Effects of Different Forest Stand Types on Insect Community Diversity (Postprint)

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Abstract

To investigate the effects of different stand types under near-natural forest management on insect community diversity in Larix principis-rupprechtii plantations, pure and mixed Larix principis-rupprechtii stands in the Saihanba Nature Reserve were selected as study objects to examine the insect community structure across six different stand types. A total of 9,542 insect specimens were collected, belonging to 7 orders, 68 families, and 187 species, with Diptera, Hemiptera, and Coleoptera as the dominant groups. The results indicated that insects in the six stand types differed in species composition and individual numbers, with similarity analysis revealing that all community structures were dissimilar. Community diversity index analysis demonstrated that both pure Larix principis-rupprechtii stands and various mixed stands exhibited relatively high richness and diversity indices. Principal component analysis showed that predatory and parasitic groups were the primary factors influencing insect community structure across stand types, and that these groups exerted strong control over phytophagous groups. Stability analysis revealed that the insect community structures in all six stand types possessed relatively high stability.

Full Text

Effects of Different Forest Stand Types on Insect Community Diversity

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Abstract

Close-to-nature forest management is a forest management model that mimics and approaches natural processes. By fully utilizing the natural growth and development principles of forest ecosystems, it employs planning and design of forest management activities based on natural regeneration to optimize forest structure and function. This approach integrates economic needs with ecological benefits to promote forests toward their nearest natural state. The main tree species in plantations at Saihanba Nature Reserve are Prince Rupprecht' s larch (*Larix principis-rupprechtii* Mayr) and Mongolian Scots pine (*Pinus sylvestris* var. *mongolica*). Close-to-nature forest management measures were implemented in this plantation by strictly controlling external human interference and timely tending to improve the forest growing environment.

To investigate the effects of different stand types of *Larix principis-rupprechtii* on insect community diversity under close-to-nature forest management, we studied the structure of insect communities in six stand types of pure and mixed larch forests in Saihanba Nature Reserve. Insects were collected using the sweep net method, and diversity indices, similarity, principal components, and stability of insect communities in different forest types were analyzed. A total of 9,542 insect specimens belonging to 7 orders, 68 families, and 187 species were collected; Diptera, Hemiptera, and Coleoptera were the dominant groups. The results indicate that there were differences in species and individual numbers of insects among the six stand types, and similarity analysis revealed different insect community structures. Community diversity analysis showed that both pure and mixed forests had high richness and Shannon-Wiener diversity indices. Principal component analysis demonstrated that predatory and parasitic groups in each stand type were the main factors influencing community structure, exerting stronger control over phytophagous groups. Stability analysis revealed that insect community structures in different stand types all exhibited high stability. Under close-to-nature forest management in Saihanba Nature Reserve, the plantation not only showed high biological diversity but also demonstrated greater ecosystem stability and higher effective resistance to external disturbances. Therefore, traditional forest management methods should be replaced with an approach that maximally employs relationships between different species in forest ecosystems and manages forests through rational allocation of spatial tree structure and selection of appropriate tree species and planting density. The most important points include establishing a close-to-nature forest management philosophy and appropriately managing plantations. Only then can forest ecosystems achieve higher stability and play an important role in regulating the forest ecosystem itself, ultimately achieving both ecological and economic benefits of forest resources and reaching a state of sustainable use of biodiversity and healthy forest development.

Keywords: forest stand types; insect community diversity; similarity; principal component analysis; stability

Introduction

The interaction between plants and insects has long been a research focus for ecologists. Various conditions related to plant growth, forest management measures, and the effects of tree species mixing and mixing ratios on insect diversity have received widespread attention. Studies have shown that forest stands with high vegetation diversity also have high insect community diversity, and that mixing ratios significantly affect insect population distribution. Many scholars have conducted insect diversity research on different types of natural forests in various regions, but few studies have addressed insect community structure in plantations under close-to-nature forest management.

Close-to-nature forest management is a planning and management model that follows natural principles. It fully utilizes the natural growth and development laws within forest ecosystems, plans and designs forest management activities based on natural regeneration, optimizes forest structure and function, and thus represents a forest management approach that best combines ecological and economic needs. China has the largest plantation area in the world, and many scholars have analyzed the current status and management models of different types of plantations in China. It is widely believed that Chinese plantations lack scientific and effective management models, resulting in declining plantation biodiversity and reduced ecological and economic benefits.

