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The impact of urban warfare on the structure of ant assemblages on trees (Hymenoptera: Formicidae)

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Abstract
Military actions cause great harm to the environment, as well as to biocenoses. The life cycle of the colony and the activity of some species of ants is associated with trees. The purpose of the study is to analyze the relationship between the degree of damage to tree plantations and changes in the structure of ant communities as a result of hostilities. The study was conducted in August 2022 on the territory of the cities of Irpin and Bucha (Kyiv region, Ukraine), six months after the Russian attack on Ukraine (02/24/2022). Intense fighting took place in Irpin and Bucha from the end of February until April 2022. The degree of destruction of the infrastructure of Bucha was 26%, of Irpin 71%. In total, 200 trees were examined in Bucha and 201 in Irpin. 11 species of ants were found on 12 tree species. The examined trees were divided into 5 classes according to the degree of damage. The higher the damage class of a tree, the smaller the number of trees of this class. Therefore, damage to large and mature trees as a result of fighting more significantly affects ant communities. The results obtained indicate that the ants prefer to visit larger trees of certain species (oaks), but with a degree of damage up to 3rd. The hostilities can have a negative effect on ant communities within the next five months after they leave their wintering grounds.

Key words: hostilities, Ukraine, Irpin, Bucha, damage, trees, ants.

Introduction

With the technological and scientific progress of mankind, wars cause more and more damage not only to people, but also to the environment (Ehrlich et al. 1983; Reuveny et al. 2010; Gaynor et al. 2016). During the explosions of shells, mines, rockets, toxic gases are released, and the atmosphere is polluted. Also, during the combustion of explosives, NO2 is released, which, interacting with water vapor, forms an aerosol of nitric acid. Later, the aerosol settles on plants, animals and soil, causing chemical burns and other changes. In addition, fragments enter the soil, changing its structure and chemical composition (Biswas 2000). Fragments of shells, mines, bullets do not consist of one metal, but of several. Consequently, in the soil they will create galvanic couples and the electric current arising between them will affect the pH of the soil. This will affect the soil bacteria that interact with the roots of plants and contribute to their vital activity. The deterioration of the vital activity of plants will directly affect animals. The ingress of chemical compounds formed as a result of explosions into water bodies or aquifers can lead to a sharp change in such water properties as hardness, pH (Gangwar 2008; Francis 2011). Significant transformations of river systems were noted, for example, in Ukraine, even after World War II (Chepurda 2015).

The explosion of one air bomb weighing 0.5 tons can form a crater up to 6 m deep. Flying bullets and fragments from mines, shells and air bombs damage tree trunks and bushes, and kill animals (Hayward 2009). In the case of warfare in wooded areas, fires often occur. In modern wars, the most fierce military operations take place in dense urban areas. Opponents are fighting for each house, resulting in a sharp increase in the density of fire on such objects. Thus, intense hostilities in urbanized areas cause significant damage to all components of the biotope – air, soil, water resources and biota. Arid regions with limited water supplies may suffer the most from hostilities (McNeely 2003a).

After the Second World War, the most violent conflict in Europe was the war between Russia and Ukraine, which received the most powerful stage of escalation on February 24, 2022 with the military invasion of the first.

Such intense fighting actions led to a significant destruction of the urban infrastructure in Bucha, Irpin and other cities of Ukraine, and also significantly affected the biotopes (Battle of Irpin 2022; Battle of Bucha 2022). For example, in Ukraine, after February 24, 2022, until the end of spring, about 43 thousand hectares of forests burned down as a result of the war, which is 3 times higher than in spring 2021. For comparison, during the period 2014-2022 in the Donetsk region of Ukraine, 1405 hectares of forest burned out of 130 thousand hectares of the total forest fund of the region (Ministry of the Environmental Protection and Natural resources 2022). Fires in forests are often caused by the fact that not only the civilian population but also combatants are hiding in them (McNeely 2003b). The countries involved in the war account for about 25% of the timber trade, and during the war all timber supplies are cut off, placing additional pressure on the European Union forest fund (Lööf & Stephan 2022). The area of forests in countries during military operations is significantly reduced, primarily due to fires (Reuveny et al. 2010). In addition to forests, green spaces in cities are even more affected during intense hostilities, although there are no specific data on this.

Together with phytocenoses, zoocenoses suffer from intense fighting. First of all, this concerns large animals (mammals, birds), which die both directly from the effects of weapons and as a result of hunger. Nesting conditions are disturbed for many bird species, which can also lead to population decline (Machlis & Hanson 2008). Some data from the First World War showed that the ecosystems on the front line recovered quite quickly, but the main damage from the war was caused by the intensification of deforestation and the expansion of industrial production (Keller 2019). If the area is not repopulated after the war, then ecosystem recovery can occur much faster, i.e. the stability of human population and ecosystems is often oppositely directed processes (Raudsepp-Hearne et al. 2010; Francis & Krishnamurthy 2014).

Current research on the effects of wars on ecosystems is rather fragmented, limited in depth, and requires a more detailed integration of environmental sciences into military planning (Machlis & Hanson 2008). This includes studies of the effects of warfare on the structure of communities of certain groups of invertebrates and on urban tree plantations. There is generally no evidence of the impact of military operations on the structure of ant communities, despite the fact that ants are the most numerous group of invertebrates on land (Hölldobler & Wilson 1990). These data are presented in this article, where we examined how ant communities and tree plantations have changed over the course of six months on the territory of Irpin and Bucha.

The purpose is to study the relationship between the degree of damage to tree plantations and changes in the structure of ant assemblages as a result of hostilities using the example of Irpin and Bucha. Research objectives: a) to establish the species composition of tree plantations and the species composition of ants visiting these trees; b) assess the degree of damage to forest stands in these cities; c) to study the indicators of ant activity on trees of varying degrees of damage; d) compare the effect of the combat factor on the activity of ants with the effect of other factors (temperature, plant parameters, distance to houses). Research hypothesis: the higher the degree of damage to the tree, the less ants will visit or settle in its wood (at least for five months after the conflict).

