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Forestry practices can lead to changes in wildlife habitat that could have lasting effects on the distribution of species. Hence, the aim of this study was to determine the effects of forestry practices on habitat variables and habitat use by mammals in three different stands (control, clear-cut and clear-cut with reserves) in a Japanese larch *Larix kaempferi* plantation from April to October in 2016 and 2017. We recorded the presence of field signs for the following six mammal species: Korean hare *Lepus coreanus*, raccoon dog *Nyctereutes procyonoides*, Eurasian badger *Meles meles*, water deer *Hydropotes inermis*, roe deer *Capreolus pygargus* and wild boar *Sus scrofa*. Habitat variables significantly differed among three stands. Field sign (feces, foot prints and feeding signs) abundances of mammals showed significant differences between the control and clear-cut stands. Moreover, field sign abundances of all species were highest in the clear-cut with reserves stand. We calculated the impact of clear-cutting on habitat use by mammals using GLMMs. Both clear-cutting in the models were significant and had positive coefficients on habitat use by Korean hare, raccoon dog, deer and wild boar. In Eurasian badger models, only clear-cutting with reserves show positive impacts on habitat use. Habitat selection by forest edge species such as Korean hare and deer showed dependence on understory structure. Abundant understory in the clear-cut with reserves stand may not only provide vegetative food and cover for herbivores but also small prey species for omnivores and carnivores. The results of our study show that forest understory is one of the most instrumental factors mitigating the effects of clear-cutting on habitat use by mammal and it should, therefore, be given due importance in forestry practices.

Keywords: field sign, forestry, habitat use, habitat variable, mammal

Forestry practices cause temporal and spatial changes to wildlife habitat (Lyang and Lee 2010). These changes in habitat use by wildlife may affect the distribution of a species as well as the microhabitat use of an individual (Hansson 1994, Thornton et al. 2012, Kang et al. 2013). The response of wildlife species to habitat changes is different across ecosystems. Moreover, the ecological factors affecting wildlife will vary according to the different forestry practices used (Gagné et al. 2016, Son et al. 2017).

Among forestry practices, clear-cutting has huge impact on the entire ecosystem in various ways. Keenan and Kimmins (1993) defined 'clear-cutting' as the removal of the 'forest influence' in a habitat, where forest influence can be described as the effects of the canopy layer on basal area. Habitat conditions such as microclimate, soil properties, nutrient cycling and plant community change when a forest disappears. In particular, changes in the vegetation have a large impact on wildlife not only because of tree removal but also through dramatic changes in understory (Hansson 1994, Kang et al. 2013). The forest understory is one of the most important factors in habitat use by wildlife owing to its ability to supply food and cover to the animals (Mysterud and Østbye 1999, Eom et al. 2018).

Several researches on influence of clear-cut on wildlife have highlighted importance of change in the vegetation structure. The clear cutting can affect negatively some species as removing forest cover but also can affect positively other species due to abundant regeneration and the consequent food availability. Gagné et al. (2016) reported that decreased forest cover in a clear-cut area reduced habitat use by caribou *Rangifer tarandus*, but increased regeneration in the clear-cut area favored habitat use by moose *Alces alces*. de Bellefeuille et al. (2001) and Thornton et al. (2012) also reported that a clear-cut area could not provide sufficient

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vegetative cover for snowshoe hare *Lepus americanus*, which resulted in a decrease in hare abundance.

During 1960s and 1970s, Japanese larch *Larix kaempferi* was a major tree species planted in South Korea (Korea Forest Research Institute 2009). Forestry practices, such as thinning and clear-cutting have been very popular in Japanese larch plantations. These practices have greatly affected the forest habitat and mammals inhabiting them. Recently, many forestry practices have tried in the flowing various ways to reduce negative effects of the practices on wildlife (Gitzen et al. 2007, Godbout and Ouellet 2008). Variable-retention harvesting (VRH) is to retain live trees and other structural legacies during timber harvests, which makes forests sustain structural diversity and connectivity. However, there has been limited research about influence of VRH on large mammals (Sullivan and Sullivan 2019). For improved conservation and management of mammals, detailed ecological information following forestry practices is critical in intensively managed plantations.

