



Varying responses of arthropod assemblages to clear-cutting and aggregated retention harvestings

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Abstract

Local environmental conditions shape forest biodiversity, while silvicultural practices like clear-cutting and retention harvesting can rapidly alter forest structure and microclimate, affecting ecosystem services. This study investigated the short-term impacts of logging practices, specifically clear-cutting and aggregated retention, on arthropod diversity and community structure in the Japanese larch forest in South Korea. Responses of arthropods to logging varied among taxa: Hemiptera and Coleoptera were abundant in logged areas, whereas Araneae and Formicidae in Hymenoptera were more abundant in unlogged areas than in logged areas. This variation underscores the challenge of assessing logging impacts using specific taxa alone. Multivariate analyses clearly distinguished the differences in arthropod communities between logged and unlogged areas. Our findings show that arthropod responses to logging vary among taxa, resulting in distinct community structures in logged and unlogged stands of Japanese larch forests. These short-term changes emphasize the importance of retention-based management for conserving arthropod communities.

Keywords: aggregated retention, arthropods, biodiversity, clear cutting, community abundance

Introduction

The abundance and distribution of forest organisms are shaped by local environmental conditions. Silvicultural practices such as clear-cutting (CC) and retention harvesting can abruptly alter forest structure and microclimate, triggering cascading effects on biodiversity and influencing ecosystem services (Lee et al. 2024). Assessing these impacts is a central theme in forest ecology, as shifts in species composition often reflect broader changes in ecosystem function and resilience (Paillet et al. 2010). CC remains one of the most widely used harvesting methods because of its operational efficiency and low cost; however, it is frequently associated with ecological drawbacks such as fragmentation, habitat loss, and reduced species richness (Escobar et al. 2015). In contrast, retention harvesting, particularly aggregated retention (AR), has been promoted as a more biodiversity-friendly alternative (Lee et al. 2017).

Korean forests, particularly in South Korea, have experi-

enced pronounced cycles of forest degradation and reforestation. Until the early 1970s, these forests were extensively degraded due to exploitation during the Japanese occupation, the Korean War, and the subsequent economic hardship (Choi et al. 2019). A large-scale, government-led reforestation, along with a societal shift to fossil fuels as a heating source, eventually facilitated substantial recovery (Lee 2010).

Although the restoration produced considerable ecological benefits, it also yielded unintended consequences for grassland-inhabiting insects. As forests matured and canopy cover increased, large scale logging and reforestation have again implemented to manage stands reaching harvest age. These activities are expected to influence arthropod communities strongly, yet research on ecological consequences of such extensive logging remains limited. To mitigate the environmental impacts of logging and preserve biodiversity, experimental approaches such as AR are increasingly used. AR retains patches of standing trees, a practice expected to reduce risks such as landslides and

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promote biodiversity by providing habitats suitable for both forest-dwelling and open-area species (Moon et al. 2018).

As forest canopies mature and close, sunlight penetration declines, suppressing the growth and diversity of understory vegetation (Kashian et al. 2023; Van Pelt and Franklin 2000). Conversely, logging increases ground-level light availability, promoting the growth of new herbs and shrubs and potentially boosting arthropod populations. Logging is therefore expected to alter arthropod community structure and diversity (Aggarwal et al. 2023; Wang et al. 2025). AR sites may support greater arthropod diversity than CC sites for this reason. In addition, natural forests containing diverse tree species generally support higher biodiversity than monoculture plantations (Korea Forest Research Institute 2010; Liu et al. 2018; Wang et al. 2019). Therefore, oak forests are expected to harbor greater arthropod diversity than Japanese larch plantations. Taxa differ widely in their responses to forest alteration; for instance, herbivorous Hemiptera and predatory Araneae may respond differently to logging (Kwon et al. 2010, 2013; Straw et al. 2023). Previous research in the study area examined CC and AR effects on moth communities (Moon et al. 2018), but did not include the broader arthropod assemblage.

This study assesses the effects of CC and AR in a broader range of arthropods within Japanese larch forests by comparing unlogged forests with forests subjected to these two management treatments. We also compare these communities with those in natural oak forests.