Material and methods

Research region

The studies were carried out in August 2022 on the territory of the Kyiv region, in the cities of Irpin and Bucha (Ukraine, Fig. 1A, B), 5 months after the end of active hostilities. Both cities suffered from the fighting to varying degrees - if in Irpin the destruction is almost universal (71 % of suffering damage, as the opposing sides exchanged blows right within the city), then in Bucha they are less noticeable (27 % of suffering damage, (the Degree of Destruction of Irpin, Bucha, Gostomel, Gorenka, Mariupol, Chernihiv and Western Kyiv, 2022)). Four locations were chosen for research in Bucha: Vokzalnaya Street (intense fighting, a large column of Russian armored vehicles was burned); Vodoprovidna Street (shelled houses, partial destruction); school (partially damaged building as a result of shelling); Shopping Center Epicenter (completely burnt out large shopping center) (Fig. 1A, B). In Irpin, 2 locations were examined: Neznayko Park (trees heavily damaged as a result of artillery and small arms battles) and the Tax Academy (completely burned out building with sagging structures between floors, Fig. 1A, B).

Days with sunny weather and the same temperature regime (18-21 °C) were selected for the study. The studies were carried out in August, since during the time elapsed since the end of hostilities (5 months), the ants, having awakened from hibernation, found themselves in new conditions for them, and the expected changes had time to occur in their assemblages. In the event of a potential decrease in the amount of food resource, the number of ants should have decreased by the end of summer, and the effect of hostilities should already have manifested itself in the form of reduced activity on damaged trees compared to undamaged ones.

Study design

According to the aim and objectives, it is necessary to conduct a study of the state of tree plantations, and, in parallel,

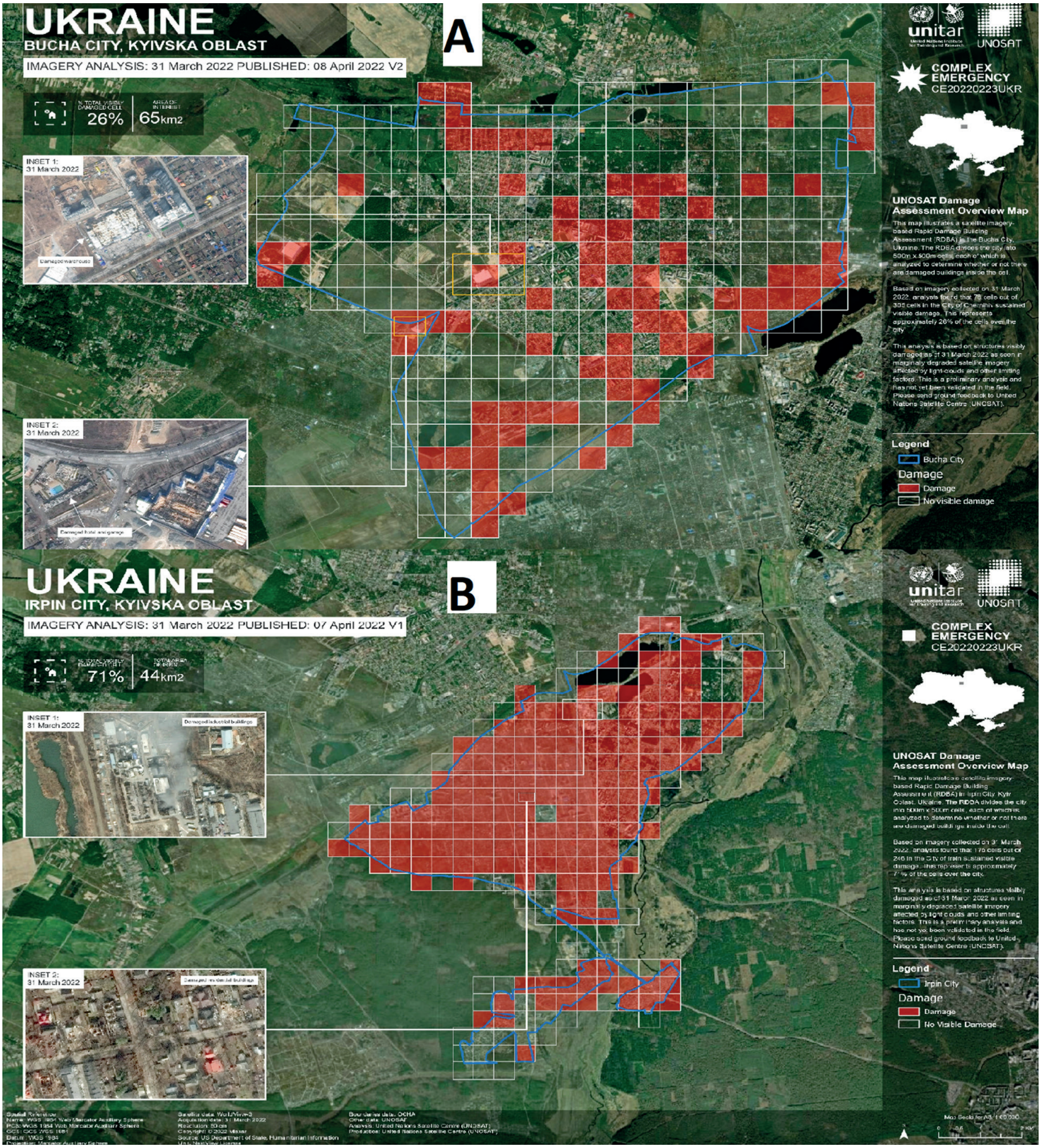

Fig. 1A-B – Investigated locations in the Kyiv region: **A** – Bucha; **B** – Irpin. Areas of cities affected by military operations are highlighted in red. Data by UN Satellite Center.

the number of ants of different species on trees. In addition to biogenic factors associated with ants or trees, we also took into account abiogenic factors: temperature, humidity of air, distance to the nearest building (see research methods). The study of tree parameters and abiogenic factors will allow a comparative assessment of the influence of each of the factors on the activity of ants.

