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Ecological factors influencing the winter abundance of mammals in temperate forest

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Abstract. We examined the ecological factors influencing winter abundance of mammals in the natural deciduous forest and the Japanese larch, *Larix leptolepis*, plantation in Mount Maehwa, Hongcheon, South Korea. We counted the tracks of five mammal species – the Korean hare, *Lepus coreanus*; the raccoon dog, *Nyctereutes procyonoides*; the Siberian weasel, *Mustela sibirica*; the water deer, *Hydropotes inermis* and the wild boar, *Sus scrofa* – in the snow from November 2013 to February 2014. We showed that the mean basal area, canopy cover and shrub cover were significantly higher in the Japanese larch plantation than in the natural deciduous forest. The winter abundances of Korean hares, raccoon dogs and water deer were higher in the Japanese larch plantation than in the natural deciduous forest. The results of stepwise analysis revealed that the winter abundances of four species were significantly correlated with ≥ 1 of the habitat variables. The winter abundances of Korean hares, water deer and wild boars were significantly correlated with shrub cover. The winter abundances of Korean hares, raccoon dogs and wild boars were significantly correlated with fallen logs; and the winter abundance of water deer was significantly correlated with canopy cover. For all of the investigated species, the preferred winter habitat was the Japanese larch plantation, with dense shrub cover and high number of fallen logs. Our results indicate that for planning conservation and forest management strategies for mammal species, the preferred forest habitat variables must be taken into consideration.

Key words: Japanese larch plantation, natural deciduous forest, track

Introduction

Mammals, especially larger-bodied species (> 3 kg body weight), are particularly prone to population declines because of a wide range of anthropogenic threats, such as habitat loss, poaching, forestry operations, pollution and degradation (Lee et al. 2010, Pillay et al. 2011). These threats have resulted in population declines and range contractions of many species globally (Cardillo et al. 2005, Morrison et al. 2007). Therefore, there is a need for greater clarify in our understanding of the impact of anthropogenic activities on natural ecosystems. Most mammals interact with their habitats in important and complex ways (Anderson & Katz 1993). Studies on the occurrence of mammals in relation to habitat characteristics have been conducted (Verner et al. 1986, Rhim & Lee 2007, Kolowski & Alonso 2010). However, ecological factors influencing the winter abundance of mammals in temperate forest of South Korea have not been intensively studied.

Since many mammal species are declining, a better understanding of the status of populations in relation to prevailing environmental conditions is essential for informing their management and conservation (Smallwood & Fitzhugh 1995). However, standardized monitoring programs exist for only a few mammal species globally. In snow-bound areas, the use of field tracks to estimate animal abundance is a traditional and frequently used technique (Rhim & Lee 2007, Møller & Mousseau 2013). Field track census data can be adjusted for the time during which field signs have accumulated, and also according to the site (Beauvais & Buskirk 1999).

In South Korea, ≥ 60 % of land cover is forest. Most of these forests are young (< 50 years), and include natural forests and plantations (Korea Forest Service 2012). Elucidation of the associations between mammals and associated habitat conditions is an important issue for forest management (St-Laurent et al. 2008). However, there is lack of information on mammal ecology in South Korean forest ecosystems. When planning conservation and management strategies for mammal species, basic information on abundance, distribution and habitat use patterns in relation to different climatic conditions and habitat types must be taken into conservation.

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Different species of mammals can be identified from tracks and signs by examining various characteristics of these signs (Salvador et al. 2011), for example, movement direction and topography. However, few studies on mammal distribution and habitat use have been conducted in winter. Winter is a period of physiological stress for mammals, and affects important processes such as population dynamics (Borkowski & Ukalska 2008). Moreover, forest damage by many herbivores is most serious in winter (Gill 1992). Therefore, elucidation of the factors influencing winter abundance is an important aspect of mammal conservation and management strategies.

In the present study, we hypothesized winter mammal abundance would be influenced by habitat variables in the two land use types. We analyzed (1) the patterns of relative mammal abundance in the natural deciduous forest and the Japanese larch plantation; (2) differences in habitat variables within and between forest types; and (3) the relative importance of different habitat variables as ecological factors on the winter abundance of mammals.

Material and Methods

We collected data between November 2013 and February 2014, in the natural deciduous forest and the Japanese larch, *Larix leptolepis*, plantation located within the national forest of Mount Maehwa (37°39′43″ N to 37°40′14″ N and 127°52′11″ E to 127°52′34″ E), Hongcheong, Gangwon Province, South Korea. The altitude of the study area ranged from 200 m to 300 m a.s.l. The dominant tree species in the natural deciduous forest was the Mongolian oak, *Quercus mongolica*. The Japanese larch stand was planted in the 1960s (Kang et al. 2013). We selected two study sites in the natural deciduous forest and two study sites in the Japanese larch plantation. In each study site, we established ten transects (length 100 m, width 10 m). Each transect was spatially separated from other transects by a distance of 500 m.

