University of Sopron

Faculty of Forestry

Thesis of PhD dissertation

FOREST HEALTH RELATED MYRMECOLOGICAL STUDIES IN HUNGARIAN OAK FORESTS

Ágnes Fürjes-Mikó

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Doctoral school:	Roth Gyula Doctoral School of Forestry and Wildlife Management Sciences
Head of Doctoral School:	Prof. Dr. Sándor Faragó, corresponding member of HAS
Program:	Biological Basis of Forest Management (E2)
Program leader:	Prof. Dr. Ferenc Lakatos
Supervisor:	Dr. György Csóka

Introduction

Forest ecosystems are under increasing pressure due to climate change and biological invasions. Global warming, increased frequency of droughts, changes in rainfall patterns and extreme weather events are all putting pressure on trees and forests reducing their health status and resilience. Weakened stands become more susceptible to pathogens and pests, which are also benefited by milder winters and longer growing seasons. This is one major reason why some species having positive impacts on forest health, such as red wood ants (*Formica rufa* group), become more important in maintaining forest resistance, resilience and regeneration potential.

This is particularly important in the case of oak forests, which have prominent ecological and economic value. Hungarian oak forests are highly diverse habitats, with nearly 700 herbivorous insect species - many of them are oak specialists. They also play an important role in the timber industry, carbon sequestration, water balance regulation and soil conservation. However, climate change also have severe negative impacts on these ecosystems as well, making it especially important to investigate the role species such as red wood ants since they may play important roles in decreasing the damage risks and supporting ecological stability of forests.

Although the ecological roles of red wood ants have been studied for a long time, many aspects are not yet completely known. Previous studies have mainly been carried out in conifer forests, especially in Switzerland and Germany, and in boreal forests such as Scandinavia and Finland, where these species are more widespread and therefore easier to study. However, the results from these areas have limited applicability to other forest types, especially temperate deciduous forests, where the behavior and ecological role of red wood ants may differ in some cases.

Aims

The aim of the research was to provide more detailed quantitative and qualitative data on the ecological role of red wood ants. Particular attention was given to oak stands, as significantly less data is available on them compared to boreal coniferous forest. Therefore, the studies were carried out in hilly forest stands dominated by sessile oak and where red wood ants were found at a particularly high density (14 nests/ha). This concentration allowed a more detailed investigation of the impact of the species group on the arthropod communities.

The research aimed to answer the following questions:

1. We hypothesized that the presence of wood ants reduces significantly the abundance of herbivorous insects in oak forests, thereby also decreasing the damage they cause.

    - To what extent do red wood ants reduce the populations of Micro- and Macrolepidoptera species in oak forests?

2. We hypothesize that the prey spectrum of red wood ants is concentrated on soft-bodied insects (e.g. caterpillars) living primarily on the canopy, but also "samples" species living at different layers of the forest, reflecting the vertical activity of ant species.

    - What species of caterpillars are eaten by ants, at what time of the year and in what quantities?

    - What other arthropod species are preyed by red wood ants?

3. We hypothesized that red wood ants have a positive effect on the density of sessile oak and Turkey oak seedlings by preying on or disturbing insects that damage acorns and seedlings.

    - Is there a significant difference in the number of seedlings between areas frequented by ants and those without ant activity?

4. The galls of gall wasps developing on oaks are used as microhabitats by several insect species, but little is known about their relationship with ants.

    - What types of galls are utilized by ants?

    - Which species use the galls of oak gall wasps as microhabitats, and in what ways?