When examining a forest stand, we assessed its condition according to the developed damage classification. To date, the method of visual inspection of trees for damage assessment remains one of the most common and accurate (Rahmawaty et al. 2018; Defects in lumber 2022). To determine the degree of damage to trees as a result of active hostilities using that took place in Ukraine in the suburbs of Kyiv, we developed a methodology in which we used a digital scale from 0 to 5 (Fig. 2A-F).

The score of "0" was assigned to completely intact individuals. A score of "1" was assigned to trees with light surface or shallow minor damage, up to 5-6 cases. A score of "2" is responsible for numerous penetrations and tears in the wood tissue by fragments of mines, shells and bullets (up to 50), but only in the surface tissue. In the case of a tree with a large diameter, the depth of penetration of shrapnel can be up to 10 cm. We assigned a score of "3" to shrapnel-affected individuals that had numerous (20-30) and, most importantly, deep penetrations into the wood to a depth of more than 10 cm, and in some places up to 20-25% of the trunk diameter with tissue ruptures to smithereens, whipped up with large fragments. Trees of this class had branches or trunks with large sections of pieces of wood and bark torn out. Score "4" was given to trees in which the trunk was destroyed or was in a dried state, but the individuals themselves were still alive (there were intact lateral branches, new young branches formed from dormant buds, etc.) and had green leaves. And finally, the score of "5" was given to trees that had already died at the time of our survey. Their trunk was knocked down and they did not recover from dormant buds, or the trees were burned, or the tree was completely destroyed by an explosion and a crater or stump was formed in its place (Fig. 2A-F).

Research methods

When examining the trees, each specimen was evaluated to the top, visually, carefully studied the trunks, branches, crown condition. Assigned the degree of damage to each plant. Trees were studied all growing in a row, that is, a continuous accounting was carried out. We have identified two types of biotopes - parks and tree alleys. The parks include Neznayko Park in Irpin and a school in Bucha, the rest of the points are alleys of trees. In addition to damage, the distance between the trees was noted, as well as the

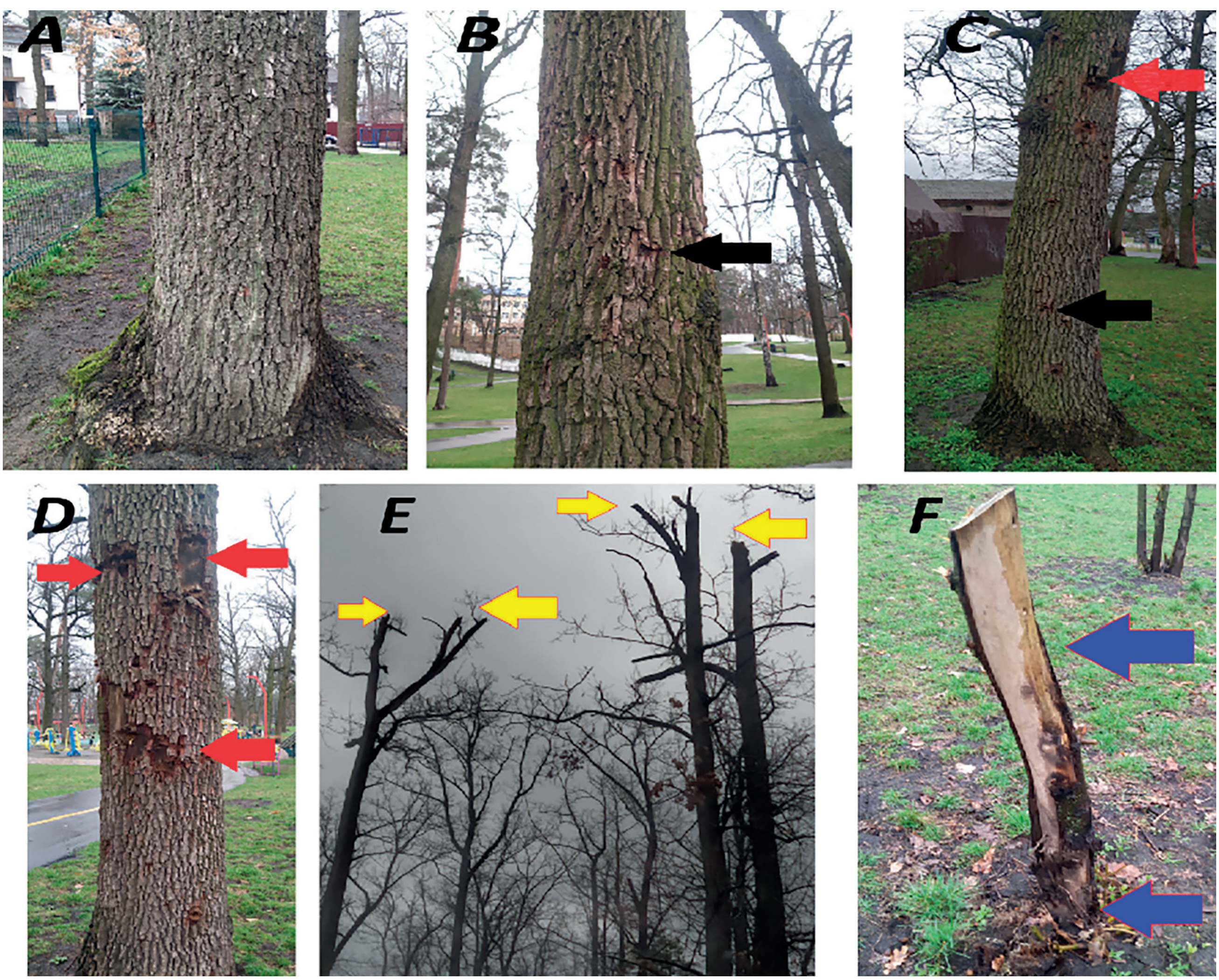

Fig. 2A-F – Degrees of damaged trees. **A** – undamaged trees, **B** – 1st degree of damage, **C** – 2nd degree, **D** – 3rd degree; **E** – 4th degree; **F** – 5th degree. Black arrows indicate superficial damage to the tree bark, red arrows indicate deep damage to conductive tissues, yellow arrows - destruction of the upper part of the tree trunk, blue arrows - irreparable damage to the tree (destruction of the trunk).

distance between the tree and the nearest building. Each tree had parameters of temperature (in °C) and humidity (in %) of the air. For this, a portable sensor UT (Ukraine) was used. Measurement accuracy of air humidity ± 5%, temperature ± 0.1 °C. For each tree, the diameter of the trunk at a height of 1.5 m was also measured. For each of the trees, the species was also taken into account. In Bucha, 200 trees were examined (75 – on Vokzalna Street, 10 – on Vodoprovidna Street, 15 – school, 100 – Epicenter). In Irpin, 201 trees were examined (143 trees in Neznayko Park, 58 near the Academy).

