ABSTRACT: Carrion is an example of ephemeral and patchy microhabitat, rich in organic matter and therefore frequently colonized with a specific and repeated sequence by various arthropods. Beetles of the family Histeridae are a stable component of carrion communities, however their biology and ecology is poorly studied. Succession of insects on decomposing carrion may be used to determine elapsed time since death (so called post-mortem interval, PMI in forensic entomology). Recent studies have shown that some species of histerid beetles are highly useful for this purpose. However it requires detailed information on their biology, phenology and habitat preference. Seasonality, habitat preference and residency on carrion of histerid beetles were analyzed while studying succession of insects on 36 pig carcasses (mean weight = 25.8 kg) in spring, summer and autumn, in pine-oak forest, hornbeam-oak forest, and alder forest (2 carcasses/forest type/season/year). The experiment was conducted in the Wielkopolska region (Western Poland) in 2006 and 2007. The spring part lasted 88 days in 2006 and 105 days in 2007, the summer part – 49 days in both years and the autumn part – 94 days in 2006 and 105 days in 2007. Among 21 adult species recorded, Saprinus semistriatus (Scriba), Margarinotus striola succicola (Thomson) and Margarinotus brunneus (Fabricius) were the most numerous. Moreover, larvae of Saprinus and Margarinotus were collected. Abundance (numbers per one carcass) of most adult species of Margarinotus was influenced both by the forest type and season whereas abundance of species of Saprinus was influenced only by the season. Most species reached the highest number of adults in spring. Only S. semistriatus was similarly abundant both in spring and summer. Larvae of Margarinotus were most abundant in spring, whereas larvae of Saprinus in summer. Most species reached their higher numbers in spring. The majority of Margarinotus species reached their higher numbers in hornbeam-oak forest. Residency on carrion in adult S. semistriatus had a clear peak of abundance in spring (after 36 days of decomposition) and was shorter than residency in adult M. striola succicola and M. brunneus for which no clear peak was found. We suggest that differences in forest type preferences may result from differences in soil humidity and temperature near the forest floor, whereas differences in residency period on carrion between Margarinotus and Saprinus may be explained by differences in release patterns of volatile organic compounds (VOCs) attracting these genera.

KEY WORDS: carrion ecology, Histeridae, Margarinotus, Saprinus, habitat preference, seasonality

1. INTRODUCTION

Carrion, like animal droppings, dead wood or bird nests, is an example of ephemeral and patchy microhabitat. Such micro-
habitats are characterized by relatively short duration and rapidly changing physicochemical conditions. On the other hand, they are rich in organic matter and therefore frequently colonized with a specific and repeated sequence by arthropods. Insects inhabiting carrion and animal droppings represent various feeding guilds: coprophagous or necrophagous species, parasitoids and predators. Communities of coprophagous beetles are one of the best studied insect communities. They were subject of many studies dealing with biology and ecology e.g. competition or spatial and temporal variation in species composition (Hanski and Koskela 1979, Finn et al. 1999, Roslin 2000, 2001, Finn and Gittings 2003). On the other hand, biology and ecology of predatory dung and carrion beetles is poorly studied. Predators constitute most of the species frequenting carrion and dung (Hanski 1987). They include typical carrion and dung predators (e.g. Staphylinidae, Histeridae, larvae of Hydrophilidae) and noncarrion and nondung predators (e.g. Carabidae). In the case of animal droppings, predation is the main force structuring community (Hanski 1987).

Beetles of the family Histeridae are a stable component of carrion and dung communities. They are terrestrial and very heterogeneous in ecology with many species found in rotting animal or vegetable matter, under bark, or in ant nests (Mazur 1981, Koch 1989). Both adults and larvae are predacious and feed on other insects, mainly larvae of Diptera (Nuorteva 1970, Achiene and Giliomee 2007). Histeridae were the subject of many taxonomic and faunistic studies, as well as applied studies dealing with control of dipterous communities and forensic entomology (Mazur 1997, 2009, Arnaldos et al. 2004, Grassberger and Frank 2004, Achiene and Giliomee 2007, 2008, Matuszewski et al. 2008). However, little is known on their biology and ecological interactions with other arthropods in dung and necrophilous communities as compared to for example Staphylinidae and Hydrophilidae (Koskela and Hanski 1977, Hanski 1980, Otronen and Hanski 1983).

Our previous papers reported preliminary results on insect succession on exposed pig carrion in selected forests of Western Poland (Matuszewski et al. 2008) and closing results on pattern and rate of carrion decomposition, species composition, residency and succession of forensically-important carrion insects in these habitats (Matuszewski et al. 2010, 2011). These results indicate that some histerids are highly useful in forensic entomology particularly for estimation of succession-based post mortem interval (PMI) (a time elapsed since death).