Materials and Methods

Study area

The field survey was conducted in the Japanese larch and

Mongolian oak forests of Nambyeong Mountain (1,150 m, 37°25' N, 128°27' E), South Korea (Fig. 1). This national forest is regulated by the regional forest authorities, limiting public access and use. Between 2001 and 2010, the area experienced an average annual temperature of 7.0°C and precipitation of 1,556.2 mm (Korea Meteorological Administration 2017). The landscape comprises a mosaic of natural pine and oak forests and Japanese larch plantations. Although specific arthropod surveys of Nambyeong Mountain are lacking, studies from the nearby Gariwang Mountain document diverse arthropod communities, including stink bugs, beetles, and ants (Jung et al. 2013; Lee et al. 2014). Within the Nambyeong Mountain, forest management experiments assessing CC and AR effects are ongoing (Moon et al. 2018).

Field sampling

Sampling was conducted across four forest stands representing different management treatments: CC, AR, no cutting in the larch forest (NC), and a natural Mongolian oak forest (OA). The OA site served as a natural reference, while NC served as a control for the logged larch treatment. Each site covered approximately 5 ha at an elevation of 910–980 m. In the AR site, three retention patches (40 m diameter; 0.13 ha each) were preserved, spaced 60 m apart. Further site details are available in Moon et al. (2018).

Arthropods were collected six times from May to October 2016 using a sweeping net once per month. At each site, we slowly walked a 50 m transect while sweeping a 33 cm net approximately 100 times across shrubs and grasses. Samples were transferred into plastic bags and kept cool during transport. In AR site, sweeping covered both logged areas and retained-tree patches. Arthropods were identified to the order level, and their abundance data were used in the analyses.

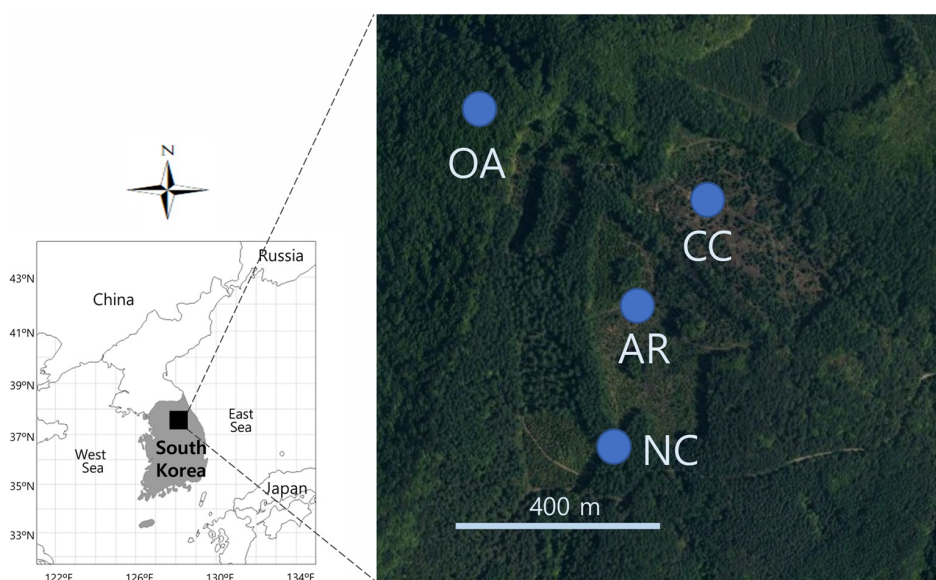


Fig. 1 Location of the study sites in South Korea. CC: clear-cutting area; AR: aggregated retention area; NC: no cutting area; OA: Mongolian oak area. The satellite image was obtained from the V-WORLD (<https://map.vworld.kr/>).

