Phoretic relationships between *Plagionotus detritus* (Coleoptera: Cerambycidae) and *Trichouropoda sociata* (Acari: Mesostigmata)

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The aim of the study was to explore phoretic relationships between *Plagionotus detritus* and mites from the order Mesostigmata. In total, 635 individuals of *P. detritus* were caught, and mites were found on 86 of them. The dominant species among 8,154 individuals of mites was *Trichouropoda sociata* (8,152 individuals), and the sporadically found species were *Lasioseius thermophilus* (1 ind.) and *Typhlodromus* sp. (1 ind.). Generally, the difference in the total abundance of females and males of *P. detritus* was not statistically significant (311 females vs 324 males). The proportional abundance of *P. detritus* with *T. sociata* differed between samplings, and in the pooled data, the proportional abundance of *P. detritus* females with *T. sociata* (39.5%) was less than that for *P. detritus* males (60.5%).

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1. Introduction

Mesostigmatid mites are tiny arachnids, whose body length usually does not exceed 1 mm. Such a tiny body size makes it difficult for them to move large distances and inhabit specific microhabitats such as decaying wood, sub-bark layers, excrements, carcasses etc. This is why they also developed an ability to disperse by means of other animals, for instance insects. Such phoretic relationships between insects and mites have been the object of numerous research studies, and these were primarily faunistic ones. The results of these studies are mainly lists of mite species reported from selected insects (Haitlinger 1991, 2008, Salmane & Telnov 2009). However, the authors most frequently focused on phoretic relationships with regard to particular insect species (Chmielewski 1977, Haitlinger 1988, 1990, Mašan 1993, 1994), or particular species or groupings of mites (Athias-Binche 1993, Athias-Binche et al. 1993, Bajerlein & Błoszyk 2004, Gwiazdowicz & Coulson 2010, Bajerlein 2011). In the case of some insect species, mites that were found were described as species new to science (Gwiazdowicz & Haitlinger 2010). Moreover, the phenomenon of phoresy has also been analyzed from the ecological perspective, and that has concerned mainly the relationship between the sub-bark insect fauna and mite groupings (Moser 1976, Gwiazdowicz *et al.* 2011, 2012, Pernek *et al.* 2012). However, the problem of phoretic relationships between insects and mites in a specific period of time has not been investigated yet. The question is about the dynamics of this phenomenon in relation to the biology of the insect species, for instance immediately after leaving the bark beetle galleries under the bark, when swarming or shortly before death.

The longhorn beetle *Plagionotus detritus* (Linnaeus) is most frequently found on oak trees and it is only when the primary host plant is absent that it may occur on other tree species, such as beech, hornbeam, elm and birch. The range of the occurrence of *P. detritus* also overlaps with the natural range of oak trees in Europe (Rossa R. unpubl.). The analysis of the biology of *P. detritus* demonstrates that during its lifespan each female lays approximately 30 eggs in the crevices and cracks of oak bark. The larvae hatch around two weeks after the eggs have been deposited. They start to eat their way in the inner bark next to the cambium, through the coarse bark and leave a slightly winding path. At the end of the larval development the larva goes a bit further into the wood where it makes its pupal chamber (Rossa R. unpubl., Sundkvist L. unpubl.). The imago may leave the sub-bark layers from April to September, however in the case of the Białowieża Forest, the period lasts from the end of May until the end of July following year (Rossa R. unpubl.).

The aim of this research was to explore the phenomenon of phoresy which occurs on *P. detritus* in a specific period of time, for instance, from the emergence of the imagoes from under the bark until the decline of their activity after swarming. *P. detritus* is most frequently found in old oak tree stands (Tippmann 1952) like those of natural tree stands of the Białowieża Forest (NE Poland). Previous research on phoretic relationships in this area was conducted by Gwiazdowicz (2000), but it focused on other groups of insects. In some countries, for instance in Sweden, *P. detritus* is a relatively rare beetle and therefore it is under protection (Sundkvist L. unpubl.), whereas in Poland it is treated as one of the biotic factors causing the extinction of oak trees (Rossa R. unpubl.). However, regardless of the fact whether we want to protect a species or to control it, it is worth investigating its impact on forest ecosystems and assessing its role in the diffusion of other species, including mites. Another reason for this type of research is the fact that the phenomenon of phoresy among beetles of the family Cerambycidae has not yet been sufficiently investigated (Haitlinger 2008).

