhim and Lee, 2001) as these areas presumably provide greater protection from predators and food availabilities (Gliwicz, 1997; Manson and Stiles, 1998). Many small rodent species inhibit woodlands where dense vegetation would seem to provide a structurally complex environment. The density of cover offered by vegetation and tunnel systems which is crucial for protecting small rodents from both predators and harsh weather can also vary considerably over areas and also changes seasonally (Lee, 2011).

Additionally, forest fires are an important aspect of the natural and anthropogenic disturbance regime in forest ecosystems, causing alternations to natural landscapes (Smith, 2000). This heterogeneous landscape may alter the spatial dynamics of species at the regional scale and consequently, their local scale distribution and abundance (Ricklefs, 2008). Changes in habitat structure and function caused by forest fires should profoundly influence small rodent populations (Converse *et al*., 2006). Information regarding the impacts of fire and post-fire silvicultural practices on small rodents should prove useful for biodiversity conservation and management in areas in which forest fires occur.

Most of the pine *Pinus* sp. forest in South Korea is planted young forest (<30 years). Forest fires occur frequently in South Korea and a great many large-scale forest fires have occurred since the 1990s. Post-fire management practices for regeneration have been implemented in burned areas (Lee, 2011). Post-fire silvicultural practices such as the removal of snags,

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downed trees and woody debris can alter a broad variety of forest ecosystem processes (Ford *et al*., 1999). Changes in the structure and function of post-fire pine planted stands have been poorly documented and discussed in the context of the spatial behavior of small rodents.

The Korean field mouse *Apodemus peninsulae* is one of the major forest-dwelling small rodent species in South Korea (Lee *et al*., 2008). This mouse is a critical component of the trophic relationships inherent to forest ecosystems which are demographically influenced by the complexity of and changes in habitat structure (Eo *et al*., 2009). However, little information is currently available regarding the movements and home ranges of this rodent. In this study, researchers compared the seasonal movements and home range sizes in 50 years old unburned and 7 years old pine planted stands after a forest fire and evaluate the influence of post-fire management practices on the spatial behavior of *A. peninsulae* in a South Korean pine forest.

MATERIALS AND METHODS

This study was conducted in a pine forest area in Mt. Gumbong, Samchuk, Gangwon province, South Korea (37°13'N, 128°18'E), between September 2008 and August 2009. At this location, the elevation range of the study area was 250-400 masl. The mean annual temperature was 11.8°C. The mean annual precipitation was 1,793 mm and mean snow depth was 57 cm. The dominant tree species in the study area was the Japanese red pine *Pinus densiflora* (Lee *et al*., 2008). This forested area was also disturbed by human activity during the Korean War (1950-1953) such as cutting, forest fire, etc. After these disturbances, Japanese red pine was planted in this area. The unburned forest was, therefore, approximately 50 years old.

A fire in April 2000 burned thousands of hectares of pine forest in the study area. Researchers selected two types of study sites, the 50 years old unburned and the post-fire Japanese red pine planted stands within a pine forest. These seedlings were 7 years old during the study. In the burned area, all the trees were damaged and dead. The post-fire silvicultural practices included removing all damaged trees, coarse woody debris and understory cover. The number of standing wood/ha, volume of downed coarse woody debris, number of downed trees/ha and number of woody seedlings/ha were significantly higher in the post-fire pine planted stand than in the unburned stand. However, the basal area and vegetation coverage were higher in the unburned stand (Lee, 2011).

Researchers placed a grid (100×100 m) of Sherman live-traps with an inter-trap spacing of 10 m to capture and radio-collared specimens of the Korean field mouse *Apodemus peninsulae* in both study sites. The traps were baited with peanuts and peanut butter and checked every morning thereafter until all available radio-collars had been fitted onto the mice. Upon capture, all individuals were weighed, sexed and assigned to an age class (Lee *et al*., 2008; Lee, 2011).

Researchers radio-collared 56 individuals with adjustable necklace transmitters (PIP 2 transmitters, 1.2 g, Biotrack Ltd. Wareham, Dorset, UK) in the unburned (27 individuals) and the post-fire pine planted (26 individuals) stands during the study period. Standard radio tracking methods were used (White and Garrot, 1990; Marby and Stamps, 2008). Researchers determined the diurnal and nocturnal location of *A. peninsulae* by following the radio-collars' signals until researchers were directly above them using a Telonics TR-4 receiver with a directional three-element Yagi antenna (150-152 MHz, Biotrack, Ltd. Warehem, Dorset, UK) and a hand-held GPS (Garmin GPS-V plus).