Table 1 Number of individuals belonging to different orders collected by sweeping net at four sampling sites

Class	Order	CC	AR	NC	OA	Total	
Arachnida	Araneae	15	28	61	75	179	
	Opiliones		1	19	5	25	
Chilopoda	Lithobiomorpha			2	3	5	
Insecta	Coleoptera	31	12	10	8	61	
	Dermoptera			1		1	
	Diptera	112	94	84	49	339	
	Hemiptera	162	119	19	7	307	
	Homoptera	31	16	36	27	110	
	Hymenoptera (Formicidae)	22 (15)	34 (16)	86 (33)	50 (34)	192 (98)	
	Lepidoptera	5	8	9	14	36	
	Neuroptera		2	8	3	13	
	Odonata	1	1			2	
	Orthoptera	6	8	1	3	18	
	Plecoptera	1		1		2	
	Total		386	323	337	244	1,290

CC: clearcutting area; AR: aggregated retention area; NC: no cutting area; OA: Mongolian oak area.

Data analysis

Because monthly taxon counts were low, we pooled abundance data across sampling months. We compared arthropod abundances among sites to assess the effects of forest management on the arthropod community structure. A two-way hierarchical cluster analysis was conducted using a Bray-Curtis distance measure and average linkage method to characterize similarities among sampling sites and the occurrence patterns of arthropod taxa. The same data was used for non-metric multidimensional scaling (NMDS). Statistical analyses were conducted in R version 4.4.0 (R Core Team 2024) with relevant packages: two-way cluster analysis with a *hcluster* function in the *vegan* package (Oksanen et al. 2019) and a *pheatmap* function in the *pheatmap* package (Kolde 2025), and NMDS using a *metaNMDS* function in the *vegan* package (Oksanen et al. 2019).

Results and Discussion

A total of 1,290 individuals from 14 orders in three classes were collected across four sampling sites (Table 1). Diptera was the most abundant Order (339 individuals), followed by Hemiptera (307 individuals) and Hymenoptera (192 individuals). Formicidae constituted 51% of Hymenoptera (98 individuals).

Responses to forest management varied across taxa (Table 1). Diptera exhibited the highest abundance in more open habitats, following the pattern CC > AR > NC > OA. Hemiptera and Coleoptera showed similar trends. In contrast, Araneae and Formicidae were more abundant in forested sites. Total arthropod abundance was the highest in CC (386 individuals), followed by NC (337), AR (323), and OA (244). Although logging generally increased overall abundance, responses differed substantially among taxa.

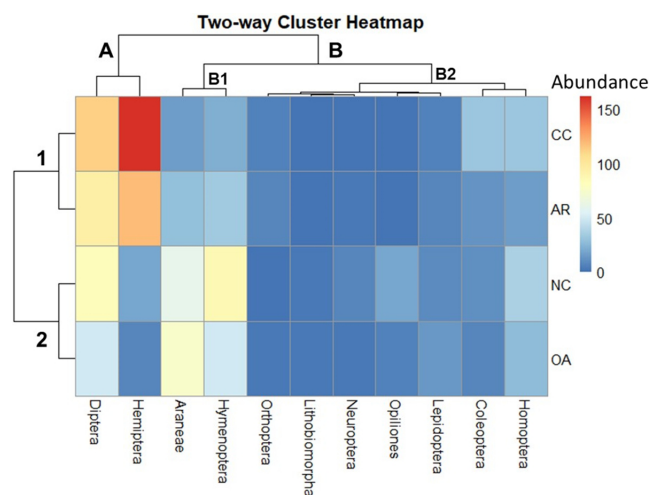


Fig. 2 Two-way hierarchical cluster analysis with the abundance of each order using the Bray-Curtis distance and the average linkage method. Both sampling sites (CC, AR, NC, and OA) and taxa were classified. The heatmap presents the abundance of each taxon at each sampling site. CC: clear-cutting area; AR: aggregated retention area; NC: no cutting area; OA: Mongolian oak area.

Hemiptera, Coleoptera, and Diptera were most abundant in CC, whereas Araneae, Opiliones, and Formicidae were more common in NC and OA.

Cluster analysis clearly separated logging (CC and AR; cluster 1) from unlogged sites (NC and OA; cluster 2) (Fig. 2). Logging sites were characterized by high abundances of Diptera and Hemiptera, whereas unlogged sites were characterized by Hymenoptera and Araneae. NMDS ordination (stress < 0.01 for the first two axes) mirrored this pattern (Fig. 3), positioning CC and AR on the left side of the ordination space and NC and OA on the opposite side.