This study was conducted to determine the effects of forestry practices on habitat variables and habitat use by mammals in a Japanese larch plantation. The retention harvesting makes habitat structure complex at local scale. And the changes in the microhabitat condition would affect habitat use by mammals. We focused on the short-term response of mammal community to clear-cutting. Because the impact of disturbance is the biggest right after the harvests and the short-term response can affect the potential for long-term response. We designed this experiment with three treatments; control, clear-cut and clear-cut with reserves. Moreover, we tested if there were differences in habitat variables and habitat use by mammals among three treatments in a Japanese larch plantation. We hypothesized that the clear-cutting would affect habitat use of mammals because of the difference in the vegetation structure. Also, we expected that edge species such as hare and deer would prefer the clear-cut with reserve stand than the others, and forest-dwelling carnivore species such as badgers would prefer the control stand.

Methods

This study was conducted from April to October in 2016 and 2017 in a Japanese larch *Larix kaempferi* plantation (37°25′25″N, 128°26′51″E) on Mt Nambyeong, Pyeongchang, South Korea. The mean annual precipitation of the region was 1073.4 mm and the mean annual temperature was 11.2°C (range 35.9 to −18.3°C). The altitude of the study area ranges from 900 to 1100 m a.s.l. (National Institute of Forest Science 2017). We selected study sites within the plantation (400 ha) and allocated them to three treatment groups: a control stand (200 ha), clear-cut stand (100 ha) and clear-cut with reserves stand (100 ha). No forestry practice, such as tree-cutting and understory removal, had occurred in the control stand. In the other two treatments, trees had been clear-cut in 2015. In the clear-cut stand, all trees and understory vegetation were cut and removed. In the clear-cut with reserves stand, all trees and understory vegetation were removed, except in the reserve areas. Each reserve was 30 × 30 m size; thus, the total remaining area in the stand was 100 ha (5%). There were three transects per stand, each 500 m long and 10 m wide. Transects were separated from each other transect by a distance of 100 m.

In August 2017, we established 20 circular plots (5.64 m in radius) at 25 m intervals along each transect (Rhim et al. 2015). In each circular plot, we measured habitat variables describing the vegetation and available cover. We measured and classified the vertical structure of the vegetation according the following five layers: v0 (0–1 m), v1 (1–2 m), v2 (2–8 m), v8 (8–20 m) and v20 (20–30 m). Foliage cover in each vegetation layer was measured and classified according the following four categories: 0 (percentage cover = 0%), 1 (1–33%), 2 (34–66%) and 3 (67–100%). We surveyed the number of standing trees and the volume of felled tree and coarse woody debris (CWD) (Rhim and Lee 2007, Son et al. 2017).

We conducted monthly field sign surveys on mammals from April to October in 2016 and 2017. We conducted