Radio tracking was carried out in 8 h sessions (07:00-15:00, 15:00-23:00 and 23:00-07:00) separated by 8 h breaks. Researchers completed four radio-tracking periods with 45 sessions in each season; Autumn (15 September to 30 October), Winter (27 November to 12 January), Spring (18 April to 27 May) and Summer (1 July to 14 August). Each of the radio-tagged mice was located 20 times per week using home-in technology (Marby and Stamps, 2008) throughout the study period.

From the 53 studied animals, researchers obtained a total of 2,417 radio fixes during the study. The home ranges of *A. peninsulae* were calculated via the Minimum Convex Polygon Method (MCP; Samuel and Garton, 1985) using 95% MCP. The 95% MCP is a consecutive estimate which minimizes the risk of including areas that are never used by the individuals.

The objective of this analysis was to estimate the distance of movement as well as the size and spacing of the home ranges for each radio-tagged mouse. Researchers employed data from these radio-tagged individuals to calculate the distances moved per hour. In each season, seasonal movement distances and home ranges werecompared between sexes via a Mann-Whitney U-test. Seasonal movement distances and home range sizes were compared between sites and seasons using a Kruskal-Wallis test (Zar, 1999). Pearson correlation analysis was also employed to evaluate the relationship between the length of daytime and the duration of the mice's movement in each of the four seasons.

RESULTS AND DISCUSSION

The 56 individuals were radio-collared during the study period; however due to transmitter failure, 45 individuals were included in the analysis. Six to seven individuals were radio-collared in each study site in each season. The mean body weights were higher in the unburned stand than in the post-fire pine planted stand except in Summer (Mann-Whitney U-test; Autumn, Z = -2.24, p = 0.01; Winter, Z = -3.16, p = 0.01; Spring, Z = 1.93, p = 0.01; Table 1). The transmitters apparently did not affect the individual specimens negatively as the body masses of the mice did not decline while the mice were wearing the radio-collars (Z = -4.37, p = 0.01).

Researchers observed a great deal of individual variation in movement. Seasonal movement distances varied from 3.09-48.28 m per hour. In both stands, the distances moved also differed significantly among the seasons (Kruskal-Wallis test; unburned stand, H = 16.63, p = 0.01; post-fire pine planted stand, H = 17.17, p = 0.01). The mice moved the longest distances in Autumn and the shortest distances in Winter. The seasonal movement distances of *A. peninsulae* were significantly longer in the post-fire pine planted stand than in the unburned stand in each season (Mann-Whitney U-test; Z = -2.80~1.33, p = 0.01~0.02, Table 2). However, no differences were detected in the seasonal movement distances of males and females during the seasons in both stands (Z = -1.44~1.75, p = 0.08~0.39, Table 3).

Table 1: Number of radio-collared *Apodemus peninsulae* in 50 years old unburned and 7 years old pine planted stands after forest fire within a pine forest at Samchuk, Gangwon province, Korea

	Stands					
	Unburned			Post-fire pine planted		
Seasons	Male	Female	Body weight	Male	Female	Body weight
Autumn	5	2	36.34±1.12*	4	5	33.36±3.59
Winter	4	3	28.01±2.80	3	4	24.07±1.49
Spring	5	2	34.10±2.44	4	3	31.70±1.28
Summer	3	3	31.38±1.06	4	2	38.90±3.03

*Mean±SE

Table 2: Seasonal movement distances (meters per hour) of *Apodemus peninsulae* in 50 years old unburned and 7 years old pine planted stands after forest fire within a pine forest at Samchuk, Gangwon Province, Korea

	Stands			
Seasons	Unburned	Post-fire pine planted	Z	p-value
Autumn	12.20±2.45 (5)*	48.28±6.62 (6)	1.33	0.02
Winter	3.09±0.24 (6)	5.40±0.23 (6)	-2.80	0.01
Spring	15.29±1.60 (6)	25.23±1.72 (6)	-2.48	0.01
Summer	6.55±0.36 (5)	19.44±3.05 (5)	-2.51	0.01

*Mean±SE (No. of individuals)

The mice were most active in Autumn and least active in the Winter. The maximum movement distance was 90.6 m per hour during 19:00-20:00 in the post-fire pine planted stand in Autumn. In the Winter, the maximum movement distance was 9.7 m per hour during 17:00-18:00 in the post-fire pine planted stand (Fig. 1). Additionally, the durations of movement were found to be correlated with day length (Pearson correlation analysis, r = -0.98,

