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# Effects of Logging Intensity on Small Rodents in Deciduous Forests

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**Abstract:** This study was conducted to clarify the effects of logging intensity on small rodents in deciduous forests in Mt. Maehwasan, Hongcheon, Korea. All habitat variables of stand structure and downed trees except the volume of downed trees were significantly different among the control, thinned and clearcut stands. Researchers captured 197 *Apodemus agrarius* and 52 *A. peninsulae* during the study. Both the total number of captures and the total number of captured *A. agrarius* were higher in the clearcut stand. The higher abundance of *A. agrarius* in the clearcut stand was primarily due to the higher number of captured subadults. The population density of *A. peninsulae* did not differ among study stands while coverage of ground, volume of downed coarse woody debris and number of downed trees were dominant predictor variables for population density. Small mammals differed in sensitivity to habitat change caused by logging. Understanding the response of small rodents to forest logging is necessary to evaluate the long-term ecological effects of forest management.

**Key words:** Clearcut, deciduous forest, small rodents, thinning

## INTRODUCTION

The post-treatment changes that occur in habitat quality following forest management practice may have effects on forest-dwelling wildlife species (Hayes *et al*., 1997). Intensive forest practices simplify habitat structure by removing stand trees and shrubs and are recommended for maintaining biodiversity and heterogeneity of habitat (Hunter, 1999; Homyack *et al*., 2004). It is important to monitor wildlife according to forest practices based on ecology and their habitat change. Understanding associations between wildlife and habitat change is an important issue for sustainable forest management (Venier and Pearce, 2005; St-Laurent *et al*., 2008).

The effects of that forest practices such as thinning and clearcutting have on forest ecosystems have been debated from the perspective of biodiversity and sustainability (Rowe, 1994; Fuller *et al*., 2004). Forest practices have direct implications for wildlife populations; numerous habitat variables have been quantified and related to abundance and diversity of wildlife (Sullivan *et al*., 1999; Schmid-Holmes and Drickamer, 2001). Forest practices have potential to change habitat structure which has been postulated to influence small rodent populations (Dueser and Porter, 1986). Forest patch characteristics measured at a local level may be good indicators of small rodent abundance. Most studies on small rodent community dynamics indicate that abundance and species composition may be changed by forest practices (Ecke *et al*., 2002).

Thinning reduces the density of stands to minimize mortality from competition and accelerate growth of residual trees (Brissette *et al*., 1999). Clearcutting causes dramatic changes in forest structure by removing all standing trees and increasing coarse woody debris and shrub vegetation (Rhim and Lee, 2001). The structural changes associated with thinning and clearcutting within forests could potentially influence small rodents (Mengak and Guynn, 2003; Homyack *et al*., 2005). Moreover, the effects of logging on small rodent abundance appear to be species and area-specific (Fuller *et al*., 2004).

Forest-dwelling mice (*Apodemus* sp.) are a relevant taxon for examining the responses of small rodents to forest practices because they are consumers of invertebrates and fungi and act as prey for mammalian and avian predators in forest ecosystems. Also, *Apodemus* sp. are very common in forest areas of South Korea (Rhim and Lee, 2001). Habitat selection by small rodents is strongly influenced by factors involving food and shelter (Ecke *et al*., 2002). Thus, mice can be used as indicator of forest ecosystem health after forest management.

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Researchers evaluated the effects of logging intensity on small rodents in deciduous forests, Korea. The objective was to compare the abundance of small rodents, associated stand structure and amount of downed trees relation to thinning and clearcutting practices.

## MATERIALS AND METHODS

This study was carried out at the deciduous forests in Mt. Maehwasan, Hongcheon, Gangwon Province, South Korea (37°37'N, 127°49'E). Elevation range was 400-500 masl. Sawtooth oak *Quercus acutissima*, cork oak *Q. variabilis* and Mongolian oak *Q. mongolica* were dominant species in the study area. Researchers selected three types of stands within deciduous forests based on management practices: control, thinned and clearcut stands. In the study area, thinning occurred in 2010 and clearcutting occurred in 2009. In each stand, researchers selected three study plots. Each 100×100 m study plot was divided into a grid pattern, consisting of a 15×15 m array for trapping and surveying habitat (Korea Forest Service, 2012).