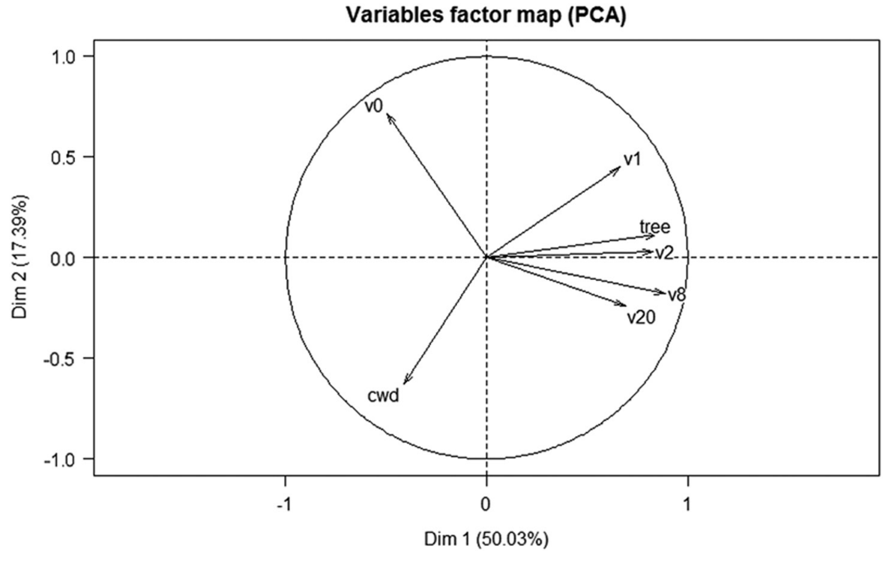

Figure 1. Principal component analysis (PCA) biplot for all covariates for habitat variables: v0 = 0–1 m high (ground cover), v1 = 1–2 m, v2 = 2–8 m, v8 = 8–20 m, v20 = 20–30 m, tree = tree density (no ha^{-1}) and cwd = volume of coarse woody debris and felled tree ($m^3 ha^{-1}$). Dim1 and Dim2 explain 49.57% and 17.42% of total variance, respectively.

Table 1. Differences in habitat variables (mean ± SE) between the control and clear-cut stands in a Japanese larch *Larix kaempferi* plantation on Mt Nambyeong, Pyeongchang, South Korea (using a Kruskal–Wallis test). Habitat variables include v0 = 0–1 m high (ground cover), v1 = 1–2 m, v2 = 2–8 m, v8 = 8–20 m, v20 = 20–30 m, tree = tree density (no. ha^{-1}) and CWD = volume of coarse woody debris and felled tree (m^{3} ha^{-1}).

Variables	Stands			χ^2	p
	Control	Clear-cut	Clear-cut with reserves		
v0	1.50 ± 0.08^{c}	2.00 ± 0.33^{b}	2.46 ± 0.24^{a}	18.79	<0.001
v1	1.07 ± 0.17^{a}	0.00 ± 0.00^{b}	0.71 ± 0.10^{a}	51.00	<0.001
v2	1.60 ± 0.36^{a}	0.00 ± 0.00^{b}	0.32 ± 0.17^{b}	55.23	<0.001
v8	2.00 ± 0.13^{a}	0.00 ± 0.00^{b}	0.07 ± 0.02^{b}	75.88	<0.001
v20	1.63 ± 0.33^{a}	0.00 ± 0.00^{b}	0.10 ± 0.04^{b}	46.53	<0.001
tree	420.00 ± 2.40^{a}	0.00 ± 0.00^{c}	107.14 ± 13.89^{b}	60.74	<0.001
CWD	4.64 ± 1.26^{b}	773.72 ± 55.86^{a}	741.06 ± 14.59^{a}	46.39	<0.001

^{a,b,c} Indicates a significant difference.

28 days (2 day month^{-1} × 7 months × 2 years) of tracking in each stand. We counted the field signs of mammal species found in the transects. We recorded all kinds of field signs, such as feces, footprints, feeding signs, hair, shelter and rub by antler or tusk, if we could figure out which species leave the field signs. In case of deer fecal pellets, we recorded only pellet group having more than four pellets to count only fresh feces. In case of herbivory signs, we counted a plant having feeding signs as one feeding sign. We could verify inhabitation of following eight mammal species through the field sign surveys: Korean hare *Lepus coreanus*, raccoon dog *Nyctereutes procyonoides*, Siberian weasel *Mustela sibirica*, Eurasian badger *Meles meles*, yellow-throated marten *Martes flavigula*, water deer *Hydropotes inermis*, roe deer *Capreolus pygargus* and wild boar *Sus scrofa*. As we could not clearly distinguish between the field signs of the different deer species, they were combined into one group known as deer. We excluded Siberian weasel and yellow-throated marten in analysis because the number of field signs of both species were too small. The number of field signs recorded per sampling day in each transect was used as an index of habitat use frequency (Eom et al. 2018).