2. Material and methods

The Białowieża Forest was selected for the research as it is considered as one of the best-preserved forest areas in the Lowlands of Europe (Gutowski & Jaroszewicz 2004, Okołów *et al.* 2009). It is commonly regarded as a model forest in which all observations and research related to deciduous and mixed forests of this climatic zone can be conducted (Gutowski 2004). The research site was located in an old tree stand close to a natural forest, in the area of a mixed forest and a deciduous forest, in the compartment 496C (N52°40'; E23°47') approximately 4 km southwest of the village of Białowieża. The tree stand featured such species as Norway spruce *Picea abies* (L.) Karst., English oak *Quercus robur* L., European hornbeam *Carpinus betulus* L., Scots pine *Pinus sylvestris* L., aspen *Populus tremula* L., and European silver birch *Betula pendula* Roth.

In total, 18 IPM-Intercept traps (2 blocks × 9 traps), with substances attracting Cerambycidae, were set up in the research area. The distance between blocks was some 50–100 m, and the distance between the traps was 25–30 m within one block. The total duration of the study was eight weeks. The traps were set up from 25.V.2011 and they were emptied 4 times: 1.) 8.VI., 2.) 22.VI., 3.) 6.VII., and 4.) 20.VII. The traps were suspended from a rope tied between two trees so that the trap was at least 1 m away from each tree, and the collecting bucket was some 10 cm above the ground. The IPM-Intercept trap has two intersecting panels (30.5 by 80.5 cm) with a top and bottom funnel (40 cm square at the top opening by

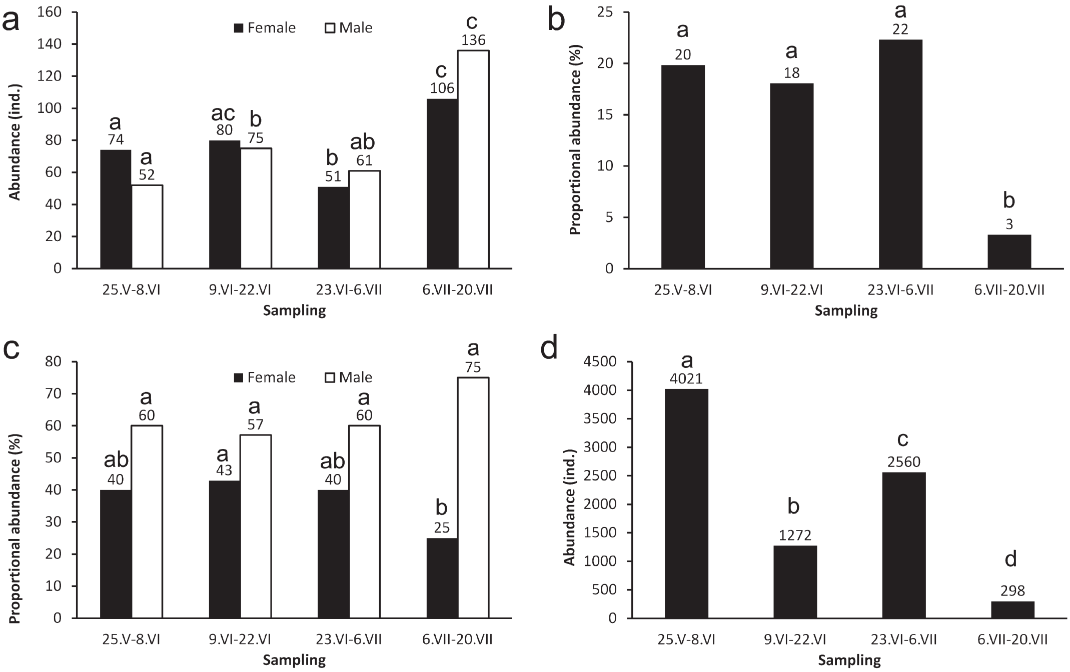

Fig. 1. Abundance of *Plagionotus detritus* and *Trichouropoda sociata*. – a. Total abundance of females and males of *P. detritus*. – b. Proportional abundance of *P. detritus* with *T. sociata*. – c. Proportional abundance of females and males of *P. detritus* with *T. sociata*. – d. Total abundance of *T. sociata*. Different letters above bars indicate statistically significant differences among sampling dates ($p < 0.05$), analyzed separately for females and males in figures a. and c.