When assessing the number of ants, the trunk of each tree was examined for 2 minutes up to a height of 1.8 m. The number of ants located on tree trunks was counted. If necessary, ant samples were taken to determine the species. Ant species were identified according to Czechowski et al. 2012; Radchenko 2016; Seifert 2018.

Statistical analysis

Statistical analysis was carried out using the program Past, v. 4.09_32. The significance of differences between the medians for the compared parameters was checked using the Kruskal-Wallis test (K-W), in case of pairwise comparison, the Dunn's post hoc test (D). The chi-square test was used to compare the attendance by ants of different tree species, between number of ants in different types of biotopes and between number of ants in the different locations. We carried out an additional analysis between the degree of damage to the tree and individual groups of ants. The corresponding graphs were built in the Origin 2021b program.

To analyze the influence of each of the factors on the species composition and activity of ants, Multivariate multiple linear regression (overall MANOVA) was used. The dependent factors were the species of ants and the number of ants on trees. Temperature, air humidity, distance from buildings to trees, distance between trees, tree damage, tree trunk diameter, tree species were independent factors. Next, a paired comparison (Multivariate linear regression (1 independent, n dependent)) was carried out, in which, depending on the analysis, either the number of ants on the trees or the degree of damage to the trees acted as a dependent factor. In a pairwise comparison of the number of ants and the degree of tree damage, the dependent factor was the number of ants.

Results

Damage to trees in Irpin and Bucha as a result of hostilities. In Bucha, most of the surveyed trees were assigned class 0, i.e. they were intact (Supplementary Table 2). In Irpin, on the contrary, there were almost 2 times more damaged class 1 trees than class 0 trees. The number of trees with class 2 and 4 damage in Irpin was also 2-4 times

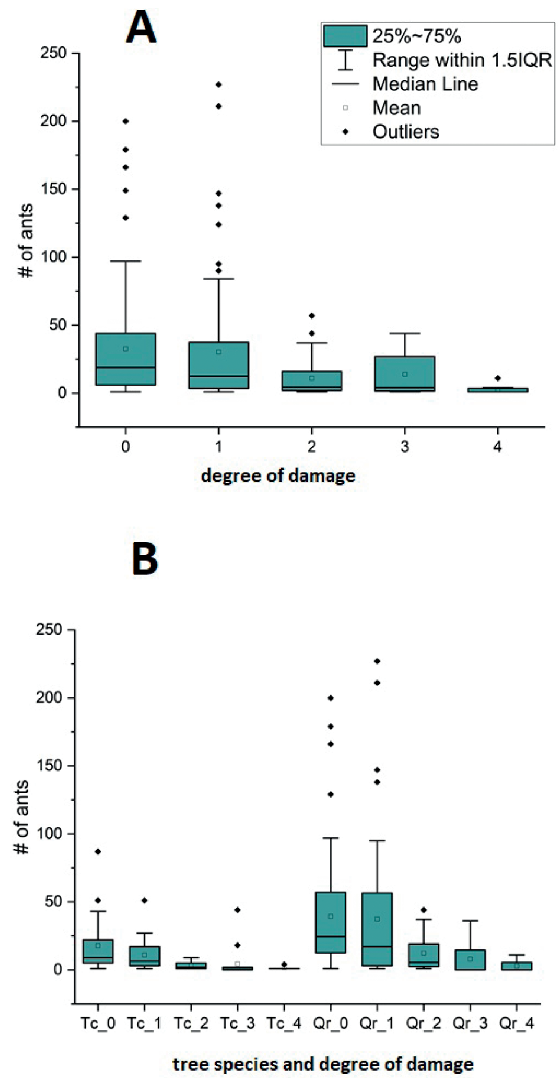

Fig. 3A-B – Average number of ants / 2 min on trees of different damage classes. **A** – for all trees, regardless of species; **B** – on lindens and oaks of different damage classes from 0 (no damage)) to 4 (heavy damage). Tc – *Tilia cordata*, Qr – *Quercus robur*.

higher than in Bucha. In tree plantations, the number of damaged trees in both locations was approximately equal to the number of undamaged trees (Supplementary Table 2). In the parks, on the contrary, the number of damaged trees with ants was 1.5 times higher than the undamaged ones, and 4 times more without ants. This means that the ants could have left many of the trees damaged in the spring-winter 2022. The number of damaged trees, both in Bucha and Irpin and in different biotopes, decreases with an increase in damage class (Supplementary Table 1). Most of the examined trees with deep damage, starting from grade 3, had a recently formed fungal infection (wood-destroying fungi, wood rot) in the places of damage.