Habitat variables were measured at each trapping station within 5.64 m diameter circles. Researchers recorded tree species and Diameter at Breast Height (DBH), number of downed trees, volume of downed trees and volume of downed coarse woody debris within the circle. Vertical structure was defined as ground (0-1 m), understory (1-2 m), mid-story (2-8 m), sub-overstory (8-20 m) and overstory (20-30 m). Coverage was classified into the following four categories based on the percentage of cover in each vertical layer following Rhim and Lee (2001): 0 (coverage percentage = 0%), 1 (1-33%), 2 (34-66%) and 3 (67-100%).

Researchers trapped small mammals during three consecutive nights per month in nine study plots from September to November 2012. Trapping grids (100×100 m) had 49 (7×7 array) trap stations distributed at 15 m intervals with a Sherman live trap at each station. Researchers used peanuts as bait and checked all traps in the morning (Lee *et al*., 2012). Researchers recorded the following data: trap location, species, individual identity, new or recapture status, age class, sex, mass and release condition. All captured small rodents were toe-clipped for individual identification and immediately released at the point of capture (Lee *et al*., 2008).

For analysis of stand-structure and small rodent abundances, a randomized-block ANOVA (Zar, 1984) was conducted to compare number of standing trees, basal area, vegetation coverage (overstory, sub-overstory, mid-story, understory and ground), volume of downed coarse woody debris, number of downed trees and volume of downed trees. Abundance estimates in each stand were obtained by analyzing the mark-recapture data for each small rodent species using the Jolly-Seber Stochastic Model (Seber, 1982; Lee *et al*., 2012). Abundance estimation was carried out using the program MARK 3.2 (White and Burnham, 1999). For every mode, MARK processed the Akaike Information Criterion corrected for a small sample size ($AIC_c$). Throughout the analysis, an information-theoretic philosophy of model selection was employed with a focus on multi-model inference (Rhim, 2013). Akaike weights ($\omega$) were determined for each of the variables that were present in at least one selected model. The means of parameter estimates were computed across all of the models which a given variable occupied along with the 95% confidence interval (Burnham and Anderson, 2002; Rhim, 2012). Values were considered statistically significant at $p<0.05$.

## RESULTS AND DISCUSSION

All measured variables of stand structure and downed trees except the volume of downed trees (ANOVA, $F = -8.35$, $p = 0.25$) were significantly different among the stands ($F = 10.39\text{-}21.36$, $p<0.05$). Number of standing trees, basal area, coverage of foliage layers (overstory, sub-overstory, mid-story and understory) and number of downed trees were lower in the clearcut stand than in the control and thinned stands while coverage of ground and volume of downed coarse woody debris were increased in the clearcut stand (Table 1). The distribution of DBH (Diameter at Breast Height) was similar between the control and thinned stands. Most of the trees were removed in the clearcut stand; therefore, the number of trees was lower in each diameter class in the clearcut stand (Fig. 1).

During the study period in nine study plots in three stands we captured 183 small rodents belonging to two species (249 captures in total). Researchers captured 197 *Apodemus agrarius* and 52 *A. peninsulae*. The study revealed the same species richness of small rodents among control and experimental stands. Total number of captures and total number of captured *A. agrarius* were both higher in the clearcut stand. The captured number of *A. peninsulae* did not differ among control and experimental stands (Table 2).

Age structure and sex ratio of *A. agrarius* were similar in the control and thinned stands. However, numbers of subadults and females were higher in the clearcut stand. Numbers of captured adults and females of *A. peninsulae* were higher in all three stands (Table 3). Mean population densities (ind./ha) obtained from

Table 1: Summary of the stand-structure attributes (density, basal area and coverage) and characteristics of downed trees (volume and number of trees) together with results of ANOVA in deciduous stands that are control, thinned and clearcut in Mt. Maehwasan, Hongcheon, Korea