In January 2014, we measured seven habitat variables describing vegetation structure at 50 random sampling points in each of the study sites. We randomly established circles (diameter, 5.64 m) (Lee et al. 2008). Within each circle, we recorded the stand characteristics, including number of standing trees, basal area of standing trees, tree diameter at breast height (DBH), number of snags and number of fallen logs. We also measured the canopy and shrub covers (%) within each of the circles (Rhim 2013).

We counted the mammal trails of five mammal species – the Korean hare, *Lepus coreanus*; the raccoon dog, *Nyctereutes procyonoides*; the Siberian weasel, *Mustela sibirica*; the water deer, *Hydropotes inermis*; and the wild boar *Sus scrofa* – in snow from November 2013 to February 2014, on each morning after a snowfall had occurred during the previous evening (Hansson 1994). We recorded the fresh tracks in new snow. In each of the four study sites, we conducted eight snow-tracking sessions during the study period. We used the number of tracks recorded per sampling day in each site as an index of the winter abundance of mammals (Rhim & Lee 2007). We determined the mammal species richness based on the total number of species detected by using all of the field tracks.

We performed statistical analyses by using the SPSS statistical package for Windows. We compared habitat variables between the natural deciduous forest and the Japanese larch plantation by using multivariate analysis of variance. We converted track counts to

Table 1. Habitat variables of the four study sites in the natural deciduous forest (ND) and the Japanese larch, *Larix leptolepis*, plantation (JP) in Mount Maehwa, Hongcheon, South Korea.

	Natural deciduous forest (ND)[a]				Japanese larch plantation (JP)[a]				F^b
	ND1	ND2	Mean	SE	JP1	JP2	Mean	SE	
Standing trees (no./ha)	984.2	957.3	970.8	104.23	918.6	1127.3	1022.9	214.57	1.27
Basal area (m^2/ha)	19.5	22.4	20.8	5.38	26.5	27.1	26.8	4.36	8.31*
Tree DBH (cm)	16.5	17.3	16.9	3.35	16.2	17.0	16.6	1.95	0.35
Canopy cover (%)	10.9	8.6	9.8	4.29	43.2	40.9	42.1	3.75	13.42**
Shrub cover (%)	5.1	6.7	5.9	1.98	12.5	15.9	14.2	2.24	11.69**
Snags (no./ha)	1.5	0.8	1.2	0.38	2.5	0.3	1.4	0.63	1.08
Fallen logs (no./ha)	276.5	292.3	284.4	89.36	324.9	347.1	336.1	64.23	2.53

[a] Natural deciduous forest and Japanese larch plantation columns show mean ± SD calculated across both sites per area.
[b] Comparisons between the natural deciduous forest and the Japanese larch plantation based on multivariate analysis of variance.
* $p < 0.05$, ** $p < 0.01$.

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Table 2. Number of tracks per 100 m of sampling day (*n* = 8 tracking days per site) of mammal species from winter field censuses data in Mount Maehwa, Hongcheon, South Korea.

Species	Natural deciduous forest (ND)[a]				Japanese larch plantation (JP)[a]				Z^b
	ND1	ND2	Mean	SE	JP1	JP2	Mean	SE	
Korean hare	0.21	0.29	0.25	0.05	0.35	0.46	0.41	0.12	16.3*
Raccoon dog	0.05	0.10	0.08	0.07	0.31	0.15	0.23	0.07	18.7*
Siberian weasel	0.04	0.08	0.06	0.04	-	0.25	0.13	0.08	7.5
Water deer	2.13	0.42	1.27	0.48	6.21	7.29	6.75	1.45	25.3**
Wild boar	0.21	0.13	0.17	0.06	0.32	0.19	0.26	0.13	5.1

[a] Natural deciduous forest and Japanese larch plantation columns show mean ± SD calculated across both sites per area.
[b] Comparisons between the natural deciduous forest and the Japanese larch plantation based on the Mann-Whitney U test.
* p < 0.05, ** p < 0.01.

Table 3. Results of stepwise analysis of habitat variables and forest type effects on the winter abundance of mammals in the natural deciduous forest and the Japanese larch, *Larix leptolepis*, plantation in Mount Maehwa, Hongcheon, South Korea.

Species	First variable	Coefficient	Partial r^2	Second variable	Coefficient	Partial r^2	Model r^2	Model p
Korean hare	shrub cover	0.0019	0.76	fallen log	0.0214	0.49	0.63	0.001
Raccoon dog	fallen log	0.0048	0.51					
Water deer	shrub cover	0.0073	0.68	canopy cover	0.0457	0.38	0.75	0.005
Wild boar	shrub cover	0.0025	0.79	fallen log	0.0396	0.44	0.69	0.001

number of tracks per 100 m, and compared these data by using Mann-Whitney U tests. We evaluated the effect of the investigated habitat variables on the winter abundance of mammals by using stepwise analysis.