Among the examined 12 species of trees, 2 species prevailed in number, the common oak (*Quercus robur* L.) and the heart-leaved linden (*Tilia cordata* L.) (Supplementary

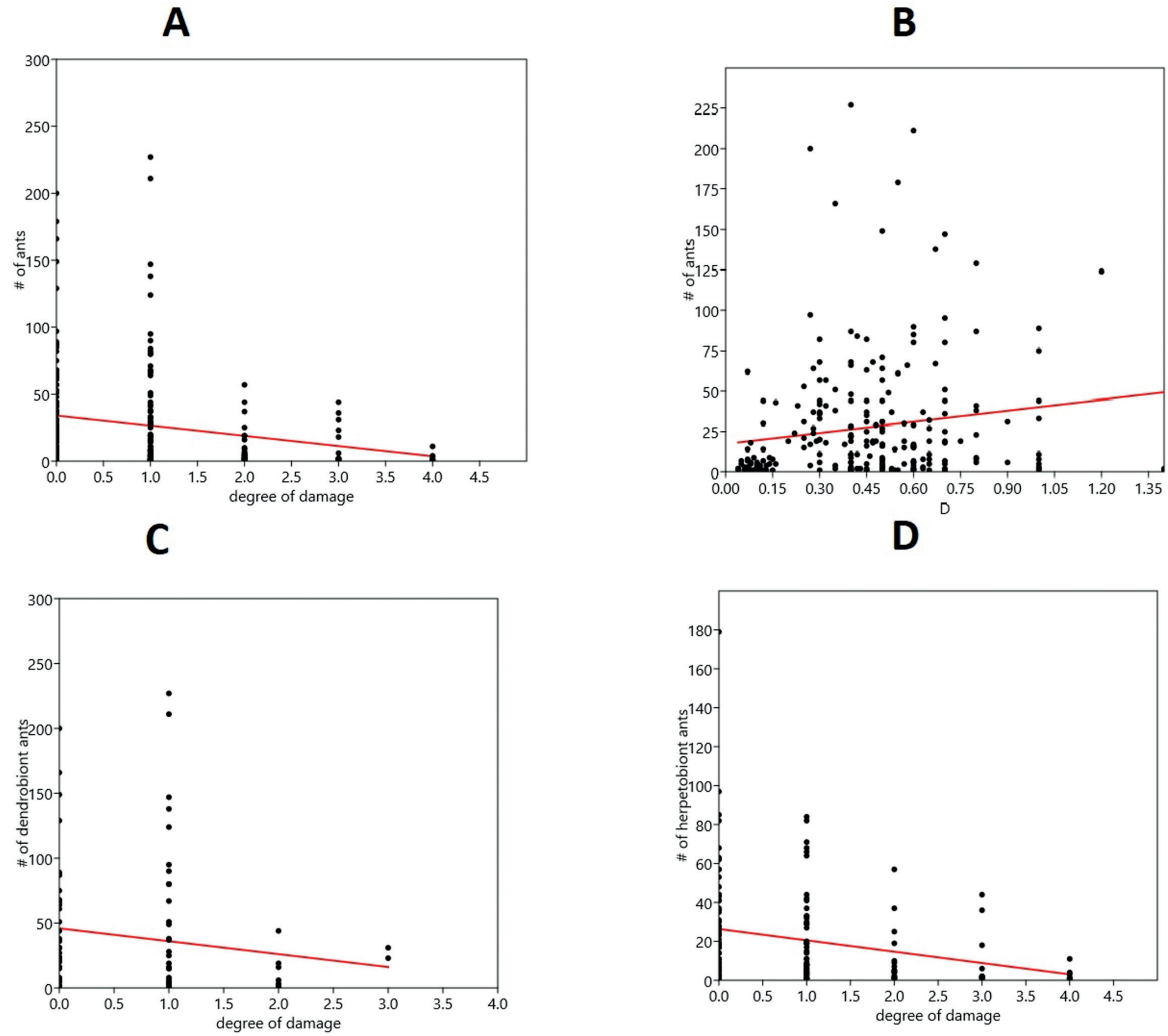

Fig. 4A-D – Multivariate linear regression (1 independent, n dependent) for different parameters: **A** – between degree of damage and number of ants; **B** – between number of ants and tree diameter; **C** – between dendrobiont (nesting in trees) ants and degree of damage; **D** – between herpetobiont (nesting in soil) ants and degree of damage.

Table 2). These two species were taken by us as model ones, since they are represented by a sufficiently large number of individuals. Oak in most cases was visited by ants, linden - in half of the cases (Chi^2=20.76, Supplementary Table 1). 11 species of ants were found on oak, and 5 species on linden.

Species of ants. 11 ant species were found, among which *Lasius niger* (Linnaeus, 1758), *L. brunneus* (Latreille, 1798), *L. fuliginosus* (Latreille, 1798), *L. emarginatus* (Olivier, 1792), *Dolichoderus quadripunctatus* (Roger, 1862) and *Formica cinerea* Mayr, 1853 predominate (Supplementary Table 1). In Bucha, 1.3 times more ants were found on trees than in Irpin (Chi^2=27.5, df=241), and in tree alleys there were 2 times more ants than in parks (Chi^2=23.82, df=241). This may be due to the large number of damaged trees in the parks. For all the most common ant species, their abundance on trees above damage class 1 dropped by an order of magnitude (Supplementary Table 1). The number of ants on undamaged trees and trees of damage class 1 is comparable, therefore, ants visit trees with minor surface damage to the same extent.

Ant activity on trees of different damage classes. Ant activity was found to decrease by 3-19 times with increasing tree damage class, as for all trees with ants (K-W: $p \leq 0.001$ (Chi^2=26.67, Hc=26.77, df=238);D: 0 vs 2, $p \leq 0.0001$; 0 vs 3, p=0.029; 0 vs 4, $p \leq 0.001$; 1 vs 2, p=0.014;

1 vs 4, p=0.0015; Fig. 3A) and for individual oaks and lindens (K-W: p=0.001 (Chi^2=21.14, Hc=21.24, df=212); *Tilia cordata*, D: 0 vs 2, p=0.005; 0 vs 3, p=0.015; 0 vs 4, p≤0.001; 1 vs 4, p=0.015; *Quercus robur*, D: 0 vs 2, p=0.004; Fig. 3B). Consequently, ants prefer not to visit damaged trees, starting from the 3rd class, and not to settle in them if they are arboreal-nesting ants. Damage class 5 trees are not visited by ants at all.