| | Stands | | | | |
|---|---|---|---|---|---|
| Variables | Control | Thinned | Clearcut | F-value | p-value |
| No. of standing trees/ha | 975.50±54.21 | 810.25±23.65 | 39.50±5.50 | 10.39 | 0.05 |
| Basal area ($m^2$/ha) | 29.54±1.320 | 21.98±2.170 | 0.94±0.02 | 21.36 | 0.01 |
| Coverage of overstory (20-30 m) vegetation | 1.19±0.250 | 0.71±0.120 | 0.23±0.04 | 14.25 | 0.05 |
| Coverage of sub-overstory (8-20 m) vegetation | 2.59±0.540 | 1.34±0.310 | 0.28±0.01 | 18.32 | 0.01 |
| Coverage of mid-story (2-8 m) vegetation | 1.97±0.360 | 1.14±0.180 | 0.46±0.15 | 20.31 | 0.01 |
| Coverage of understory (1-2 m) vegetation | 1.63±0.290 | 1.42±0.360 | 0.43±0.09 | 12.39 | 0.05 |
| Coverage of ground (0-1 m) vegetation | 1.60±0.140 | 1.51±0.250 | 2.49±0.36 | 13.67 | 0.05 |
| Volume of downed coarse woody debris ($m^3$/ha) | 4.16±1.750 | 5.37±1.420 | 6.45±1.18 | 15.36 | 0.01 |
| No. of downed trees/ha | 105.50±23.50 | 312.50±25.00 | 556.00±24.0 | 10.82 | 0.05 |
| Volume of downed trees ($m^3$/ha) | 2.69±0.250 | 2.71±0.440 | 1.84±0.12 | -8.35 | 0.25 |

Table 2: Total number of captured small rodents together with thenumber of captured individuals and number of times recaptured (in parentheses) in deciduous stands that are control, thinned and clearcut in Mt. Maehwasan, Hongcheon, Korea

| | Stands | | | |
|---|---|---|---|---|
| Species | Control | Thinned | Clearcut | Total |
| *Apodemus agrarius* | 49 (34.15) | 31 (25.60) | 117 (89.28) | 197 (148.49) |
| *A. peninsulae* | 18 (13.50) | 16 (9.70) | 18 (13.50) | 52 (35.17) |
| Total | 67 (47.20) | 47 (34.13) | 135 (102.33) | 249 (183.66) |

Table 3: Age structure (adult:subadult) and sex ratio (female:male) of small rodents in deciduous stands that are control, thinned and clearcut in Mt. Maehwasan, Hongcheon, Korea

| | Stands | | |
|---|---|---|---|
| Variables | Control | Thinned | Clearcut |
| ***Apodemus agrarius*** | | | |
| Age structure | 16:18 | 11:14 | 22:67 |
| Sex ratio | 16:18 | 14:11 | 50:39 |
| ***A. peninsulae*** | | | |
| Age structure | 9:4 | 7:2 | 8:5 |
| Sex ratio | 9:4 | 5:4 | 8:5 |

Jolly-Seber estimates of *A. agrarius* (F = 10.12, $p<0.01$) differed significantly between the stands with the population density of *A. agrarius* higher in clearcut and lower in thinned stands; however, the density of *A. peninsulae* did not differ among three stands (Table 4).

The best model of abundance of small mammals in the studied stands had an Akaike weight (ω) of 0.12-0.48. The top-ranked model ($r^2$ = 0.59, ω = 0.48) for *A. agrarius* abundance in deciduous forest was 0.42 [coverage of ground] + 0.34 [volume of downed coarse woody debris]+ 0.26 [number of downed tree]. The second-ranked model (ω = 0.26) contained coverage of ground and volume of coarse woody debris. The second-ranked model ($r^2$ = 0.42) was 0.31 [coverage of ground] + 0.24 [volume of downed coarse woody debris]. The top-ranked model ($r^2$ = 0.75, ω = 0.36) for *A. peninsulae* was 0.39 [coverage of ground] + 0.31 [volume of downed coarse woody debris] + 0.22 [number of downed tree]. Coverage of ground, volume of downed coarse woody debris and number of downed trees were dominant predictor variables (Table 5).

Table 4: Jolly-Seber population estimates of density (mean±SD, ind./ha) of small rodents together with results of a repeated-measures ANOVA in deciduous stands that are control, thinned and clearcut in Mt. Maehwasan, Hongcheon, Korea

| | Stands | | | | |
|---|---|---|---|---|---|
| Species | Control | Thinned | Clearcut | F-value | p-value |
| *Apodemus agrarius* | 5.68±2.31 | 3.57±1.12 | 12.24±3.68 | 10.12 | 0.01 |
| *A. peninsulae* | 2.32±0.25 | 2.14±0.18 | 2.28±0.36 | -8.68 | 0.47 |