Saihanba Nature Reserve contains plantations dominated by *Larix principis-rupprechtii* and *Pinus sylvestris* var. *mongolica*. Close-to-nature forest management measures have been implemented in the reserve, including strict control of external human interference and timely forest tending to improve the growing environment. Compared with plantations outside the reserve, major forest pests such as pine caterpillars rarely occur inside the reserve, and even when they do, they do not cause disasters, achieving a near-natural forest state with good ecological and economic benefits. Therefore, from the perspective of insect ecology, this study investigates the natural pest control function of forest ecosystems under this close-to-nature management regime. Using pure *Larix principis-rupprechtii* stands and different types of mixed larch stands as research objects, we explore insect community structure and its variation patterns across different stand types to clarify the effects of different stand types on insect communities and the pest control mechanisms for major pests, providing references for pest control and management of *Larix principis-rupprechtii* plantations.

1. Study Area Overview

Saihanba Nature Reserve is a forest ecosystem reserve established in 2002 with provincial government approval in Hebei Province. Located in Weichang Manchu and Mongolian Autonomous County, Chengde City, Hebei Province

(42°22 -42°31 N, 116°53 -117°31 E), adjacent to the Inner Mongolia Plateau, the reserve covers an area of 29,798.8 hm² with a forest coverage rate of 80.74%. The reserve belongs to a temperate semi-humid monsoon climate zone with an annual average temperature of -1.2°C. The climate features dry and windy springs, short cool summers, and long cold winters with low precipitation.

The reserve is rich in plant resources, with various vegetation types including forests, shrubs, meadows, and swamp vegetation. The main tree species are *Larix principis-rupprechtii* and *Pinus sylvestris* var. *mongolica*, both accounting for a large proportion of the total reserve area. The mixed larch forests are primarily composed of *Larix principis-rupprechtii* mixed with *Pinus sylvestris* var. *mongolica*, *Betula platyphylla*, and *Rosa davurica*. Shrub communities mainly include *Rosa davurica* scrub, *Potentilla fruticosa* scrub, *Malus baccata* scrub, and *Ostryopsis davidiana* scrub.

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2. Research Methods

2.1 Sample Plot Setup Based on common vegetation types in the reserve, six different stand types of *Larix principis-rupprechtii* forests were selected. Stand age was 35–40 years with a density of approximately 650–750 trees/hm², and the mixing ratio of larch with other species was about 5:5. Sample plots of 20 m × 20 m were established, with three replicates for each stand type. Plot details are shown in .

Survey of the plots in different forest stand types

2.2 Community Survey Methods Surveys were conducted from June to September 2014. The sweep net method was used for sampling within plots, using a white nylon net (50 cm diameter, 30 cm depth). Five sweeps were randomly taken in each cardinal direction within each plot. Collected specimens were killed in poison bottles, then placed in triangular paper bags, labeled with time and location, and brought back to the laboratory for identification. Insect specimens were identified at least to family level, with unidentifiable specimens treated as separate species based on their serial numbers.

2.3 Data Analysis Methods Data were statistically analyzed using Excel and ForStat software. Community characteristic indices were calculated as follows:

- **Richness Index (S):** Number of species in the community
- **Shannon-Wiener Diversity Index (H):** H = -Σ(Ni/N)ln(Ni/N), where S is species number, Ni is individual number of species i, and N is total individual number
- **Evenness Index (J):** J = H /Hmax = H /ln(S), where Hmax is diversity index when species are completely evenly distributed

- **Berger-Parker Dominance Index (D):** D = Nmax/N, where Nmax is individual number of dominant species and N is total individual number

Community similarity was calculated using the formula: q = 2c/(a+b), where a and b are species numbers in two plots, and c is number of shared species. Similarity levels were defined as: 0.00–0.25 (extremely dissimilar), 0.25–0.50 (moderately dissimilar), 0.50–0.75 (moderately similar), and 0.75–1.00 (highly similar).

Principal component analysis was performed using SPSS for Windows, with species and individual numbers of different insect groups as factors.

Community relative stability was determined using the ratio of species number to individual number (S/N), reflecting interspecific quantitative constraints. Additional stability indices included: - St: Ratio of predator group species number to herbivore group species number - Si: Ratio of predator group individual number to herbivore group individual number - Sp: Ratio of natural enemy group species number to herbivore group species number, reflecting food web relationships and pest control complexity

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3. Results

3.1 Community Composition Structure A total of 9,542 specimens were collected, belonging to 7 orders, 68 families, and 187 species. The dominant orders were Diptera (48.66% of families, 48.13% of species, 27.81% of individuals), Hemiptera (34.76% of families, 32.09% of individuals), and Coleoptera (45.99% of families, 22.36% of individuals). Dominant families included Muscidae (Diptera), Tachinidae, Calliphoridae, Sarcophagidae, Cicadellidae (Hemiptera), Miridae, Aphrophoridae, Chrysomelidae (Coleoptera), Coccinellidae, and Nabidae. Common species included *Musca domestica*, *Sarcophaga haemorrhoidalis*, *Cicadella viridis*, *Adelphocoris suturalis*, *Aphrophora flavipes*, *Cryptocophalus kulibini*, *Nabis stenoferus*, and *Chrysolina aurichalcea*.