Results

The mean number of standing trees, mean tree diameter at breast height, mean number of snags, and mean number of fallen logs were similar among the four study sites (Table 1). However, the mean basal area (MANOVA, $F = 4.36$, $p < 0.05$), mean canopy cover ($F = 3.75$, $p < 0.01$) and mean shrub cover ($F = 2.24$, $p < 0.01$) were significantly higher in the Japanese larch plantation than in the natural deciduous forest.

We identified ≥ 6 species of mammals during the study period. When we included opportunistic sightings, the total richness had an additional species, namely the red squirrel, *Sciurus vulgaris*. The species richness did not differ significantly between the Japanese larch plantation and the natural deciduous forest.

The total number of tracking days after a snowfall had occurred during the previous day was 32 (eight tracking days per study site). The most abundant species was water deer, whereas the occurrence of Siberian weasels was very low. The total numbers of species did not differ significantly among the four study sites. However, the mean numbers of tracks for Korean hare (Mann-Whitney U test, $Z = 16.3$, $p < 0.05$), raccoon dog ($Z = 18.7$, $p < 0.05$) and water deer ($Z = 25.3$, $p < 0.01$) were > 1.6-fold higher in the Japanese larch plantation than in the natural deciduous forest; in particular, the mean number of water deer tracks was > 5-fold higher (Table 2).

The results of stepwise analysis revealed that the winter abundances of four of the five species were significantly correlated with ≥ 1 of the habitat variables (Table 3). On the other hand, the winter abundance of Siberian weasels was not significantly correlated with any of the habitat variables. In the Japanese larch plantation, the winter abundances of Korean hares (Bonferroni test, $p = 0.001$) and water deer ($p = 0.001$) were significantly correlated with shrub cover. For each of these species, the first variables had $r^2 \geq 0.68$ and the overall model had $r^2 \geq 0.63$. The winter abundance of raccoon dogs was significantly correlated with fallen logs ($p = 0.01$), whereas the winter abundance of wild boars was significantly correlated with shrub cover ($p = 0.001$) and fallen logs ($p = 0.05$). The first variable had $r^2 = 0.79$, and the overall model had $r^2 = 0.69$.

Discussion

Track counting has frequently been used as an index of mammal abundance (Thompson et al. 1989). Track counting data do not provide absolute numbers of individuals, but can indicate the status of populations within the study area (Smith 1990). The density of mammal field tracks may reflect existing conditions,

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rather than long-term habitat quality. Thus, the method enables the prediction of recent habitat conditions (Forsey & Baggs 2001, Bali et al. 2007).

In the present study, the higher occurrence of water deer tracks in the Japanese larch plantation (Table 2) may be explained by the presence of smaller shrubs and understory vegetation as a food source and refuge against predators and humans (Lee et al. 2010). Dense understory vegetation has frequently been reported to occur in South Korean habitats that support water deer populations (Choi & Choi 2007, Kim et al. 2011).

Shrub cover was significantly correlated with the winter abundances of Korean hares, water deer and wild boars. Dense shrub coverage provides important thermal protection, security and refuge (Hagar et al. 1996, Sullivan et al. 2001), and also provides forage. Therefore, when planning conservation management strategies for Korean hares, water deer, and wild boars, shrub and understory cover must be considered.

Fallen logs were significantly correlated with the winter abundances of Korean hares, raccoon dogs and wild boars (Table 3). Fallen logs likely result in greater habitat heterogeneity (Ecke et al. 2002), thereby increasing the availability of shelter for Korean hares. Dead organic matter may therefore represent an important structural and functional element for small rodents (Tallmon & Mills 1994, Bowman et al. 2000, Rhim & Lee 2001), which are suitable food resources for raccoon dogs (Won 1967, Yoo 2000). Thus, in the present study, raccoon dogs may have responded to the greater availability of fallen logs in this study. The presence of fallen logs in forests also has the potential to provide microhabitats for invertebrates, fungi and plants, which are suitable food resources for wild boars (Lee et al. 2010).

The canopy cover was significantly correlated with the winter abundance of water deer, which prefers dense forest and early successional vegetation (Won & Smith 1999, Kim et al. 2011). Higher canopy cover provides thermal cover and protects the species against several climatic factors such as temperature, snow and wind (Borkowski & Ukalska 2008).

The results of our present study suggest that a combination of food and cover determine the habitat preference of mammals in winter. For all of the investigated species, the preferred winter habitat was the Japanese larch plantation, with dense shrub cover and high numbers of fallen logs. The status of the forest floor, such as shrub cover and fallen logs, should influence food and cover. Moreover, the dense canopy cover of the Japanese larch plantation has an important role as thermal cover.

There is a need for studies that assess the interrelationship between environmental variables and seasonal differences in mammal abundance. Moreover, seasonal differences will be analyzed in future study. In planning conservation and management strategies for different species of mammals, it is important to take their preferred habitats into consideration.

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