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Editorial

Biodiversity and Ecology of Organisms Associated with Woody Plants

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1. Introduction

Woody plants serve as hosts for a vast array of organisms, ranging from herbivores and pathogenic species—often considered detrimental—to beneficial organisms that contribute to plant health and ecosystem stability. Natural enemies of pests, for instance, play a crucial role in maintaining the health of wild woody plants, production forests, and ornamental tree vegetation in urban green spaces, including city parks, gardens, and urban forests. While interactions between woody plants and herbivores have been extensively studied, much less is known about the intricate relationships among the diverse organisms that inhabit these plants.

Recent research has highlighted the ecological significance of these interactions. For example, mycoparasitic fungi and endophytic entomopathogenic fungi offer promising avenues for the biological control of woody plant fungal pathogens and pests. Similarly, certain deciduous tree species serve as reservoirs for predatory mites (Acari: Phytoseiidae) [1,2], which contribute to the regulation of phytophagous mite populations in adjacent orchards and vineyards [3]. The presence of abandoned leaf mines has also been shown to enhance phytoseiid mite densities [4], further illustrating the complexity of these interactions. However, our understanding of such ecological networks remains incomplete, and further studies are needed to elucidate their roles in ecosystem functioning.

The impact of climate change on woody plant-inhabiting organisms is another pressing issue [5]. Rising temperatures, prolonged drought periods, shifts in hydrological conditions, and air pollution are contributing to the declining physiological activity of woody plants, often triggering outbreaks of insect pests and fungal pathogens. The widespread decline in forest trees due to bark beetles and their fungal associates continues to be a major research focus, yet significant knowledge gaps persist regarding their biology, ecology, epidemiology, and management [6,7]. Understanding the diverse types of bark beetle–fungus interactions is critical for developing effective mitigation strategies [8].

This Special Issue aims to present the recent advances in our knowledge of the biodiversity and ecological interactions of both beneficial and harmful organisms associated with woody plants. Relevant topics include, but are not limited to, the following: (1) above- and below-ground communities, (2) micro- and macro-organisms, (3) population dynamics and seasonal variations, (4) invasive pests and pathogens, (5) pollinators and natural enemies, (6) mutualistic interactions and competition, (7) effects of pollution and climate change, and (8) methods and modeling approaches for studying plant-associated organisms.

This Special Issue presented cutting-edge research on woody plant–pathogen and woody plant–arthropod interactions, as well as studies exploring their combined effects.

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Contributions covered diverse ecosystems and geographical regions. While field studies were particularly emphasized, laboratory-based research was also included. By compiling the latest research in this field, this Special Issue will contribute to a deeper understanding of the ecological roles of the organisms associated with woody plants and their implications for forest health, conservation, and sustainable management.

2. Summary of Papers Included in the Special Issue

This Special Issue comprises 15 papers written by 72 authors from 11 countries, namely Croatia, Czech Republic, Japan, Latvia, Norway, Portugal, Russia, Serbia, Slovakia, Spain, and the USA. The collection represents a diverse array of studies on various organisms associated with woody plants ranging from microorganisms to invertebrates and mammals. As such, this Special Issue offers valuable examples of recent research activities in this global discipline.

Four studies published in this Special Issue highlight the significant role of fungal communities in forest health, resilience, and disease management. One study examined the diversity of culturable endophytic fungi in symptomatic and asymptomatic *Fraxinus excelsior*, identifying dominant species such as *Diaporthe eres* and *Alternaria alternata*. The inhibitory potential of certain endophytes against *Hymenoscyphus fraxineus*, the causative agent of ash dieback, was demonstrated, with *Fusarium lateritium* and *Didymella aliena* showing the strongest suppressive effects in planta [9].