Influence of factors on the activity of ants on trees. The analysis carried out by MANOVA showed a different degree of influence of factors on the activity of ants, as well as on the degree of damage to trees (Supplementary Table 3). The following factors, in descending order, had the greatest influence on ant species and their activity on trees: distance to buildings, location, region, air humidity, diameter, species of tree, degree of damage to the tree, type of habitat, distance between trees, air temperature (Supplementary Table 3). At the same time, the activity of ants was more influenced by independent factors than species. From this it follows that the most important for ants is the location of the tree (apparently, the microclimatic conditions associated with it), its size and appearance, as well as the degree of damage. The rest of the factors are secondary. The air temperature was identical on the days of observation, so this factor did not have a significant effect. The distance to buildings can be of paramount importance for ant activity, because, firstly, the trees near the houses are in different microclimatic conditions (for example, they are more shaded on the north side and there will be higher humidity). Secondly, it is buildings that are the primary target during hostilities, since combatants and civilians take refuge in them. Therefore, trees that are closer to buildings receive more damage compared to trees that are further away. A separate paired comparison did not provide significant confirmation of this hypothesis (F=1.491, p=0.222 (df=415)). A positive relationship was found between humidity and distance from trees to buildings (F=5.819, p=0.016 (df=415)). Stronger relationship between distance to buildings and air temperature (F=78.28, p≤0.0001 (df=415)), the farther the tree is from the building, the lower the temperature. Consequently, the combat action factor in this case is not decisive for the activity of ants; microclimatic factors play a role.

Influence of other factors on tree damage, pairwise comparison. The diameter of the tree has no connection with its damage, i.e. trees, regardless of size, had damage (F=3.608, p=0.059 (df=415)). Distances between trees play an even smaller role in the degree of damage (F=0.073, p=0.78 (df=415)).

Effect of tree damage on ant activity, pairwise comparison. A pairwise comparison of the degree of damage to trees and the activity of ants revealed a direct relationship (F=10.47, p=0.001 (df=241), Fig. 4A). Regardless of the tree species, ants visit trees of 0-1 degrees of damage to a greater extent than other, more damaged trees. Trees of the 5th degree of damage are not visited. Only trees visited by ants are included in the analysis. The largest number of ants on trees of 0-1 degree, 2-3 times less on trees of 2-3 degrees, at least on the 4th, on the 5th are absent. For individual regions, significant relationships between ant activity and the degree of damage to trees have not been established (Bucha, F=2.422, p=0.12 (df=104); Irpin, F=3.07, p=0.082 (df=135)). These relationships exist between ant activity and biotope type (parks: F=5.98, p=0.016 (df=107); tree alleys: F=4.042, p=0.046 (df=132)). In both biotopes, ants visit intact trees and trees of the 1st degree of damage. The species affiliation of a tree is important for ants (F=28.68, p≤0.001, (df=415)), for example, oaks are visited more often than other trees. In a separate analysis for oaks and lindens, it was found that undamaged trees and trees of the 1st degree of damage are most visited by ants: F=5.014, p=0.026 (df=139) for oaks and F=8.721, p=0.003 (df=71) for lindens. Tree diameter matters for ants (F=5.894, p=0.015 (df=241)). Ants tend to visit middle-aged trees with a diameter of 0.3 to 0.7 m (Fig. 4B). Therefore, damage to large and old trees affects ant communities more significantly. Distances between trees had no significant effect on ant activity (F=1.02, p=0.31 (df=241)). We identified two groups of species: arboreal nesting (nesting and foraging in the tree layer) and ground nesting. Arboreal nesting species include *Camponotus fallax* (Nylander, 1856), *Dolichoderus quadripunctatus*, *Lasius brunneus*, *L. emarginatus*, *L. fuliginosus*. Ground nesting species include *L. niger*, *Formica cinerea*, *F. pratensis* Retzius, 1783, *F. rufibarbis* Fabricius, 1793, *F. cunicularia* Latreille, 1798, *Myrmica* sp. For arboreal nesting species, no direct relationship with the degree of tree damage was found (F=1.948, p=0.166 (df=88), Fig. 4C), while this relationship is clearly seen in ground nesting species (F=11.16, p=0.001 (df=151), Fig. 4D). This may indicate that arboreal nesting species leave trees heavily damaged in the war, or do not populate them.

Discussion

Warfare may vary in intensity, but all of them have a predominantly negative effect on biodiversity (Hanson 2018). Irreparable damage is caused to the environment during intensive artillery shelling, as well as carpet bombardments. This type of warfare refers to deliberate, when infrastructure is destroyed, as well as the environment (forest and other ecosystems), in order not to give the enemy a resource or place to hide. In the case of post-war changes, the presence of wilderness areas from which the restoration of the ecosystem structure can take place plays an important role (Westing 2013). Environmental damage from wars has very long roots, as early as the 14th century, during the Anglo-Scottish war, many pastures were devastated, which led to loss of livestock and famine (Slavin 2014). War zones are dangerous, so research is usually carried out years after the war ends (Lawrence et al. 2015). We managed to fix the result, which manifested itself already five months after the end of the conflict in this region. Undoubtedly, the factor of hostilities leads to damage to the main source of food for ants - woody vegetation, on which numerous colonies of aphids feed, which provide ants with a carbohydrate resource.

Land conflicts may primarily harm large animals, as they may be directly killed by poaching, forage by soldiers and refugees (Dubey & Shreni 2008). On the other hand, some large predators can feed on the battlefield without fear of gunshots (McNeely 2003b). Large animals are also often killed by landmines (Daskin & Pringle 2018), but not small animals (Kim 1997).

Formed after the explosions of artillery shells and bombs during World War II, deep sinkholes became unsuitable for plant growth decades later, as the groundwater regime changed in them (Hupy 2006; 2008). Likewise, forested areas subjected to intense artillery fire and other forms of warfare have also significantly lost their species richness (McNeely 2003c). The use of aerosols camouflaging the battleship Tirpitz during World War II caused tree growth to stop or slow down within a radius of up to 4 km from her stay for up to 9 years (Hartl et al. 2019). It is to be expected that hostilities have a greater impact on populations of invertebrates not directly, but indirectly. The forage base decreases, contamination with toxic products of combustion and explosions of soil, groundwater, and air occurs. While drones or sensor systems are usually used to study populations of vertebrates (birds, mammals) (Schiffman 2014), these methods are apparently ineffective for invertebrates. In the case of ants, results can be obtained by direct observation, and by trapping (pitfalls etc).

