

**Interactions between biotic and abiotic  
environmental factors and red wood ants  
in Central-Europe**

Thesis statements of the Ph.D. dissertation

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## INTRODUCTION

The red wood ants are keystone species of coniferous and mixed-coniferous forest ecosystems in Europe. They affect the nutrient cycle, soil composition, the range and growth of the plant species, but also the invertebrate and vertebrate community. Moreover, the nest mounds of red wood ants provide shelter for various associated invertebrate and microbial communities.

On their turn, the range and viability of red wood ant populations and their effect on the ecosystem is affected by the environmental conditions both on large- and small-scale. Temperature, precipitation, and irradiation change along with large-scale environmental factors such as latitude and altitude. These affect the range and traits of animals and plants along these gradients leading to patterns and regularities such as Bergmann's rule. According to Bergmann's rule, the body size of animals increases with the decrease of temperature from the Equator to the Poles. In red wood ants, the validity of Bergmann's rule was not tested yet.

To fulfil their role in the ecosystem, red wood ants need certain habitat conditions that are mainly available in coniferous and mixed-coniferous forests. For example, the main carbohydrate source of red wood ants is the honeydew of aphid colonies on coniferous trees. To build their nest mounds they use pine needles and pine resin to disinfect the nest material. Anthropogenic climate change leads to the disappearance of coniferous forests in Central-Europe mostly due to the high spread of bark beetles favoured by the changing climate. The forestry management reacts with clear-cutting of these forests, and due to the changes of their main habitat, red wood ants are forced to populate alternative habitats. However, studies about their viability and long persistence in these habitats are lacking in Central-Europe.

The global temperature is rising due to anthropogenic climate change and leads to unexpected, extreme weather events causing an increase of biotic (bark beetle gradation) and abiotic (drought) damages in forests. This leads to a growing need for alternative biological control against biotic damages instead of conventional protection tactics (clear-cutting) that usually have a detrimental effect on forest specialist species and forest ecosystems. The red wood ants are known

as effective biological pest control agents because of their territoriality and high protein demand. They were used successfully against *Oporinia autumnata* gradation, however, their usefulness against bark beetle gradation is unknown so far.

Red wood ants affect all the invertebrate communities around their nests. They also shape the ant community due to their territorial behaviour, large colony size and aggressiveness of their workers, characteristics that make them highly ranked in the competitive hierarchy of ants. This regulatory role of red wood ants is well studied in Scandinavia but in Central-Europe these studies are still lacking, mostly related to the comparison of the effects of different wood ants having different colony structures.

## **AIMS**

The aims of this thesis were the followings, grouped in two main categories based on the direction of the interaction between ants and the environment:

### **The effect of the environment on red wood ants**

#### *1. Research: Effects of large- and small-scale environmental factors on the colony size of red wood ants*

I presumed that,

- a) the latitudinal and altitudinal gradients will affect the nest size of the red wood ants according to Bergmann's rule.
- b) the small-scale environmental factors will fine-tune the effects of large-scale gradients.

#### *2. Research: The effect of the absence of coniferous trees on red wood ants*

I presumed that,

- a) the absence of coniferous trees will lead to the decrease of the nest mound size and changes in the colony structure.
- b) in the deciduous forest the nest shape will change in the lack of pine needles.

## **The effect of red wood ants on the environment**

### 3. Research: The effect of red wood ants on *Ips* spp. infestation

I presumed that,

- a) the presence of red wood ants will decrease the number of trees damaged by *Ips* spp.
- b) red wood ants will not affect other wood dwelling beetle groups.

### 4. Research: The effect of red wood ants on other ant species

Both red wood ant species (*F. rufa* and *F. polyctena*) tend to exclude other territorial ant species, reduce the number of the nests of encounter ant species, whereas they tend to show a higher tolerance towards the submissive ants. However, due to the differences found in the social organisation of the two wood ant species, I presumed that in the same habitat the two species will have

- a) a different impact on the occurrence of other ant species nests situated near their mounds, and this effect will be also influenced by the
- b) size of and
- c) distance from their mounds.

