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Different diversity patterns of butterfly and moth assemblages between deciduous and evergreen broad-leaf forests

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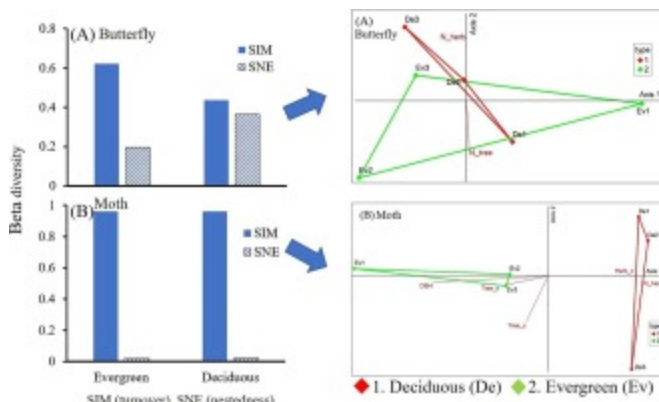
Highlights

- We compared the diversity and abundance of butterflies and moths in warm temperate forests.
- Estimated species richness was higher in the evergreen community than in the deciduous community.
- High turnover rates in moths and high nestedness in butterflies within the deciduous forest.
- Changes in canopy openness and tree density may affect insect communities in deciduous forest.

Abstract

In this study, we compared the diversity and abundance of two groups of Lepidopteran insects—butterflies and moths—across deciduous (DBL) and evergreen broad-leaved (EBL) tree communities in warm temperate forests. Over three years (from 2018 to 2020) at the Wando Arboretum, we used transect and point methods to sample butterflies and light traps to sample moths. Our findings revealed that the total estimated species richness was higher in EBL compared to DBL. Non-metric multidimensional scaling (NMDS) analysis confirmed distinct moth assemblages between the two tree communities, while butterfly assemblages did not exhibit such separation. The seasonal diversity patterns of butterflies in both forests differed significantly, whereas those of moths exhibited a similar trend with a peak in June. Beta diversity components indicated high turnover rates in moth assemblages across both tree communities and high nestedness in butterfly assemblages within the DBL. Although the diet breadth of butterflies and moths did not significantly differ between the two tree communities, the number of butterfly species per host plant was higher in DBL and that of moths was higher in EBL. Considering the ongoing vegetation transition from DBL to EBL, changes in forest structure—such as canopy openness and tree density—may adversely impact insect communities within DBL.

Graphical abstract



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Introduction

Warm-temperate climate can be characterized by mostly humid temperate climates with warmer summers and a longer growing season, and milder winters with mean

temperatures above freezing, which is quantified by the temperature sums above and below a growth threshold of 5°C. Warm-temperate evergreen and deciduous are differentiated by the degree of winter cold (Kira, 1977, Box and Fujiwara, 2015). Warm temperate forests are composed of evergreen broad-leaved trees such as *Quercus*, *Castanopsis*, *Cinnamomum*, and *Machilus* species, and are located in the intermediate region between temperate and tropical regions, at latitudes of 30°~40° (Yi, 2011, Park et al., 2013, Kang et al., 2014). Warm temperate forests in Korea are found in the southern region, where the average annual temperature is above 14°C, and cover an area of about 51.552 Km². Excluding Jeju Island (25.658 Km²), the largest warm temperate forest in the Korean Peninsula is located in Wando County (14.945 Km²) (Park and Shin, 2011).