Tree plantings in urban environments are often use as long-term sources of resources by ants. The most common ant species in Kyiv, the nearest city to Bucha and Irpin, is *Lasius niger* (Radchenko et al. 2019). *Formica cinerea*, and species of the genus *Lasius*, found by us in Bucha and Irpin, are also quite common in Kyiv (5-48% of all ants in different habitats, see Stukalyuk et al. 2020). Among the tree species in Kyiv, oak is the most visited by ants - 17 species of ants were found on it, which is slightly higher than in Bucha and Irpin (11 species). 8 species of ants were found on linden in Kyiv, which exceeds the indicators of Bucha and Irpin (5 species) (Stukalyuk et al. 2020). This result may be due to the smaller number of examined trees in Bucha and Irpin compared to Kyiv. The reason for the high attendance of oak and linden by ants in the areas of Bucha and Irpin affected by military operations is the large number of myrmecophilic aphid species on this plant, according to the literature data, 8 on oak and 1 on linden (Stukalyuk et al. 2020). Thus, oak is a more attractive tree for ants both in terms of foraging and in terms of settlement (for arboreal nesting species). That is, depending on the species, trees will be attractive to ants in different ways, but even the most attractive of them are abandoned by ants if they are significantly damaged. Therefore, massive damage of 3rd degree or more to mature and old trees with a trunk diameter of 0.3 m or more can be associated with irreparable degradation of ant assemblages. This is especially true for oaks. Even a single deep damage to the trunks in most cases, according to our observations, led to the development of a fungal infection, the consequences of which could be the death of a tree in the coming years. Therefore, the expected negative effect of hostilities on trees and ants will be extended for at least several years, until the damaged trees completely fall out of the forest stand. Our data on the distribution of damaged and undamaged trees as a result of hostilities are consistent with data on areas with heavy traffic load - trees with light damage predominate there, the number of which is comparable to the number of healthy trees (Rahmawaty et al. 2018). Also, ants do not to colonize dead wood of trees with 5 degree of damage.

There are few studies indicating a direct relationship between the size (diameter) of a tree on the one hand and the number of ant species, as well as their quantitative indicators (number of individuals) (Tschinkel & Hess 1999; Schifani et al. 2022). Our data confirmed this relationship, at least for undamaged trees, and trees with weak damage of classes 1-2.

A sharp decrease in the source of the resource (i.e., mature trees of a suitable species with aphid colonies) as a result of hostilities in ants of the genus *Lasius*, *Formica*, which have large colonies of tens and hundreds of thousands of individuals in urban environments (Stukalyuk et al. 2022) can lead to their disappearance. The presence of invasive tree species such as *Acer negundo* L. in war-affected areas, which hardly attract ants, may be an additional negative factor for surviving ant populations.

Regarding the war between Ukraine and Russia, there are already publications where the authors express fears about the upcoming violation of biodiversity, degradation of soils and landscapes, and the transfer of pollutants from groundwater and rivers to reservoirs (Pereira et al. 2022). These consequences will be reflected in all groups of organisms that make up biocenoses, and the impact will be directly proportional to the intensity of hostilities.

Based on the results of our work, it can be summarized that military operations with the use of armored vehicles, small arms, bombardment and shelling of the territory with MLRS and artillery, as was the case in Bucha and Irpin in February-March 2022, unequivocally led to a decrease in the activity of ants, already for the next five months. This was especially evident in Irpin, where the fighting was more intense than in Bucha, and where a greater number of damaged trees from class 2 and above. Ant colonies that woke up after hibernation associated with damaged trees of class 3 and above faced the choice of extinction or relocation. As a result, all these trees were practically free of ants. The more such trees there are as a result of hostilities, the more damage will be done to ant assemblages that play a significant role in ecosystems. Changes in the structure of ant assemblages will lead to changes in other components of the biota, which will lead to structural changes in ecosystems as a whole.

Conclusion

The results obtained indicate that the ants prefer to visit larger trees of certain species (oaks), but with a degree of damage up to 3rd. Trees of the 1st degree of damage are visited to the same extent as undamaged ones, then there is a decrease in the attendance by ants. Regions and locations that have more damaged trees, especially old (large) trees, will have a negative impact on ant species richness and activity rates. Depending on which group this ant species belongs to, one can expect their different reactions to trees with different degrees of damage. Ground nesting species are more likely to visit trees with a damage level of 3 or higher. The general negative impact of the military factor is more pronounced in Irpin, where the destruction is much stronger. There is a greater number of damaged trees, as well as a smaller number of ants found, despite the fact that many oaks, the most visited trees by ants, were surveyed here.

Apparently, it is advisable to conduct an observation of trees damaged to varying degrees within six months to a year after the end of hostilities. This is because trees will regenerate these damages if they are not too severe. In the future, 2-3 years after the hostilities, such damage will be quite difficult to distinguish from other types of damage (mechanical as a result of logging, exposure to xylophagous fungi). Fungal rot, penetrating through deep damage in tree trunks, will also eventually hide traces of plant damage as a result of hostilities. We assume that long-term monitoring of the same trees, the damage of which was established soon after the end of hostilities, may turn out to be effective.

In the future, it is necessary to continue such studies. which can give a more complete picture of changes in ant assemblages and in tree vegetation in other settlements of Ukraine. This applies both to the Kyiv region (Borodyanka, Vorzel, Vasylkiv, Moschun, Gostomel), and the cities of Donbass region (Rubizhne, Kreminna, Severodonetsk, Lysychansk, Soledar, Ugledar, Bakhmut). Changes are expected to the greatest extent in Mariupol, where almost all houses were destroyed, and tree vegetation may have been badly damaged. In the event that most of the trees in the area affected by the war will be classified as damage categories 4-5, ant assemblages, like other invertebrates associated with trees, will inevitably degrade.