Whole-community arthropod studies remain relatively rare, as most research focuses on selected taxa that are easier to identify. By incorporating multiple arthropod groups, this study provides a broader perspective on the

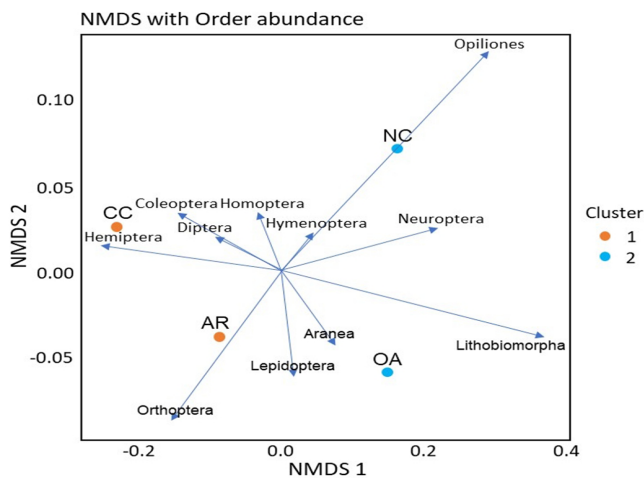


Fig. 3 NMDS ordination of sampling sites with abundance of each order (stress < 0.01 for the first two axes). CC: clear-cutting area; AR: aggregated retention area; NC: no cutting area; OA: Mongolian oak area; NMDS: non-metric multidimensional scaling.

ecological effects of forest management practices. Our results demonstrate that unlogged forests with closed canopies (NC and OA) support communities distinct from those in logged areas (CC and AR), emphasizing the importance of canopy structure in shaping arthropod assemblages. Predatory taxa such as Araneae and Formicidae were more abundant in unlogged forests, reflecting their dependence on stable microhabitats and structurally complex environments. Their reduced abundance in logged sites suggests that these taxa are sensitive to habitat disturbance and may serve as indicators of forest integrity. In contrast, herbivorous groups—particularly Hemiptera and Coleoptera—were more common in logged areas, likely due to increased light availability and enhanced understory vegetation. This finding aligns with previous studies showing that herbivores thrive in open, disturbed habitats (Gossner 2009) and parallels patterns observed for moths following CC and AR in the same region (Moon et al. 2018).

Logging influenced arthropod communities in contrasting ways: predators declined, herbivores increased, and AR consistently produced intermediate values between CC and NC. This suggests that retaining trees can moderate the ecological impacts of clear cutting by partially preserving forest structure and microhabitats. Differences between oak and larch forests also contributed to community variation. Several taxa exhibited higher abundance in larch forests, likely due to richer understory vegetation beneath larch canopies.

Although responses varied across taxa, overall community structure aligned consistently with canopy openness. This pattern corresponds with previous findings that logged areas support increased arthropod abundance in leaf litter (Burghouts et al. 1992). Logging projects thus generate both positive and negative effects on arthropod

communities, depending on taxon-specific ecological requirements. AR appears promising for mitigating biodiversity loss, as most taxonomic groups showed intermediate abundances between CC and NC. Overall, this study highlights that logging-induced environmental changes strongly influence arthropod community structure.

While species-level identification is ideal for detecting environmental changes and assessing species diversity, responses can vary widely among taxa, making it difficult to generalize from a single group. Higher-level taxonomic data, though coarser, can effectively capture ecological gradients and disturbance responses by integrating information across multiple lineages. Previous studies have shown that such approaches remain sensitive to environmental disturbances including forest fires, urbanization, and warming (Goehring et al. 2002; Koltz et al. 2018; Kwon et al. 2016). Our findings support the utility of higher-level taxonomic analyses, particularly for large-scale forest management assessments where species-level identification may be impractical.