Matherials and methods

The experimental site is located in Northern Hungary, in the Mátra Mountains (47°52'41.4"N, 19°56'41.0"E), with the control site situated 125 meters to the southeast. The studied forest compartments (Gyöngyössolymos 56/A, 57/B, 57/G) are part of the Natura 2000 network. Compartment 57/G is designated for experimental purposes and has been the subject of forest health monitoring for 42 years by the Department of Forest Protection of the University of Sopron's Forest Research Institute. The dominant tree species are sessile oak (*Quercus petraea*) and Turkey oak (*Quercus cerris*), with hornbeam (*Carpinus betulus*) forming the secondary canopy layer. The oaks have an average age of 120 years, while the hornbeams are of mixed age and originate from natural regeneration. Both sites are 5 hectares in size, have a southwestern exposure, and are situated at elevations between 550 and 650 meters with slopes ranging from 10% to 15%. The average canopy closure is 75%, with partial canopy gaps

occurring only in the northeastern corner. The climate corresponds to the hornbeam-oak forest zone, and the soil is brown forest soil, free from surplus water.

The main point in selecting the experimental site was the high density of ant nests. According to observations, no ant nests or significant ant activity were detected in the control area, while based on preliminary surveys the experimental area hosts approximately 70 nests, with slight temporal fluctuations in their number. The present supercolony has been established for at least 10 years.

The following methods were used to answer the research questions:

1. Sticky belt traps:

   The impact of red wood ants on the population of herbivorous insects was assessed using sticky belt traps. A total of 180 adhesive belt traps, 30 per tree species, were installed in both the sample and control areas. The investigations were conducted annually between 2018 and 2024, from November to mid-April. The traps were fastened at breast height (approximately 130–150 cm) and were 15 cm wide. In the case of trees with thicker bark, partial bark removal was necessary – while preserving the integrity of the phloem – to prevent moths from bypassing the trap underneath. The trap surfaces were sprayed with a non-drying adhesive (Fytofarm, Chemstop Ecofix). To account for differences in tree trunk circumference, results were expressed as the average number of individuals per meter of trap length per day.

2. Chauvin traps:

   Studies on the prey spectrum of wood ants were conducted using Chauvin traps. Trap testing and calibration took place in

2022, while actual data collection occurred in 2023 and 2024, using three traps per year. Observations were carried out once or twice weekly during the study periods, always in the morning hours, with a standardized observation time of 90 minutes per session. The number of observation sessions was 18 in 2023 and 16 in 2024.

3. Seedling survey:

The aim of the seedling survey was to assess the forest's natural regeneration capacity. It was conducted in the end of May 2021, following a year of a mass acorn crop. Due to low acorn yield in the subsequent years, no further sampling was carried out. In the Gyöngyössolymos 56/A, 57/B, and 57/G forest compartments, 300 quadrats of 1×1 meters were designated semi-randomly in both the control and experimental plots. Within each quadrat, the number of one-year-old seedlings originating from the previous year's acorn crop of sessile oak (*Quercus petraea*) and Turkey oak (*Quercus cerris*) was counted and recorded.

4. Gall survey:

Galls were collected non-systematically from 21 locations across Hungary between 2014 and 2016. Sampling was selective, targeting older galls with visible emergence holes, as these were considered most likely to support ant colony establishment. Consequently, no data is available on the proportion of potentially suitable galls that are actually colonized by ants.

Results

1. During the six sampling periods between 2018 and 2024, the sticky belt traps captured a total of 77,208 moth individuals. The vast

majority of these belonged to the Geometridae family by a significant margin. Other groups (Microlepidoptera, Noctuidae, Notodontidae, and Erebidae) were represented in much smaller numbers. The number of individuals from the Geometridae family was found to be significantly lower in the ant-occupied experimental plots compared to the control plots. In contrast, no similarly clear pattern was observed for the other moth groups studied. This result suggests that Geometridae species densities are influenced by the presence of wood ants, although this effect was not consistently detectable across all years. This indicates that ants are not selective in their feeding habits but rather consume what is abundant and easily accessible at the time. In other words, their diet shifts toward what is most abundant during a given period, allowing them to regulate population densities opportunistically. While ants are unlikely to eliminate population outbreaks entirely, they may contribute to increasing the intervals between outbreaks and reducing their amplitude, thus exerting a stabilizing influence on herbivore populations.