Functional group classification revealed that herbivorous groups had the highest species and individual numbers across all stand types, while predatory and parasitic groups had species numbers comparable to herbivorous groups. Neutral groups had the lowest species and individual numbers. Natural enemy groups (predatory and parasitic) occupied advantageous positions in all six stand types, providing control over some herbivorous pests and contributing to community stability.

Insect community composition in different forest stand types
Insect functional groups in different forest types

3.2 Community Characteristic Indices Richness, diversity, evenness, and dominance indices showed significant differences among stand types. At the 0.05 significance level, pure larch stands and larch-birch mixed stands showed higher

richness indices, likely due to high understory vegetation coverage providing increased feeding and survival opportunities for insects. Although larch-birch mixed stands had high vegetation coverage, the species composition was relatively simple (dominated by fine-leaf sedge, *Potentilla supina*, meadow bluegrass, and sheep fescue), resulting in lower evenness indices.

Diversity indices were high across all stand types with no significant differences among them, likely because the close-to-nature management approach has created near-natural forest conditions even in pure stands and simple coniferous mixed stands. Dominance indices showed that pure larch stands had more prominent dominant groups (primarily Cicadellidae) compared to other stands, while larch-pine-birch-rose mixed stands showed the most balanced species distribution.

[Figure 1: see original paper] Characteristic index of insect communities for different forest stand types

3.3 Community Similarity Analysis Similarity coefficients between different stand types ranged from 0.2308 to 0.3750, indicating that all insect community structures were moderately dissimilar ($q < 0.50$). The lowest similarities (0.2308 and 0.2432) occurred between pure larch stands and larch-pine-birch-rose mixed stands, showing extremely dissimilar community structures. These results demonstrate that different tree species composition and mixing patterns significantly affect insect species composition, with each stand type having distinct insect community characteristics.

Comparison of similarity of insect communities between different forest stand types

3.4 Principal Component Analysis Principal component analysis identified the main factors structuring insect communities in each stand type. Two principal components were extracted for each stand type, with cumulative contribution rates reaching 100%, sufficient to summarize community composition.

In pure larch stands, the first principal component represented a combined factor of parasitic insect species number, parasitic insect individual number, and neutral insect species number; the second principal component represented a combined factor of predatory insect individual number and herbivorous insect individual number. In larch-pine mixed stands, the first principal component represented predatory insect species number, parasitic insect species number, and parasitic insect individual number; the second represented predatory insect individual number and neutral insect species number.

Across all stand types, predatory and parasitic insects were the dominant factors influencing insect community structure, with strong controlling effects on herbivorous insects. The consistent high contribution of these natural enemy groups indicates stable insect community structure.

Principal component analysis of insect communities in different forest stand types

3.5 Community Stability Analysis The St ratio (predator species/herbivore species) and Si ratio (predator individuals/herbivore individuals) varied among stand types. Larch-birch and larch-rose mixed stands showed higher St and Si ratios, indicating more balanced insect species distribution and stronger interspecific constraints. The Sp ratio (natural enemy species/herbivore species) was also higher in these stands, suggesting more complex internal relationships and higher community stability and resistance to external disturbances.

Relative stability value of insect communities for different forest stand types

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4. Conclusion and Discussion

Insect community characteristic indices are important indicators of community structure, representing not only community diversity, evenness, and variation patterns, but also reflecting geographic conditions, survival environments, and stand conditions. Some special insects can even serve as indicator species for evaluating ecosystems or environments. Therefore, analyzing diversity and stability of different stand types from an insect community perspective is significant for seeking scientific conditions favorable for tree growth and management measures, providing references for planning close-to-nature forest management activities.

This study shows that different stand types have rich insect species with no significant differences in overall diversity indices, though individual stands differ significantly in richness, evenness, and dominance indices. Community similarity analysis reveals that insect community structures are dissimilar among different stand types, indicating that tree species composition and mixing patterns significantly affect insect species composition. Predatory and parasitic natural enemies are the main factors influencing insect community structure across stand types, exerting strong control over herbivorous insects.