## **MATERIAL AND METHODES**

We investigated the characteristics of red wood ant populations in three Central-European countries (Hungary, Slovakia, Poland) between 2017 and 2019. We chose our sampling plots across a latitudinal (Ásotthalom 46.215283°N – Koszalin 54.069650°N) and an altitudinal (75 m – 954 m) gradient. We collected the background variables from the WorldClim (Global Climate Data) database. We chose 12 regions to describe the red wood ant populations and their habitat. In each region, we chose three 150 × 150 m sampling plots in coniferous and mixed-coniferous forests.

**1. Research:** We marked the location of red wood ant nests with the help of a GPS (GARMIN Oregon 700t). We measured the size of each nest (two perpendicular diameters and height) and determined the above-ground nest volume. We also mapped the foraging trails of the nests (m). Considering the small-scale factors, we measured the girth of the closest trees at breast height (1.3 m) in a circle surrounding the

nests relevant to their shading (360°). In addition, we noted the species of these trees, the presence of the aphid-tending ants on them and measured the distance between these trees and the nests.

**2. Research:** To monitor the changes in the red wood ant colonies in the absence of coniferous trees we compared a mixed coniferous-deciduous forest plot to a recently clear-cutted and a deciduous plot.

**3. Research:** We also mapped the damaged/infected trees within the sampling plots. We noted the number and GPS location of every infested tree within a sampling plot and noted the type of parasite infestation (bark beetle, longhorn beetle, jewel beetle, or fungus). For a more precise characterization of the forest health status, we also recorded the status (Alive or Dead) and position (Standing or Laying) of the infested trees.

**4. Research:** To assess the effect of *F. rufa* and *F. polyctena* on the ant community, we selected 10 individual colonies of each of the considered wood ant species in Białowieża Forest (Poland). Around each of the selected nests, we marked four transects in the directions S, W, N, and E. On each of the transects, we established three squared plots with an area of 10 m<sup>2</sup> at 10, 20, and 30 m distance from the mounds. Within every plot, we mapped the number of ant nests, their location within the quadrat, their distance from each other, and the presence of wood ant workers (foraging trails or dispersed individuals). If the latter were present, we considered that plot with high wood ant presence (WA+), whereas when no wood ants were found that plot was considered with low wood ant presence (WA-).

## RESULTS AND DISCUSSION

### The effect of the environment on red wood ants

#### 1. Research: Effects of large- and small-scale environmental factors on the colony size of red wood ants (Juhász et al. 2020a).

We found that increasing latitude caused a significant increase in the nest size of *F. polyctena* in accordance with Bergmann's rule, whereas altitude did not have a significant effect on nest size. This could be because the heat-conservation mechanism. Larger nests have better

surface area to volume ratio therefore can conserve heat more effectively. From the large-scale environmental factors increasing along with the latitude, irradiation was the most important factor affecting the nest size. Irradiation is the most important factor in nest heating because the ants can actively collect the heat from irradiation while “sunbathing” and egress it inside the nest. Besides irradiation also temperature and local factors, like the perimeter of the trees and their distance from the nest, were also influencing the nest size. The small-scale environmental factors had a stronger effect on nest size in regions where the irradiation was low (Poland) and where the shading effect of trees had a stronger role in nest size determination than in the southern regions. Which is also in connection with better heat conservation.

*2. Research: The effect of the absence of coniferous trees on red wood ants (Juhász et al. 2020b)*

Coniferous tree species provide nest material and food source for red wood ant species therefore the loss of coniferous forests can cause irreversible damage to red wood ant colonies. Clear-cutting leads to the splitting of their nests, the shortening of their foraging routes, and the elevated death rate of small nests. These effects could be also observed in our clear-cutted sampling plot decreasing the vitality of the sampled colonies. On the other hand, in our deciduous sampling plot, the missing support of pine needles caused changes in the originally half-ellipsoid nest shape that became flatter and longer. The absence of coniferous aphid colonies led to longer foraging routes to trees where suitable honeydew was available. However, the colony sizes were still smaller compared to the control (mixed-coniferous forest) plot. Here we also found a high preference for *Quercus cerris* trees, being the destination of most of the foraging routes. We can presume that tannin could be a good substitute for pine resin although more research is needed to confirm this assumption. Despite that red wood ants are ecologically flexible, the altered colony size and structure make these colonies more vulnerable to environmental conditions, predators, and parasites.