One limitation of this study is the lack of spatial replication within each forest management treatment, which limits the use of formal statistical tests. Because the four stands represent operational management units, replication was not feasible, and monthly data were pooled due to low abundances. As a result, our analyses are descriptive comparisons rather than causal tests of management effects. Even so, the apparent differences observed between logged and unlogged sites provide valuable ecological insight, especially given the limited information available on arthropod responses to forest management in South Korea.

In conclusion, logging-driven alterations in forest structure strongly shape arthropod diversity and community composition, with distinct responses among functional groups. These findings emphasize the ecological importance of canopy structure and point to the potential of retention-based harvesting systems to reduce biodiversity loss in managed forests.

Abbreviations

CC: Clear-cutting area

AR: Aggregated retention area

NC: No cutting area

OA: Mongolian oak area

NMDS: Non-metric multidimensional scaling

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Authors' contributions

T.-S.K.: Conceptualization, Data Curation, Methodology, Data analysis, Writing – original draft; Writing – review and editing, S.-S.K.: Data Curation, Writing – review and editing, A.R.K.: Data Curation, Writing – review and editing, Y.-S.P.: Conceptualization, Methodol-

ogy, Visualization, Data analysis, Writing– original draft, Writing–review and editing.

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Availability of data and materials

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

- Aggarwal K, Chanda R, Rai S, Rai M, Pradhan DK, Munda B, et al. The effect of selective logging on microclimates, arthropod abundance and the foraging behaviour of Eastern Himalayan birds. *Forest Ecol Manage.* 2023;541:121076. <https://doi.org/10.1016/j.foreco.2023.121076>.
- Burghouts T, Ernsting G, Korthals G, De Vries T. Litterfall, leaf litter decomposition and litter invertebrates in primary and selectively logged dipterocarp forest in Sabah, Malaysia. *Philos Trans R Soc Lond B Biol Sci.* 1992;335(1275):407-16. <https://doi.org/10.1098/rstb.1992.0032>.
- Choi WI, Nam Y, Lee CY, Choi BK, Shin YJ, Lim JH, et al. Changes in major insect pests of pine forests in Korea over the last 50 years. *Forests.* 2019;10(8):692. <https://doi.org/10.3390/f10080692>.
- Escobar MA, Uribe SV, Chiappe R, Estades CF. Effect of clearcutting operations on the survival rate of a small mammal. *PLoS One.* 2015;10(3):e0118883. doi: 10.1371/journal.pone.0118883.
- Goehring DM, Daily GC, Şekerçioğlu ÇH. Distribution of ground-dwelling arthropods in tropical countryside habitats. *J Insect Conserv.* 2002;6:83-91. <https://doi.org/10.1023/A:1020905307244>.
- Gossner MM. Light intensity affects spatial distribution of Heteroptera in deciduous forests. *Eur J Entomol.* 2009;106(2):241-52. <https://doi.org/10.14411/eje.2009.032>.
- Jung SJ, Lee CM, Kwon TS. Effects of forest roads on Hemipteran diversity in Mt. Gariwang, Korea test of intermediate disturbance hypothesis. *J Asia Pac Biodivers.* 2013;6(2):239-48. <https://doi.org/10.7229/jkn.2013.6.2.239>.
- Kashian DM, Zak DR, Barnes BV, Spurr SH. *Forest ecology.* Hoboken: Wiley; 2023.
- Kolde R. *heatmap: Pretty Heatmaps.* 2025. <https://github.com/raivokolde/heatmap>. Accessed 3 Mar 2025.
- Koltz AM, Schmidt NM, Høye TT. Differential arthropod responses to warming are altering the structure of Arctic communities. *R Soc Open Sci.* 2018;5(4):171503. <https://doi.org/10.1098/rsos.171503>.
- Korea Forest Research Institute. *Forest eco-atlas of Korea.* Seoul: Korea Forest Research Institute; 2010.