We compared the mean values of the habitat variables among the study sites using Kruskal–Wallis tests. In addition, we constructed generalized linear mixed models (GLMMs) with poisson distribution to determine the effects of forestry practices on field sign abundance of mammals. In the GLMMs, the control site served as the reference group and we calculated the odds ratios by using both clear-cut stands compared to the control stand. Further, we modeled the habitat selection involving the habitat variables. Before analyzing the habitat selection models, we used a principal component analysis (PCA) to consider multicollinearities among habitat variables. Because there were some possibilities of multicollinearity among v2, v8, v20 and tree density, we selected v0, v1, v8 and volume of felled tree and coarse woody debris (CWD) for the habitat selection model (Fig. 1). We assumed that v0 represented ground cover or vegetation, v1 understory vegetation and v8 overstory vegetation. We tested habitat selection models with the corrected Akaike information criterion (AIC$_{c}$).

Results

All habitat variables differed significantly between the control stand and both clear-cut stands (Kruskal–Wallis test; $\chi^2 = 18.52–60.74$, $p < 0.001$; Table 1). In the clear-cut stand, all vegetation and trees had been removed by clear-cutting except for the ground cover (v0) and volume of coarse woody debris. Foliage cover classes, v0, v1 and v20, and tree density variables were higher in the clear-cut with reserves stand than in the clear-cut stand. Moreover, foliage cover of v1, v2, v8 and v20, and tree density were highest in the control stand. The volume of coarse woody debris and v0 were higher in both clear-cut stands than in the control stand.

We counted the field signs for mammal species: Korean hare (n = 320), raccoon dog (n = 107), Eurasian badger (n = 46), deer (n = 1525, water deer and roe deer) and wild boar (n = 241). Mammal species composition did not differ between the control and clear-cut stands (Table 2). However, the abundance of mammal field signs significantly different between stands ($\chi^2 = 9.40–46.27$, $p < 0.01$). Moreover, field sign abundance of all species was highest in the clear-cut with reserves stand. In contrast, field sign abundance of Korean hare, racoon dog, deer and wild boar were lowest in the control stand.

We calculated the impact of clear-cutting on habitat use by five mammal species. All models for Korean hare (χ^2

Table 2. Differences in abundance of mammalian field signs (no. 100 m^{-1}, mean ± SE) between the control and clear-cut stands in a Japanese larch *Larix kaempferi* plantation on Mt Nambyeong, Pyeongchang, South Korea (using a Kruskal–Wallis test).

Variables	Stands			χ^2	p
	Control	Clear-cut	Clear-cut with reserves		
Korean hare	0.08 ± 0.01^{c}	0.62 ± 0.02^{b}	1.34 ± 0.14^{a}	46.27	<0.001
Raccoon dog	0.06 ± 0.04^{b}	0.22 ± 0.13^{ab}	0.42 ± 0.15^{a}	9.40	<0.01
Eurasian badger	0.08 ± 0.04^{b}	0.04 ± 0.02^{b}	0.20 ± 0.09^{a}	11.81	<0.01
Deer	1.78 ± 0.05^{b}	2.78 ± 0.46^{ab}	5.62 ± 0.89^{a}	21.23	<0.001
Wild boar	0.28 ± 0.01^{b}	0.62 ± 0.09^{ab}	0.74 ± 0.17^{a}	13.04	<0.01

^{a,b,c} Indicates a significant difference.

Table 3. Coefficients of forestry practice variables from the generalized linear mixed model (GLMM) for mammalian field sign frequencies in a Japanese larch *Larix kaempferi* plantation on Mt Nambyeong, Pyeongchang, South Korea.