## **The effect of red wood ants on the environment**

### 3. Research: The effect of red wood ants on *Ips* spp. infestation (Trigos-Peral et al. under review)

We found that the number of infested trees by *Ips* spp. was significantly reduced by the increasing number of *F. polyctena* nests. Moreover, the increasing number of *F. polyctena* nests also tended to reduce the number of trees affected by fungal infestation. However, we did not find a significant effect of the number of *F. polyctena* nests on the *Cerambycidae* and *Buprestidae* infestations, nor the number of beetle groups. The tree infestation rates were not affected by the size of the nests, nor by the latitude and altitude. Our results showed that *F. polyctena* can be a good selective biological control agent against bark beetles thanks to the density-dependent preference for gradating beetles. Therefore, we highlight the need for developing protection plans for this species also to be able to exploit the benefits of the presence of their populations.

### 4. Research The effect of red wood ants on other ant species (Maák et al. 2021)

In our study site, *F. rufa* had a significantly smaller nest size than *F. polyctena*. Despite this difference, they had the same effect on the ant community living nearby. The reason behind this might be that the monogynous *F. rufa* shows more aggressive behaviour than the polygynous *F. polyctena*. In the territories of both red wood ants, other territorial species were missing but subordinates were present in an even diversity, density, and distribution along with the distance from the wood ant mounds. The genus *Myrmica* (90%) was the most well-represented genus (especially *M. rubra* and *M. ruginodis*) in the wood ant territories. Based on our results it seems that the adaptability of subordinate species makes possible for them to tolerate the circumstances close-by the wood ant mounds by changes in their strategies, foraging behaviour, and switching to the use of alternative food sources, like corpses of wood ants present in high abundance. Although these changes may not allow them to reach a normal colony size and reproduction but may allow their colonies to survive while maintaining relatively large nest densities.

## SUMMARY

### The effect of the environment on red wood ants

- 1. Research** The latitude affects the nest size of red wood ants in accordance with Bergmann's rule. The most important background variable affecting the nest size is irradiation, but also the effect of temperature was significant. Small-scale environmental variables play an important role mostly in regions where the irradiation is low (Poland).
- 2. Research** The lack of coniferous species (clear-cutting, deciduous forest conditions) has a negative effect on red wood ants. It decreases the nest and colony size and alters their foraging habits.

### The effect of red wood ants on the environment

- 3. Research** Red wood ants are applicable as biological pest control in coniferous forests against *Ips* spp. gradation. The strength of the effect of red wood ants depends on the number but not on the size of their nests present in the forest.
- 4. Research** Despite the size difference in their mounds, *F. polyctena* and *F. rufa* had a similar effect on the ant community living nearby their mounds. They excluded other territorial species but allowed the persistence of the subordinates in an even diversity, density, and distribution along with the distance from their mounds, especially *Myrmica* species. It seems that the adaptability of subordinate species makes possible for them to tolerate the circumstances close-by the wood ant mounds, especially in the patches with low wood ant activity, leading to quite high nest densities.

Based on our results, we can better understand the long-term effects of the fast-changing environmental factors on this ecologically important group. Moreover, this can also contribute to the planning of forest management tactics in a way also assuring the long-term survival of red wood ants.



## LIST OF PUBLICATIONS

MTMT ID: [10058089](#)

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### Publications support the dissertation

**Juhász O.**, Bártori Z., Trigós-Peral G., Lőrinczi G., Módra G., Bóni I., Kiss P. J., Aguilon D. J., Tenyér A., Maák I. (2020a): Large- and small-scale environmental factors drive distributions of ant mound size across a latitudinal gradient. *Insects* **11**, 350. DOI: [10.3390/insects11060350](#).

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### Publications in referred journals

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## Abstracts, posters

### Abstracts, posters supporting the dissertation

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