In clonal forestry, mycorrhizal associations play a critical role in tree performance. Research on silver birch and hybrid aspen plantations revealed that mycorrhizal communities were moderately diverse, predominantly consisting of generalist ectomycorrhizal taxa. Clone-specific differences in mycorrhizal richness were observed, with hybrid aspen productivity showing an inverse relationship to fungal diversity, emphasizing the importance of host–genotype interactions in forest regeneration [10].

Efforts to mitigate *Fusarium circinatum*, the pathogen responsible for pine pitch canker, have focused on seed disinfection methods. A comparative study tested MennoFlorades, Captan, ethanol, and hot water treatments, with hot water emerging as the most effective and environmentally sustainable option for eliminating the pathogen without compromising seedling viability, providing a practical solution for nursery and forest management [11].

Finally, fungal biodiversity serves as a key indicator of forest habitat conservation. An analysis of macrofungi and lichenized fungi in Pyrenean oak and chestnut forests revealed greater species diversity in *Quercus pyrenaica* ecosystems. The presence of pollution-sensitive lichens in oak forests and a higher proportion of ectomycorrhizal fungi in chestnut groves highlight the ecological significance of these fungal communities and the need for finer-scale conservation assessments [12].

Recent research on invertebrate pests highlights emerging threats to forestry and agriculture, as well as the ecological complexities of pest population dynamics. A significant discovery was made with the first report of *Bursaphelenchus xylophilus*, the pinewood nematode, in *Pinus sylvestris* in Europe. Previously recorded in other *Pinus* species, its detection in Portugal raises serious phytosanitary concerns, reinforcing the need for stringent monitoring and management strategies to prevent further spread [13].

Understanding the dynamics of insect seed predators is crucial for predicting pest outbreaks in fruit crops. Long-term data from Norway on *Argyresthia conjugella* and *Megastigmus brevicaudis* revealed prolonged diapause as a key factor influencing their population cycles. Both seed predators and their associated parasitoids exhibited delayed emergence, sometimes spanning up to five years. These findings emphasize the need to account for diapause when studying insect guilds in rowanberry ecosystems, particularly

given the occasional shift of *A. conjugella* to apple as an alternative host during poor rowan fruiting years [14].

Meanwhile, the increasing impact of *Ips sexdentatus*, a bark beetle species, has become evident in the Czech Republic. Population monitoring over two years revealed seasonal flight activity patterns, with peak swarming occurring in June and July. The study identified ACUMIPROTECT as the most effective pheromone lure for monitoring purposes and emphasized the potential influence of climate change on the voltinism and behavior of this pest. Such insights are essential for refining forest protection strategies [15].

The research conducted by Takagi and Kajimura [16] sheds light on the ecological traits of three species of *Xiphydria* woodwasps from Japan, emphasizing their host tree preferences and the intriguing relationships with symbiotic fungi and mucus in their bodies. As woodwasps play a significant role in forest ecosystems, understanding the ecology of Xiphydriidae is crucial, especially given the limited knowledge compared to their Siricidae counterparts. This study reveals new host records and highlights the complexity of their ecological interactions, including the presence of specialized mycangia for fungal associations and unique mucus characteristics. The findings contribute to the broader understanding of woodwasp biology and their role in forest dynamics, which is vital for effective pest management strategies.

Recent studies on natural enemies highlight their crucial role in regulating pest populations in diverse ecosystems, from urban trees to coniferous forests. A survey of predatory mites inhabiting *Aesculus hippocastanum* revealed a diverse community dominated by *Euseius finlandicus*, whose abundance was influenced by environmental factors such as urban greenery and air pollution. These findings underscore the potential of horse chestnut trees as reservoirs for phytoseiid mites, which could contribute to natural pest control in urban landscapes [17]. Similarly, research on mite communities associated with *Ips typographus* in Europe provided new insights into the diversity of these potential biological control agents. The study documented several mite species in Serbia for the first time, expanding the known distribution of key taxa and reinforcing the need for the further exploration of their ecological roles in bark beetle-infested forests [18].