Under close-to-nature forest management in Saihanba Nature Reserve, rich plant resources and complex mixing patterns provide suitable living environments for insect communities. Abundant understory vegetation provides ample food and survival conditions, resulting in relatively high insect community diversity and complex community structure with strong pest control capacity. The high species richness and coverage of understory vegetation in larch stands contribute to high insect diversity. Even pure larch stands and simply structured larch-pine mixed stands show high insect community diversity due to natural regeneration and forest closure measures that have created closed, complex ecosystems with strong internal control mechanisms.

Different stand types have abundant insect species but few shared species among

communities. Insect communities are influenced by and change with plant communities. When considering the effects of stand types on insect community diversity, both tree species and understory vegetation must be considered. This study demonstrates that plantations under close-to-nature forest management exhibit high biodiversity and good ecological benefits. To better utilize forest ecosystem stability and resist external disturbances, China should shift from traditional forest management models, establish close-to-nature management philosophies, rationally allocate spatial tree structure, select appropriate tree species and planting densities, and conduct scientific management of plantations to achieve sustainable use of forest resources and healthy forest development.

References

[1] Research on insect diversity characteristics in diversified pine forests. 2005, 25(11): 2976-2982.
[2] Preliminary study on insect community structure in different mixed forests in Tongshuo, Shanxi. *Journal of Shanxi Agricultural University* (Natural Science Edition), 2007, 27(4): 360-362.
[3] Optimal mixing ratio of *Larix gmelinii* and *Betula platyphylla* based on biodiversity conservation: A case study of Arshan Forest Region. 2009, 16(1): 92-95, 100-100.
[4] Insect diversity research in natural forests of Daming Mountain Reserve, Guangxi. 2014, 42(24): 8183-8184, 8187-8187.
[5] Research on insect community structure and diversity in natural forests of *Lagerstroemia fauriei*. *Anhui Agricultural Sciences*, 2012, 32(16): 4943-4949.
[6] Close-to-nature management techniques for Korean pine forests. *Central South University of Forestry and Technology* [D]. 2014.
[7] Current status and close-to-nature management of Chinese plantations. *Modern Agricultural Science*, 2008, 15(10): 124-125.
[8] Study on forest ecosystem service function value of Saihanba Nature Reserve. Hebei Normal University [D]. 2012.
[9] Study on plant diversity and auxiliary analysis techniques in Saihanba Nature Reserve. Beijing Forestry University [D]. 2004.
[10] Principles and methods of community ecology. Science Press, 1994.
[11] Insect mathematical ecology. Chongqing Branch of Science and Technology Literature Press, 1990: 134-160.
[12] SPSS for Windows. Electronic Industry Press, 2000: 484-492.
[13] Principles of animal ecology. Beijing Normal University Press, 2001: 394-403.
[14] Study on effects of forest closure on insect community structure and diversity stability. 2006.
[15] Research on arthropod community composition and diversity in forest-steppe ecotone. *Journal of Hebei Agricultural University*, 2013, 33(14): 4387-4397.

[16] Insect community diversity characteristics in diversified pine forests. *Journal of Hebei Agricultural University*, 1997, 20(4): 61-65.
[17] Choi S W. Diversity and composition of larger moths in three different forest types of Southern Korea. *Ecological Research*, 2008, 23(3): 503-509.
[18] Alalouni U, Brandl R, Auge H, Schädler M. Does insect herbivory on oak depend on the diversity of tree stands?. *Basic and Applied Ecology*, 2014, 15(8): 685-692.
[19] Diversity and stability of arthropod communities in different bamboo forest stand types. 2007, 50(1): 31-37.
[20] Study on biodiversity and biomass of *Larix principis-rupprechtii* plantations in Yanshan Mountains. *Forest Resources Management*, 2010, (2): 43-49.
[21] Jobidon R, Cyr G, Thiffault N. Plant species diversity and composition along an experimental gradient of northern hardwood abundance in *Picea mariana* plantations. *Forest Ecology and Management*, 2004, 198(1/3): 209-221.
[22] Moreira X, Abdala-Roberts L, Rasmann S, Castagneyrol B, Mooney K A. Plant diversity effects on insect herbivores and their natural enemies: current thinking, recent findings, and future directions. *Current Opinion in Insect Science*, 2016, 14: 1-7.
[23] Discussion on current status and close-to-nature management approaches for Chinese plantations. *Journal of Northwest Forestry University*, 2008, 23(2): 184-188.

Note: Figure translations are in progress. See original paper for figures.