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Supplementary Table 1 – The number of ants on damaged and undamaged trees in different categories.

Category	**Total # of ants**	**Total # of trees with ants**	**Undamaged trees (0)**	**Damaged trees (1)**	**Damaged trees (2)**	**Damaged trees (3)**	**Damaged trees (4)**	**Damaged trees (5)**
Bucha	3896	106	2771	964	108	48	5	-
Irpin	2800	137	781	1705	177	119	18	-
Parks	2085	110	971	1019	68	23	4	-
Tree alleys	4611	133	2581	1650	217	144	19	-
			Species of ants in Bucha and Irpin					
Camponotus fallax	8	5	2	6	-	-	-	-
Dolichoderus quadripunctatus	87	25	44	29	14	-	-	-
Formica cinerea	162	15	74	36	35	6	11	-
Formica cunicularia	2	2	1	-	-	-	1	-
Formica pratensis	48	2	48	-	-	-	-	-
Formica rufibarbis	1	1	1	-	-	-	-	-
Lasius brunneus	2282	35	1173	981	79	54	-	-
Lasius emarginatus	363	11	37	323	3	-	-	-
Lasius fuliginosus	764	13	506	258	-	-	-	-
Lasius niger	2969	132	1666	1036	149	107	11	-
Myrmica sp.	5	1	-	-	5	-	-	-

Supplementary Table 2 – The number of damaged and undamaged trees with ants (and without ants) in different categories.

Category	**Undamaged trees (0)**	**Damaged trees (1)**	**Damaged trees (2)**	**Damaged trees (3)**	**Damaged trees (4)**	**Damaged trees (5)**
Bucha	71 (56)	25 (23)	5 (4)	3 (3)	2 (6)	0 (4)
Irpin	38 (15)	63 (24)	21 (18)	9 (3)	6 (13)	0 (5)
Parks	40 (14)	47 (18)	13 (14)	5 (0)	4 (12)	0 (5)
Tree alleys	69 (57)	41 (29)	13 (8)	7 (6)	4 (7)	0 (4)
Tree species in Bucha and Irpin						
Tilia cordata	29 (25)	22 (18)	9 (9)	8 (1)	5 (11)	0 (6)
Juglans regia	2 (0)	1 (1)	-	-	0 (1)	-
Aesculus hippocastanum	0 (2)	0 (1)	-	-	-	0 (1)
Acer sacharinum	2 (0)	-	0 (1)	0 (1)	-	-
Pyrus communis	-	-	1 (0)	-	-	-
Betula pendula	5 (8)	2 (3)	-		1 (3)	-
Acer platanoides	6 (4)	5 (1)	-	0 (2)	1 (1)	-
Quercus rubra	1 (1)	-	-	-	-	-
Quercus robur	64 (30)	56 (23)	16 (11)	4 (1)	1 (3)	0 (2)
Ulmus glabrae	0 (2)	-	0 (1)	-	-	-
Prunus cerasifera	-	1 (0)	-	-	-	-
Salix fragilis	1 (0)	1 (0)	-	-	-	-

Supplementary Table 3 – Multivariate multiple linear regression (overall MANOVA) for dependent and independent factors.

Tests on independent variables						
	Wilks lambda	**F**	**df1**	**df2**	**P**	
Region	0,9813	2,205	2	231	0,1126	
Location	0,9748	2,986	2	231	0,05242	
Biotope	0,9961	0,4538	2	231	0,6358	
Tree species	0,9896	1,217	2	231	0,298	
Distance between trees	0,9978	0,2519	2	231	0,7775	
Diameter	0,9883	1,371	2	231	0,2559	
Degree of damage	0,9938	0,7189	2	231	0,4884	
Distance to the buildings	0,9682	3,792	2	231	0,02398	
Temperature	0,9998	0,01943	2	231	0,9808	
Humidity	0,9836	1,923	2	231	0,1484	
Tests on dependent variables						
	R^2	F	df1	df2	P	
# of ants	0,1854	5,281	10	232	5,29E-07	
ant species	0,1425	3,855	10	232	7,57E-05	
Regression coefficients and statistics						
		Coeff.	**Std.err.**	**t**	**p**	**R^2**
	Constant	42,811	80,767	0,53005	0,59658	
	Region	-28,285	29,331	-0,96432	0,33589	0,045886
	Location	8,1767	4,169	1,9613	0,05104	0,000195
	Biotope	-0,06958	8,0397	-0,00865	0,9931	0,040484
	Tree species	1,3615	1,1416	1,1926	0,23425	0,080208
	Distance between trees	-0,25713	0,36192	-0,71047	0,47813	0,004215
	Diameter	18,755	11,533	1,6262	0,10526	0,023874
	Degree of damage	-2,879	2,5739	-1,1185	0,2645	0,041632
	Distance to the buildings	-0,03364	0,1215	-0,27686	0,78214	0,013769
	Temperature	-0,25093	3,99	-0,06289	0,94991	2,46E-06
# of ants	Humidity	-0,17945	0,55859	-0,32125	0,74831	0,05503
	Constant	2,9904	5,3434	0,55965	0,57626	
	Region	3,9191	1,9405	2,0196	0,044571	0,053833
	Location	0,29442	0,27581	1,0675	0,28687	0,049946
	Biotope	-0,49767	0,53189	-0,93568	0,35041	0,011008
	Tree species	0,057862	0,075525	0,76613	0,44438	0,049645
	Distance between trees	0,002407	0,023944	0,10054	0,92	0,003889
	Diameter	-0,48319	0,76298	-0,6333	0,52716	0,007887
	Degree of damage	-0,03722	0,17029	-0,21857	0,82718	0,000157
	Distance to the buildings	-0,02125	0,008038	-2,6431	0,008775	0,01737
	Temperature	-0,04537	0,26397	-0,17189	0,86368	0,007567
ant species	Humidity	-0,0681	0,036955	-1,8427	0,066642	0,028699