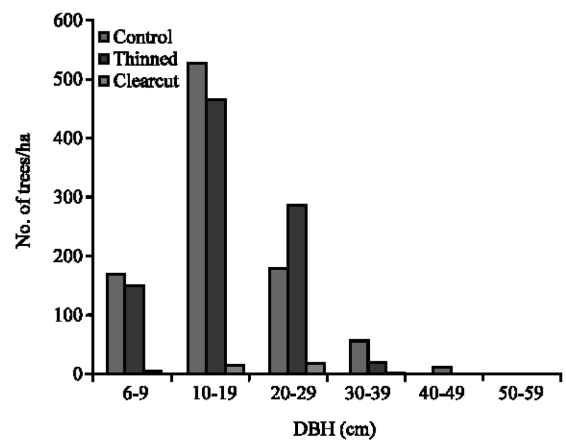


Fig. 1: DBH (Diameter at Breast Height) distributions in deciduous stands that are control, thinned and clearcut in Mt. Maehwasan, Hongcheon, Korea

Despite reduced overhead vegetation coverage, density of standing trees and basal area resulting from intensive forest practices, habitat quality was not reduced for *A. agrarius* in this study. Clearcutting positively affected the abundance of *A. agrarius* in the study areas. The observations indicated that populations of *A. agrarius* reached their greatest densities in the clearcut stand. There were no differences in abundance of small rodents between the control and thinned stands.

Small rodents had a species-specific response to logging intensity. Abundance of *A. agrarius* in clearcut stand was >2-3 times greater than in the control and thinned stands. The high abundance of *A. agrarius* in the

Table 5: Top-ranked models (based on $AIC_c$) explaining abundance of each of small rodent species based on model selection results from weighted regression analysis of small rodent densities as a function of block, practice and habitat variables

| Species | Top-ranked model | $AIC_c$ | $\Delta AIC_c$ | $w_i$ |
|---|---|---|---|---|
| *Apodemus agrarius* | Density {intercept + coverage of ground (0-1 m) vegetation + volume of downed coarse woody debris + No. of downed trees} | 736.47 | 0.00 | 0.48 |
| | Density {intercept + coverage of ground (0-1 m) vegetation + volume of downed coarse woody debris} | 678.25 | 1.05 | 0.26 |
| | Density {intercept + coverage of ground (0-1 m) vegetation + No. of downed trees} | 596.48 | 2.69 | 0.17 |
| *A. peninsulae* | Density {intercept + coverage of ground (0-1 m) vegetation + volume of downed coarse woody debris + No. of downed trees} | 345.07 | 0.00 | 0.36 |
| | Density {intercept + coverage of ground (0-1 m) vegetation + volume of downed coarse woody debris} | 298.36 | 1.39 | 0.12 |

clearcut stands was mainly due to the higher number of captured subadults. Reproductive performance of *A. agrarius* was higher in clearcut stands. But *A. peninsulae* abundances were similar among study stands. The changes in habitat structure that occurred by thinning and clearcutting practices did not appear to exert a strong influence on *A. peninsulae*.

Researchers observed higher coverage of ground (0-1 m) vegetation, volume of downed coarse woody debris and number of downed trees in the clearcut stand. Based on the intensity of forest practices, coarse woody debris and downed trees increased. Since, the canopy was cleared, sunlight reached the forest floor. Therefore, ground vegetation was dramatically increased in the clearcut stand. The positive effects of clearcutting on *A. agrarius* that researchers observed suggest that the microhabitat structure associated with intensive forest practices increases their abundance (Lindgren and Sullivan, 2001; Lee *et al*., 2012).

Coarse woody debris and downed trees are necessary to maintain small rodent populations. Both have been recommended as beneficial elements for invertebrate prey habitat, escape cover from predators (Hayes and Cross, 1987), travel corridors (Nordyke and Buskirk, 1991) and as an important source of water (Fraver *et al*., 2002). Based on the study, logging debris should be left on site which should increase the overall habitat heterogeneity and ground cover (Ecke *et al*., 2002).

Small rodent species differ in their sensitivity to changing ground cover and fragmentation as well as varying in their species composition among different landscapes (Schmid-Holmes and Drickamer, 2001). Effects of stand characteristics on small rodents vary by type of habitat and by species.

## CONCLUSION

Moreover, studying species-habitat relationships in a forest management context is difficult as there can be limiting factors to analysis such as insufficient replication and spatial bias to the analysis (Legendre, 1993).

Understanding the response of small rodents to logging intensity is necessary to evaluate the long-term ecological effects of forest practices (Homyack *et al*., 2005).

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