Efforts to improve bark beetle management have also focused on reducing unintended impacts on natural enemies. A modification to pheromone traps used for monitoring *Orthotomicus erosus* in Croatia successfully reduced the capture of key predatory beetles, such as *Temnoscheila caerulea* and *Thanasimus formicarius*, without significantly affecting bark beetle captures. This approach offers a more balanced strategy for forest protection, ensuring that beneficial predators continue to contribute to pest suppression [19].

In agroforestry, parasitoids play a vital role in controlling invasive leafminers. A long-term study on *Cameraria ohridella* in the Czech Republic revealed fluctuations in parasitism rates and a shift in the dominant parasitoid species over time. The increasing prevalence of *Pediobius saulius* suggests an adaptive response of native parasitoid communities to the invasive host, highlighting the dynamic interactions shaping biological control success [20].

Ecosystem engineers play a critical role in shaping habitats and influencing biodiversity, often in ways that are underappreciated. Deadwood-dwelling beetles, particularly those in the Eucnemidae family, are key contributors to forest decomposition processes, yet their ecology remains poorly understood. A study conducted in a beech reserve in the Czech Republic provided new insights into the distribution and habitat preferences of these elusive beetles. Results indicated that lying logs offered a more stable microclimate, supporting a higher diversity of species, including several endangered ones. This underscores the importance of maintaining diverse deadwood structures in forest management practices to support saproxylic biodiversity [21].

Similarly, the underestimated ecological role of subdominant ants is highlighted in research on *Formica lemani*, a species capable of forming large nest complexes (NCs) that restructure behavioral interactions within forest ecosystems. Within these NCs, *F. lemani* exhibited higher population densities, increased aggressiveness, and more efficient trophobiotic relationships with aphids, particularly on birch trees. This behavior enhances the species' competitive ability, allowing it to play a significant role in plant protection against herbivores. The study challenges traditional views of ant hierarchy in forest systems, emphasizing that subdominant species can act as influential ecosystem engineers under the right ecological conditions [22].

Understanding the intricate relationships between species and their environment is key to predicting how ecosystems respond to change. One such complexity arises from the interaction between non-native plants, vegetative structure, and the foraging behavior of insectivorous bats. A study conducted in the forests of northern New Jersey [23] explored these dynamics, revealing that non-native vegetation significantly alters midstory clutter but does not directly impact insect abundance. Interestingly, bat activity was highest in areas with a high percentage of non-native vegetation and reduced midstory clutter, suggesting that structural openness is a stronger predictor of bat foraging than prey availability. However, the response varied by foraging guild—bats adapted to open spaces benefited from altered vegetation, while clutter-adapted species showed no clear preference. These findings highlight the multifaceted ways in which invasive species can reshape ecosystems, influencing not only plant communities but also higher trophic levels, such as insectivorous bats. The study underscores the need for further research to disentangle the indirect effects of non-native plants on predator–prey interactions and habitat use.

3. Concluding Remarks

This collection of studies provides critical insights into the multifaceted roles of invertebrates and microorganisms in forestry ecosystems, significantly enhancing our understanding of pest management and ecological interactions. The findings reveal how fungal communities contribute to disease suppression, optimize tree performance, and serve as bioindicators for forest health. By investigating pests like *B. xylophilus* and *I. sexdentatus*, as well as their natural enemies, these studies highlight the necessity of continuous surveillance and adaptive strategies in response to climate change and emerging pest threats. Furthermore, the research underscores the importance of preserving natural enemy communities, including predatory mites and parasitic wasps, as integral components of sustainable pest management in both forestry and urban environments. Recognizing the contributions of overlooked invertebrate groups, such as saproxylic beetles and ants, reinforces their significant influence on ecosystem dynamics. Together, these studies advocate for a holistic approach to biodiversity conservation and sustainable habitat management, emphasizing the need for further research into fungal-based biocontrol methods, mycorrhizal associations, and the complex interactions within these ecosystems.

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