some 20 cm deep), a collecting cup (13.5 by 13.5 by 14.5 cm deep), and a 0.18 m^2 cross-sectional area between the top and bottom funnels (Sweeney *et al.* 2006).

The killing agent in the collecting cups was a 50:50 mixture of ethylene glycol and water. All cerambycid specimens were preserved in 70% ethanol. After sorting the material, the specimens of *P. detritus* were analyzed under a stereoscopic microscope to determine their sex and the presence of mites. The mites taken off an insect's body were placed in permanent (using Hoyer's medium) or semi-permanent (using lactic acid) microscopic slides. Such material was the base for the determination of the mite species and the developmental stage, which was conducted by means of the Axioscop 2 microscope. The slides with mites were deposited in the acarological collection of the Department of Forest Protection, Poznań University of Life Sciences.

Statistical analyses were conducted using the chi-square tests. The level of significance for all statistical tests was $\alpha = 0.05$.

3. Results

In total, 635 adults of *Plagionotus detritus* were examined for phoretic mites. As a result of this study we identified 8,154 mites from which 8,152 were classified as deutonymphs of *Trichouropoda sociata* (Vitzthum, 1923). Moreover, two other species i.e. *Lasioseius thermophilus* Willmann, 1942 and *Typhlodromus* sp., were represented by only 1 individual, therefore the ecological analysis was restricted only to *T. sociata*.

Generally, our study revealed that the difference in the total abundance of females and males of *P. detritus* was not statistically significant (311 ♀ vs 324 ♂; $\chi^2 = 0.27$, $df = 1$, $p = 0.60$). Similarly, we did not find any statistically significant differences between female and male abundance, when each sampling period was analyzed separately (Fig. 1a) (all $\chi^2 < 3.85$, $df = 1$, $p > 0.05$). In the total abundance of *P. detritus*, there were significant differences among the sampling periods, analyzed separately for females and males (Fig. 1a) (for significant differences in females and males, respectively, all $\chi^2 > 4.2$ and $\chi^2 > 4.1$, $df = 1$, $p < 0.043$; for non-significant differences, all $\chi^2 < 1.7$ and $\chi^2 < 1.5$, $df = 1$, $p > 0.22$). Especially, the abundances were clearly higher during the last sampling period than in earlier ones, although not significantly so for females in comparison with the second sampling period (Fig. 1a). Moreover, we recorded 86 *P. detritus* adults with *T. sociata* (13.54%, 86/635 ind.). The proportional abundance of *P. detritus* with *T. sociata* was the lowest in the last sampling period (Fig. 1b, the differences between the last sampling period and all other periods were statistically significant, all $\chi^2 > 10.7$, $df = 1$, $p < 0.001$).

The proportional abundance of females and males of *P. detritus* with *T. sociata* differed significantly when the data was pooled (39.53% ♀ vs 60.47% ♂; $\chi^2 = 4.38$, $df = 1$, $p = 0.036$). The sampling periods analyzed separately, there were significant differences for the first, third and fourth period (all $\chi^2 > 4.0$, $df = 1$, $p < 0.046$) but not for the second one ($\chi^2 = 1.96$, $df = 1$, $p = 0.16$), when each sampling period was analyzed separately.

The differences in the proportional abundance of *P. detritus* with *T. sociata* among the sampling periods, analyzed separately for females and males, were not significant among other periods (for females and males, respectively, all $\chi^2 < 3.5$, $df = 1$, $p > 0.062$ and $\chi^2 < 2.5$, $df = 1$, $p > 0.11$), except for females between the second and fourth sampling period ($\chi^2 = 4.76$, $df = 1$, $p = 0.029$) (Fig. 1c). Finally, we counted 8,152 deutonymphs of *T. sociata*. The total abundance differed statistically between all the sampling periods (all $\chi^2 > 324$, $df = 1$, $p < 0.001$) (Fig. 1d).