Warm temperate forests support globally significant levels of biodiversity and also play an important role in global carbon regulation (Lu et al., 2017, Li et al., 2019). Diverse ecological studies on the flora and fauna inhabiting warm temperate forests in the Korean Peninsula have been carried out and these included vegetation surveys, forest communities, and forest management (Bae and Park, 2001, Cho, 2021, Kim et al., 1999, Kim et al., 2002, Lee, 2022, Lee et al., 2016, Lee et al., 2019), and diversity of animals including moths (Ahn et al., 2021, An et al., 2017, Choi and Na, 2005, Kim et al., 2012, Kim et al., 2016b, Lee et al., 2018). Due to the limitation of light availability to broad-leaved trees, the areas occupied by deciduous broad-leaved (DBL hereafter) trees are decreasing as the transition to evergreen broad-leaved (EBL hereafter) trees such as *Machilus* and *Neolitsea sericea* along the southern coast (Box and Fujiwara, 2015, Kim et al., 2016a, Kim et al., 2016a, Kim et al., 2018, Lee et al., 2019). In the south part of Korea, the area of deciduous forests in the warm temperate forest is decreasing (Cho and Oh, 2004) since deciduous forests such as *Quercus serrata* community are inferior in competition with evergreen forests by the limitation of light availability (Park, 2012). The future climate change scenarios predicted the northward expansion of EBL trees in Korea and the competition between DBL and EBL trees will be higher (Yun et al., 2011).

This study aimed to compare the diversity of diurnal butterflies and nocturnal moths inhabiting DBL and EBL forests in the warm temperate forest in Wando Arboretum. Lepidoptera is one of the most diverse groups of insects, with about 160,000 species known worldwide (van Nieukerken, 2011). Butterflies, with their colorful wings and diurnal activity, have been actively studied. Moths, with their nocturnal habits and attraction to light, can be easily and quantitatively surveyed by light trapping, making them useful organisms for assessing impacts on ecosystems (Kitching et al., 2000, Summerville et al., 2001, Summerville and Crist, 2002, Powell et al., 2013, Wagner et al., 2021). The species composition or community structure of herbivorous insects such as butterflies and moths

may change according to the habitat (Neuvonen and Niemelä, 1981, Crawley, 1989, Fuentes-Montemayor et al., 2022). For instance, evergreen tree species have leaves with longer lifespans and higher construction and maintenance costs, causing more herbivores exposure than deciduous trees (Eamus, 1999, Dirzo and Boege, 2008, Silva et al., 2015). Therefore, it is necessary to study and compare the diversity of insects inhabiting each tree community to understand how the decrease in specific forest areas due to transition affects the diversity of herbivorous insects, one of the species-rich groups, Lepidoptera.

Section snippets

Study sites

This study was conducted in Wando Arboretum, located in Gunoe-myeon, Wando, Jeollanam-do, which is the only warm temperate arboretum in Korea and the largest warm temperate forest in Korea. The existing vegetation in the Wando area is mostly composed of EBL forests of *Quercus acuta*, with DBL forests of oaks, pines, and *Ligustrum japonicum* (Kim et al., 1999, Park, 2012, Oh et al., 2013).

To compare the diversity of Lepidoptera insects in EBL and DBL forests, three study plots were selected for...

Results

The plant diversity between the DBL and EBL forests showed a similar number of tree and shrub species: 10 (± 2.45 S.D.) and 9 (± 1 S.D.) species in DBL and EBL, respectively. The number of herb species and coverage were higher in DBL, but the tree height and DBH were higher in EBL (Table 2).

The species diversity of butterflies and moths found in EBL and DBL in warm temperate forests showed that butterflies had higher species diversity in DBL, with 30 species and 340 individuals, compared to 25...

Discussion

From the three-year study, we found that the observed numbers of species from two forests were similar but the estimated number of species was much higher in EBL. It was noted that the high proportion of singletons would increase diversity because these singleton species are active colonists (Hilt and Fiedler, 2005). The high estimation of species richness in EBL

could be the result of a high singleton rate. In addition, we found that the turnover rate, one of two components of the beta...

CRedit authorship contribution statement

Na-Hyun Ahn: Data curation, Formal analysis, Investigation, Writing – original draft. **Sang-Hun Lee:** Funding acquisition, Project administration, Resources, Software. **Sang-Hak Han:** Data curation, Formal analysis, Investigation, Resources. **Sei-Woong Choi:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Project administration, Software, Supervision, Validation, Writing – review & editing....

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper...

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