	Fixed effect						Random effect			
	Intercept		Clear-cut		Clear-cut with reserve		Month		Year	
Species	β	SE	β	SE	β	SE	Var.	SD	Var.	SD
Korean hare	-3.83^{***}	0.77	2.15^{***}	0.32	2.91^{***}	0.31	0.53	0.72	0.80	0.89
Racoon dog	-3.08^{***}	0.68	1.24^{***}	0.36	1.86^{***}	0.34	0.50	0.71	0.50	0.71
Eurasian badger	-3.57^{***}	0.59	−0.68	0.53	1.03	0.35^{**}	0.26	0.51	0.38	0.62
Deer	−0.16	0.19	0.45^{***}	0.08	1.15^{***}	0.07	0.03	0.17	0.06	0.24
Wild boar	-2.01^{***}	0.23	0.81^{***}	0.19	0.97^{***}	0.18	0.07	0.26	0.03	0.18

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

test for goodness-of-fit; $\chi^2 = 203.69$, $p < 0.001$), raccoon dog ($\chi^2 = 43.21$, $p < 0.001$), Eurasian badger ($\chi^2 = 20.34$, $p < 0.001$), deer ($\chi^2 = 326.31$, $p < 0.001$) and wild boar ($\chi^2 = 50.93$, $p < 0.001$) tested significant (Table 3). Moreover, both clear-cut and clear-cut with reserves stands had positive coefficients for habitat use by Korean hare, raccoon dog, deer and wild boar. However, the clear-cut had negative impacts for habitat use by Eurasian badger.

The model for habitat selection by Korean hare ($\chi^2 = 201.99$, $p < 0.001$) included understory (v0, $\beta = 0.33$, $p < 0.001$), midstory (v1, $\beta = 0.50$, $p < 0.001$), overstory (v8, $\beta = -1.29$, $p < 0.001$), felled trees and coarse woody debris (CWD, $\beta = 0.12$, $p = 0.02$). The habitat selection model for the raccoon dog ($\chi^2 = 44.30$, $p < 0.001$) had understory (v0, $\beta = -0.19$, $p < 0.001$), midstory (v1, $\beta = 0.71$, $p < 0.001$), overstory (v8, $\beta = -0.86$, $p < 0.001$). We found no significant models for Eurasian badger having a bigger AIC_c value than the null model (top model; $\chi^2 = 2.88$, $p = 0.09$). The number of Eurasian badger field signs may be not enough to make a habitat selection model having seven variables. The model for deer ($\chi^2 = 164.34$, $p < 0.001$) included understory (v1, $\beta = 0.12$, $p < 0.001$) and overstory (v8, $\beta = -0.32$, $p < 0.001$; Table 4). Moreover, the habitat selection model for wild boar ($\chi^2 = 50.93$, $p < 0.001$) included overstory (v8, $\beta = -0.27$, $p < 0.001$), and coarse woody debris (CWD, $\beta = 0.25$, $p < 0.001$).

Discussion

This study was conducted to assess the effects that forestry practices have on the habitat variables and habitat use by mammals in a Japanese larch plantation. We expected that the clear-cutting would affect habitat use by mammals. Moreover, our findings confirm that vegetation structure shaped by the clear-cut stands (with/without reserves) not only changed microhabitat use by mammal species but also their field sign abundances. The species responded to clear-cut and clear-cut with reserves stands depending on their habitat preferences. Clear-cut with reserves stand had more abundant understory than the others and it favored habitat use by some species.

Habitat selection by forest edge species such as Korean hare, water deer and roe deer are dependent on the forest understory structure (Son et al. 2017). In this study, the results showed that the Korean hare and deer preferred to use the clear-cut with reserves stand as it contained the most abundant understory. The dense understory at the edge of reserves could supply sufficient food and cover for the mammals. In the clear-cut stand, there was no vegetation over the height of 1 m; thus this stand could not provide suitable cover to the species. Several studies have reported that a shortage of cover in open areas could restrain habitat use by hares and deer (Hansson 1994, Hodson et al. 2017). We observed similar results in a previous study, where roe deer and Korean hare selected a site sparser than forest for its habitat, because of abundant understory (Eom et al. 2018). The hare and deer exhibited contrasting responses to felled trees and CWD. The felled trees and CWD in the study area arranged in large-sized windrows. The windrow entwined by climber plants could provide covers for small-sized Korean hare but not for middle-sized deer. Further, long and wide windrows of felled tree and CWD could obstruct movement of deer. This implies that we should consider not only har-

Table 4. First generalized linear mixed models (GLMMs) based on AIC_c (the corrected Akaike information criterion) for habitat selection by mammals in a Japanese larch *Larix kaempferi* plantation on Mt Nambyeong, Pyeongchang, South Korea. Habitat variables include v0 = 0–1 m high (ground cover), v1 = 1–2 m, v8 = 8–20 m and CWD = volume of coarse woody debris and felled tree ($m^3 ha^{-1}$).