4. Discussion and conclusions

The collected specimens of *P. detritus* hosted from 5 to 780 mite individuals. The first question we will discuss is when the beetles are inhabited by mites? Deutonymphs of *T. sociata* are very slow and they would be able to inhabit beetles only if these were immobilized for a longer period of time, for instance after the metamorphosis into imago, but yet while under the bark. But how did they get there? The most probable explanation of the presence of mites in the bark beetle galleries is the phenomenon of the co-occurrence of other insect species feeding under the bark with *P. detritus*. According to Starzyk and Starzyk (1981) and Rossa R. (unpubl.) the species co-occurring with *P. detritus* included *Scolytus intricatus* (Ratzeburg) and *Trypodendron signatum* (Fabricius), and it is probably with one of these species that mites were transported under the bark. They cannot have reached a beetle gallery on the body of a *P. detritus* larva. Moreover, it is very unlikely that deutonymphs could have entered in such large numbers through the hole eaten by a larva, as their abundance in the food deficient oak bark is very low. However, it is known that *T. sociata* occurs most frequently in the bark beetle galleries of Scolytinae and phoretically on Cerambycidae (Wiśniewski & Hirschmann 1993). The species is a mycetophage, which finds favorable living conditions in bark beetle galleries. According to Rossa R. (unpubl.) pieces of mycelium have been observed in the bark beetle galleries of *P. detritus*, which suggests that these might be favorable conditions for mites.

The other crucial question is when mites leave the body of *P. detritus*. The present study demonstrated that the number of mites on the body of *P. detritus* was definitely lower in the fourth period than in the first three research periods (Fig. 1b). This indicates that mites leave the body of *P. detritus* before the death of the insects, which according to Rossa R. (unpubl.) are not very active and almost lose their ability to fly after swarming. Thus it seems that the key period is the swarming season of *P. detritus*. The copulation may last several seconds and it is repeated many times. Successive intercourses between partners are separated by 2 to 6 minute's breaks (Rossa R. unpubl.). The successive intercourses are probably the occasions when deutonymphs of *T. sociata* are removed accidentally by mechanical scratching. However, it cannot be ruled out that deutonymphs are knocked off insect bodies also in other situations, for instance when laying eggs by a female, while burying in bark crevices during bad weather conditions or for staying overnight.

One may wonder why *P. detritus* featured only one mite species, *T. sociata*. In other species feeding under the bark, for instance Scolytinae, one insect species may feature many mite species. For example, Pernek *et al.* (2012) reported 12 phoretic mite species on *Pityokteines curvidens* (Germar) and Gwiazdowicz *et al.* (2011) eight ones on the body of *Ips typographus* (Linnaeus). This issue should constitute the subject of further research on Cerambycidae, which is poorly investigated in this respect.

Mite preferences for attaching to specific parts of beetles are poorly known (Costa 1963). Regardless of the beetle sex, elytra and the third pair of legs were the preferred parts where the phoretic deutonymphs of *T. sociata* attach on the body of *P. detritus*. Similar results were obtained by Bajerlein and Błoszyk (2004) who analyzed the places of the occurrence of phoretic deutonymphs of *Uropoda orbicularis* (Müller) on the body of coprophagous beetles. They put forward a hypothesis that this deployment of phoretic deutonymphs of uropodid mites only slightly affects the locomotion of the beetles, and that deutonymphs climb onto the back of a beetle and move forward. This hypothesis needs to be confirmed.

In conclusion, the commonness of the phenomenon of phoresy on *P. detritus* is worth an emphasis, which is evidenced by the large number of mites and the high percentage of insects inhabited by mites. Variation in numbers with time was observed both in the case of *P. detritus* and *T. sociata*. It is dependent on the insect biology and the co-occurrence of other insects in sub-bark layers. In some previous studies, phoretic relationships between insects and mites were analyzed without taking into account the specific period of time, the biology of beetles and the co-occurring species, although they are crucial to the scale of the phenomenon of phoresy.

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