2. According to the results of our Chauvin trap survey, in 2023 the three Chauvin traps captured an average of 317 caterpillars, while in the second year (2024), the average was 185. In total, 33 species from 13 moth families were identified. In both years, early May marked the peak of caterpillar predation. In both years, species from the Geometridae family dominated the prey spectrum, especially *Operophtera brumata*. Other frequently collected species included *Agriopis aurantiaria/marginaria* and *Agriopis leucophaearia* (also Geometridae), as well as *Orthosia cruda* and *O. cerasi* from the Noctuidae family. The study confirmed that wood ants transport a wide range of both living and dead insect prey into their nests, in whole or fragmented form. This method provides insight into the local insect fauna and dominance patterns, and it can reveal species that are difficult or impossible to sample using conventional methods (e.g. species living in the canopy).

3. Wood ants had a significantly positive effect on the seedling density of Turkey oak, while in the case of sessile oak, although there was a difference, it was not statistically significant. On the experimental plots, the average density of sessile oak seedlings was 18.8 individuals/m², compared to 11.2 individuals/m² on the control plots. For Turkey oak, the average was 3.9 individuals/m² on the experimental site and 1.3 individuals/m² on the control site. One likely explanation is that ants disturb and/or prey organisms feeding on or damaging oak acorns both on the tree and after they fall, thus promoting better seedling establishment.

4. Various gall wasp species provide habitat or refuge for numerous ant species. In this study, out of 182 galls, we detected the presence of 11 ant species in the galls of 10 gall wasp species. Three types of associations between ants and galls were distinguished. Strong, species-specific associations (e.g., *Temnothorax crassispinus* and *Andricus hungaricus*); distinct, separate clusters with limited overlap; and generalist species in terms of gall use, such as *Temnothorax albipennis*. The findings confirm that ant–gall wasp relationships exhibit significant ecological structuring, and analyzing these associations can be key to understanding the dynamics of interaction networks. Additionally, the presence of galls facilitates ant colonization and may increase ant abundance. Since these ant species are dominantly predators of tree-dwelling herbivorous insects, they provide valuable ecosystem services by reducing herbivore populations.

Recommendations for further research

- Although we used several approaches to assess the impacts of ants, a large volume of data was collected that could not be included in the dissertation. Therefore, we recommend further analysis of these existing datasets (examination of different moth species

using funnel pheromone traps; studies on acorns of Turkey oak and sessile oak; dendrochronological analyses etc.).

- Introduction of new methodologies: wildlife cameras to assess whether red wood ants disturb large game species; installation of a meteorological station; conducting faunistic and floristic surveys etc.
- Continuation and refinement of existing research, and expansion of the study to other areas.

Theses

Based on the results of the study, the main theses of the dissertation are as follows:

1. In the survey conducted using sticky belt traps, the number of individuals belonging to the Geometridae moth family was significantly lower in areas visited by ants compared to control areas. The dominant species belonged to this family, accounting for 93% of all trapped moths. The remaining moths belonged to the Microlepidoptera, Noctuidae, Notodontidae and Erebidae groups.

2. In the study using Chauvin traps, caterpillar consumption peaked in May in both 2023 and 2024. In both years, the Geometridae family dominated the prey composition (~50%), with *Operophtera brumata* being the most common species (28% in 2023 and 23% in 2024). Over the two years, a total of 33 species from 13 Lepidoptera families were identified.

3. In the seedling survey, a significant difference was found for Turkey oak: the number of seedlings was higher in areas occupied by ants than in the control areas. A similar trend was observed for sessile oak, although the difference was not statistically significant.

4. In the gall survey, the presence of 11 ant species was confirmed in galls of 10 gall wasp species. We observed three main patterns of interaction between ants and galls. Our findings show that ants living in galls found on the ground surface and those detected in arboreal galls form clearly distinct groups. Out of the 11 ant species, 7 were found exclusively in arboreal galls, 2 exclusively in ground galls, and 2 species occurred in both habitats.

Publications

Scientific publications in English forming the basis of the dissertation:

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