Variable	Korean hare		Raccoon dog		Deer		Wild boar	
Fixed effect	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	-2.35^{**}	0.75	-2.24^{***}	0.67	0.39	0.2	-1.35^{***}	0.19
v0	0.33^{***}	0.08	−0.19	0.13	0.12^{***}	0.03	–	–
v1	0.50^{***}	0.09	0.71^{***}	0.15	–	–	–	–
v8	-1.29^{***}	0.18	-0.86^{***}	0.16	–	–	-0.27^{***}	0.08
CWD	0.12^{*}	0.05	–	–	-0.32^{***}	0.03	0.25^{***}	0.04
Random effect	Variance	SD	Variance	SD	Variance	SD	Variance	SD
Month	0.53	0.72	0.50	0.71	0.03	0.17	0.07	0.26
Year	0.80	0.89	0.50	0.71	0.06	0.24	0.03	0.18

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

vest methods but also arranging felled tree and CWD for wildlife management.

We expected that the habitat use by mesocarnivores in both harvested stands would decrease. However, the raccoon dog and Eurasian badger used clear-cut with reserves stand more than the others. The raccoon dog preferred the sites with more mid-story vegetation. The mid-story vegetation over 1 m could be useful cover resources for raccoon dog, which it could influence the habitat use in the clear-cut with reserves stand. Further, abundant understory in the clear-cut with reserves stand could favor raccoon dog and Eurasian badger, even though raccoon dog selected the site with less understory. The clear-cut with reserves stand contained abundant understory and felled trees, which could be preferred by prey such as insects, small mammals and birds (Kang et al. 2013). We have observed similar habitat use patterns in the raccoon dog and Eurasian badger, which the forestry practices such as thinning could favor the habitat use by the both species by providing abundant prey species (Son et al. 2017). Caryl et al. (2012) also reported that unforested habitat such as grassland and scrub could serve as food patches for forest dwelling carnivores. The clear-cut with reserves stand appeared to function as food patches for mesocarnivores.

The forestry practices can affect interspecific interactions such as predator–prey interaction by changing habitat use patterns. Hansson (1994) reported that open environments in clear-cut forests made mountain hares *Lepus timidus* vulnerable to predation and, consequentially, served as a sink habitat for the hare. Gagné et al. (2016) also reported that clear-cutting affected interactions among moose and wolf *Canis lupus* by increasing habitat use by moose and wolf in clear-cuts and the consequential predation rate for moose. In this study, most mammal species, including herbivores, exhibited positive responses to clear-cut and clear-cut with reserves stands. Moreover, it is reported that small mammal abundance could be increased in tree thinned stand. Thus, there is a possibility that encounter rate among the mammal species might increase and the forest practices affect prey–predator interactions in the study area, although we could not assess a response by top predator such as yellow-throated marten in this study.

The understory was one of the most influential factors mitigating the effects of the forestry practices on mammals, which caused the differences in habitat use depending on the reserves in the clear-cut stand. Our finding confirmed that the clear-cut with reserves stand could cause the edge effects. Abundant understory in the clear-cut with reserves stand could provide vegetative food and cover not only for herbivores but also for small prey species eaten by omnivores and carnivores. In other words, damaging the understory through clear-cutting can destroy the wildlife community by removing feeding sites or shelter for the mammals. Ecological studies could improve our understanding of the manner in which disturbance regimes affect habitat use by wildlife. In this study, we confirm that retaining reserves would be highly effective in mitigating the effects of clear-cutting on habitat use by mammals. Further research is required on the long-term effects of clear-cuts and retention harvests on mammal communities and their responses to other successional stage in forest regeneration.

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