- Korea Meteorological Administration. *Climate change outlook report for Gangwon Province in preparation for the new climate regime.* Seoul: Korea Meteorological Administration; 2017.
- Kwon TS, Kim YS, Lee SW, Park YS. Changes of soil arthropod communities in temperate forests over 10 years (1998–2007). *J Asia Pac Entomol.* 2016;19(1):181-9. <https://doi.org/10.1016/j.aspen.2016.01.003>.
- Kwon TS, Park YK, Lim JH, Ryou SH, Lee CM. Change of arthropod abundance in burned forests: different patterns according to functional guilds. *J Asia Pac Entomol.* 2013;16(3):321-8.
- Kwon TS, Yang HM, Shin JH, Kim SK, Yi HB. Effects of thinning on abundance and community structure of arthropods in a *Pinus koraiensis* plantation. *Korean J Appl Entomol.* 2010;49(3):187-98. <https://doi.org/10.5656/KSAE.2010.49.3.187>.
- Lee CM, Kwon TS, Park YK, Kim SS, Sung JH, Lee YG. Diversity of beetles in Gariwangsan Mountain, South Korea: influence of forest management and sampling efficiency of collecting method. *J Asia Pac Biodivers.* 2014;7(3):319-46. <https://doi.org/10.1016/j.japb.2014.06.005>.
- Lee DK. *Korean forests, lessons learned from stories of success and failure.* Seoul: Korea Forest Research Institute; 2010.
- Lee K, Yun SJ, Kim M, Yang HM, Kim AR. The effect of thinning on trade-offs in ecosystem services: the case study of a Korean pine plantation on Mt. Gari. *J Ecol Environ.* 2024;48(2):137-43. <https://doi.org/10.5141/jee.23.079>.
- Lee SI, Spence JR, Langor DW. Combinations of aggregated and dispersed retention improve conservation of saproxylic beetles in boreal white spruce stands. *For Ecol Manage.* 2017;385:116-26. <https://doi.org/10.1016/j.foreco.2016.11.032>.
- Liu CLC, Kuchma O, Krutovsky KV. Mixed-species versus monocultures in plantation forestry: development, benefits, ecosystem services and perspectives for the future. *Glob Ecol Conserv.* 2018;15:e00419. <https://doi.org/10.1016/j.gecco.2018.e00419>.
- Moon MY, Kim SS, Lee DS, Yang HM, Park CW, Kim HS, et al. Effects of forest management practices on moth communities in a Japanese larch (*Larix kaempferi* (Lamb.) Carrière) plantation. *Forests.* 2018;9(9):574. <https://doi.org/10.3390/f9090574>.
- Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR, O'Hara RB, et al. *Vegan: Community Ecology Package.* R package version 2.5-6. 2019. <https://CRAN.R-project.org/package=vegan>. Accessed 3 Mar 2025.
- Paillet Y, Bergès L, Hjältén J, Odor P, Avon C, Bernhardt-Römermann M, et al. Biodiversity differences between managed and unmanaged forests: meta-analysis of species richness in Europe. *Conserv Biol.* 2010;24(1):101-12. <https://doi.org/10.1111/j.1523-1739.2009.01399.x>.

- R Core Team. R: a language and environment for statistical computing. 2024. <https://www.R-project.org/>. Accessed 23 Jun 2024
- Straw NA, Williams DT, Fielding NJ, Jukes MR. Invertebrate predators in Sitka spruce plantations managed by clear-cutting or continuous-cover silvicultural systems. *For Ecol Manage.* 2023;259:120712. <https://doi.org/10.1016/j.foreco.2022.120712>.
- Van Pelt R, Franklin JF. Influence of canopy structure on the understory environment in tall, old-growth, conifer forests. *Can J For Res.* 2000;30(8):1231-45. <https://doi.org/10.1139/x00-050>.
- Wang X, Hua F, Wang L, Wilcove DS, Yu DW. The biodiversity benefit of native forests and mixed-species plantations over monoculture plantations. *Divers Distrib.* 2019;25(11):1721-35. <https://doi.org/10.1111/ddi.12972>.
- Wang Y, Liu X, Jin M, Xie G, Li L, Yu A. Logging intensity reshapes insect biodiversity in pine wilt disease forests: a multi-trophic assessment from Jiangxi, China. *Front For Glob Change.* 2025;8:1679737. <https://doi.org/10.3389/ffgc.2025.1679737>.