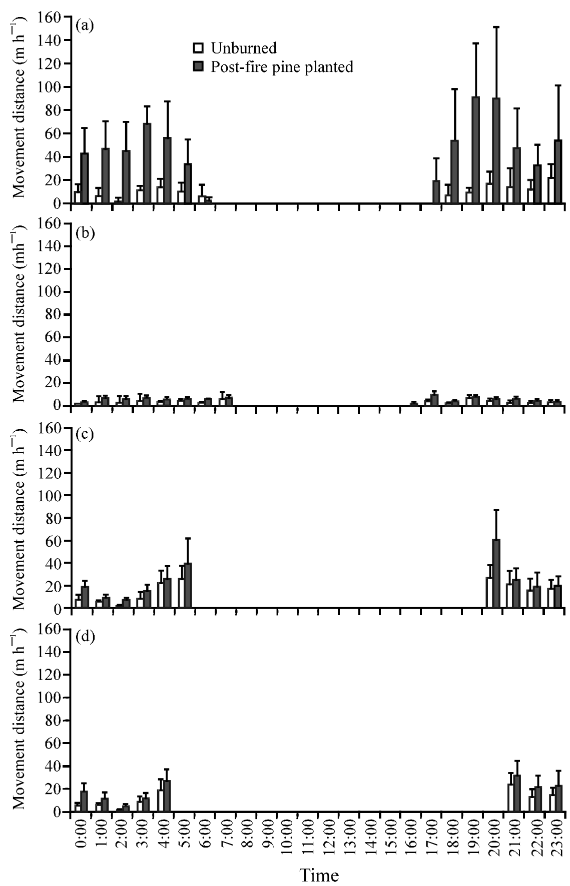

Fig. 1: Activity patterns (movement distance per hour) of *Apodemus peninsulae* in a) Autumn; b) Winter; c) Spring and d) Summer in in 50 years old unburned planted stand and 7 years old planted pine seedling stands after a forest fire at Samchuk, Gangwon province, Korea

Table 3: Seasonal movement distances (meters per hour) of male and female of *Apodemus peninsulae* in 50 years old unburned and 7 years old pine planted stands after forest fire within a pine forest at Samchuk, Gangwon province, Korea

	Stands							
	Unburned				Post-fire pine planted			
Seasons	Male	Female	Z	p-value	Male	Female	Z	p-value
Autumn	16.10±0.79 (3)	6.34±0.73 (2)	-1.44	0.15	54.33±3.78 (3)	40.12±8.41 (3)	0.89	0.37
Winter	3.44±0.35 (3)	2.74±0.14 (3)	1.31	0.19	5.51±0.34 (3)	5.18±0.13 (3)	1.31	0.19
Spring	18.15±1.07 (4)	9.56±0.47 (2)	-1.62	0.11	23.03±2.15 (3)	28.73±0.92 (3)	1.75	0.08
Summer	7.15±0.52 (2)	6.15±0.32 (3)	0.87	0.39	23.77±2.57 (3)	12.94±1.34 (2)	1.44	0.15

*Mean±SE (No. of individuals)

$p = 0.02$) which varied among the four seasons (Autumn, 11.40±0.40 h; Winter, 9.37±0.20 h; Spring, 13.08±0.34 h and Summer, 14.25±0.08 h).

The home range sizes of *A. peninsulae* were determined by sex and season. The home range size varied from 125.85-9 to 152.24 m^2. In both stands, home range sizes were largest in Autumn and smallest in Winter. Seasonal home range sizes were significantly larger in the post-fire pine planted stand than in the unburned stand in each season (Mann-Whitney U-test; Z = -4.02~-3.23, $p = 0.01$). In each stand, the home range sizes also differed significantly among seasons (Kruskal-Wallis test; unburned stand, H = 16.15, $p = 0.01$; post-fire pine planted stand, H = 12.56, $p = 0.01$, Table 4). In both stands, no differences in home-range sizes were noted between males and females in each season (Mann-Whitney U-test; Z = -1.58~2.75, p = 0.06~0.50, Table 5).

The study is to the best of the knowledge, the first to document the seasonal differences in movement distance and home range size of the Korean field mouse *A. peninsulae* in South Korea. The movements of this species varied among seasons and between stands. Like many other species of rodents for which light is believed to the main factor controlling the onset of their activity (Montgomery and Gurnell, 1985), the *A. peninsulae* were nocturnal. The temporal pattern of activity in these mice may be related to day length. In the longer day length seasons, the activity of the mice increased. Animals cope with seasonal environments by using physiological and behavioral strategies. While large animals can move large distances (Alerstam *et al*., 2003), small mammals must either endure the environmental conditions in the habitat in which they live or bear the high costs of dispersal, frequently to unknown areas (Schradin and Pillay, 2006). Perception of the environment by animals and strategies used for locating resources can be deduced from movement patterns (McIntyre and Wiens, 1999).

Table 4: Seasonal home range estimations (m^2) of *Apodemus peninsulae* by 95% MCP (Minimum Convex Polygon) in 50 years old unburned and 7 years old pine planted stands after forest fire within a pine forest at Samchuk, Gangwon province, Korea

	Stands			
Seasons	Unburned	Post-fire pine planted	Z	p-value
Autumn	1,658.25±298.96 (5)*	9,152.24±2,571.06 (6)	-3.23	0.01
Winter	125.85±30.720 (6)	1,478.25±413.3600 (6)	-4.02	0.01
Spring	2,014.09±418.73 (6)	7,259.25±2,206.28 (6)	-3.38	0.01
Summer	921.24±217.21 (5)	3,825.25±1,188.10 (5)	-4.01	0.01

*Mean±SE (No. of individuals)

During the Winter ambient temperature is low, snow is present and food availability for herbivores is reduced. In order to cope with or energetically evade unfavorable environmental conditions, animals evidence a variety of distinct behavioral adaptations (Sailer and Fietz, 2009). Cold periods are energetically damaging for small mammals and energetic costs can be reduced by restricting movement activities outside the insulating nest to a minimum (Yletyinem and Norrdahl, 2008). In the Winter, it was evident that movement was profoundly restricted after a snow fall. The restricted movement was linked to the low level of activity at this time which probably reflected the need to conserve energy, the reduction in availability of high quality food and the thermoregulatory advantages of remaining in a nest (Bubela *et al*., 1991).

The reduction in home range size during the Summer compared with that in the Autumn and Spring may be explained by the population density of the mice. As the density of many rodent populations increases, average home range size is reduced (Ostfeld *et al*., 1993). The Summer season density of this population (3.87±1.14 ha^{-1}) was nearly double that seen in the Autumn (1.94±0.76 ha^{-1}) and Spring season (1.58±0.62 ha^{-1}) in the study area (Lee, 2011). The smaller home ranges observed at higher density may have been due to greater interference among individuals and the subsequent contraction of home range (Abramsky and Tracy, 1980).

An earlier study determined that the understory cover and woody debris were the habitat components most strongly related to sparse rodent density in burned pine forest (Lee *et al*., 2008). In the study area, greater more amounts of understory cover and woody debris were detected in the unburned than the post-fire pine planted stands. The mice may delay their movement to spend

Table 5: Seasonal home range estimations (m^2) of males and females of *Apodemus peninsulae* by 95% MCP (Minimum Convex Polygon) in 50 years old unburned and 7 years old pine planted stands after forest fire within a pine forest at Samchuk, Gangwon province, Korea

	Stands							
	Unburned				Post-fire pine planted			
Seasons	Male	Female	Z	p-value	Male	Female	Z	p-value
Autumn	2,543.92±56.910 (3)	408.72±31.550 (2)	-1.08	0.06	13,443.15±386.520 (3)	6,875.53±243.65 (3)	-1.58	0.11
Winter	224.93±95.770 (3)	172.67±115.52 (3)	2.75	0.49	2,160.74±989.910 (3)	1,882.81±43.47 (3)	0.86	0.40
Spring	3,368.19±73.620 (4)	1,326.41±626.73 (2)	0.59	0.10	7,883.42±2,198.16 (3)	10,752.65±3,486.48 (3)	0.74	0.50
Summer	1,491.81±283.73 (2)	1,074.83±433.80 (3)	1.21	0.31	6,175.91±3,180.41 (3)	2,298.98±465.21 (2)	-0.85	0.08

*Mean±SE (No. of individuals)

relatively more time in high-quality habitats or move quickly through low-quality habitats (Cameron and Spencer, 2008). The smaller movement distance in the unburned stands could be related to habitat quality. The movements of *A. peninsulae* were longer in lower quality habitat (post-fire pine planted stand) than in higher-quality habitats (unburned stand).

The size of small rodents' home ranges should be determined almost wholly by the distribution of resources weighted for travel cost and secondarily by the behavioral strategy underlying its selection of habitat. Conversely, the distribution of resources may have affected the spatial movement and home range size of the mice (Mitchell and Powell, 2004; Endries and Adler, 2005). The larger size of home ranges in the post-fire pine planted stand suggests that the unburned stand is a higher-quality habitat. One characteristic that may reflect habitat quality is the differences in vegetation structure between stands.

The relationship between a small rodent and the resources that limit it changes over time, corresponding to resources needs to variation in foods to changes in movement activity and to seasonal changes in environment. In reality, interactions among animals and the changes they impose on the resources they consume are likely to strongly affect the characteristics and spatial distribution of home ranges within a population (Ims, 1987; Michell and Powell, 2004).

CONCLUSION

Patterns of space use of the Korean field mouse *Apodemus peninsulae* differed significantly among the four seasons. Additionally, the movements and home range sizes of the mice differed between the unburned and the post-fire pine planted stands. Post-fire silvicultural practices appear to affect forest-floor small rodents profoundly in the early stages after pine seedling plantation. Studying space use patterns over longer time periods should be expected to provide a better sense of the long-term impacts of post-fire silvicultural practices on small rodents in pine forest environments.

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