The use of insects in estimation of PMI requires information on their biology, phenomenology and habitat preferences. Accordingly, in this paper we present results concerning seasonality and habitat preferences of most histerid species recorded during carrion experiments. We also present complete species composition of histerid beetle community in forests under study.

In 2006 and 2007 a forensically oriented field experiment on pig carrion decomposition and insect succession was conducted in three selected forest types in Western Poland. This gave us opportunity to study communities of histerid beetles visiting pig carcasses. The aim of our research was to find out seasonality, forest type preferences and residency on carrion of histerid beetles.

2. MATERIALS AND METHODS

We used a complete factorial design with 2 factors (independent variables): season and forest type. Both factors had three levels, namely: spring, summer, autumn and pine-oak forest, hornbeam-oak forest, alder forest. In the first year of the experiment (2006) 2 replications (carcasses) in every forest type in every season were used. The study was then replicated in all details in the second year of the experiment (2007). The study was conducted in forests of the Biedrusko military range (52°31′N, 16°54′E) in Western Poland. Spring sampling started in the second half of April, summer sampling in the second half of July and autumn sampling in the second half of September. Pine-oak forest (POF) is a mixed forest formed by Scots pine (Pinus sylvestris) and two species of oak (Quercus robur and Q. petraea). Hornbeam-oak forest (HOF) is a deciduous forest formed by European hornbeam (Carpinus betulus) and common oak (Q. robur). Alder forest (AF) is a marshy deciduous...
Histerid beetles visiting exposed pig carrion

Forest growing in areas partly and temporarily flooded by groundwater in which common alder (Alnus glutinosa) is the dominant species. Research sites within the same forest were located about 50 metres from each other and at least 30 metres to the edge of the forest type. Forest types under study were located at least 500 metres from each other.

We used 36 domestic pig (Sus scrofa domestica) carcasses of similar weight (range = 14-39 kg, mean = 25.8 kg). Animals were put down by a blow to the base of the skull and were immediately transported to the study site. In the same season carcasses were randomly assigned to forest types. To enable carrion movement and inspection of the ground below, carcasses were placed on a metal grating with 5 cm meshes. To prevent scavenging, grating was staked to the ground and covered with 3 cm welded wire mesh which was wired to the grating.

Beetles were collected using pitfall traps and manual sampling. Two traps (plastic containers 16 cm in diameter and 17 cm in height) filled with 50% ethylene glycol solution were buried next to the carcass: one on the dorsal side of the pig and one on the ventral side of the pig. Manual sampling was made from carcass surface and soil under and near the carcass. Specimens were preserved in 70% ethanol. Until the end of the active decay beetles were gathered on a daily basis and then at less frequent occasions (every 2nd, 3rd, 5th, 7th days). The spring part lasted 88 days in 2006 and 105 days in 2007, the summer part – 49 days in both years and the autumn part – 94 days in 2006 and 105 days in 2007.

Identifications of adult beetles were made using key for identification of histerid beetles by Mazur (1981) and Witzgall (1971). Identifications of larvae were made using key for identification of Klausnitzer (1999). Species name in accordance to the Catalogue of Palaearctic Coleoptera (Mazur 2004). The voucher specimens are deposited in the Natural History Collections at Adam Mickiewicz University in Poznań.

Daily weather data from a local meteorological station for each part of the experiment and differences in temperature and humidity between forests were given in Matuszewski et al. (2010b).

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### Table 1. Species of histerid beetles recorded on pig carcasses (numbers represent the individuals collected from all carcasses, in all seasons and all forests).

<table>
<thead>
<tr>
<th>No. of specimens</th>
<th>Species name</th>
<th>Number of specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abraeus perpusillus</strong> (Marsham, 1802)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><strong>Atholus corvinus</strong> (Germar, 1817)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Carcinops pumilio</strong> (Erichson, 1834)</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td><strong>Gnathoncus buyssoni</strong> Auzat, 1917</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><strong>Gnathoncus namnetensis</strong> (Marseul, 1862)</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>Hister helluo</strong> Truqui, 1852</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Hister unicolor</strong> unicolor Linnaeus, 1758</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td><strong>Margarinotus bipustulatus</strong> (Schrank, 1781)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Margarinotus brunneus</strong> (Fabricius, 1775)</td>
<td>971</td>
<td></td>
</tr>
<tr>
<td><strong>Margarinotus carbonarius carbonarius</strong> (Hoffmann, 1803)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Margarinotus marginatus</strong> (Erichson, 1834)</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td><strong>Margarinotus merdarius</strong> (Hoffmann, 1803)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Margarinotus ruficornis</strong> (Grimm, 1852)</td>
<td>215</td>
<td></td>
</tr>
<tr>
<td><strong>Margarinotus striola succicola</strong> (Thomson, 1862)</td>
<td>2302</td>
<td></td>
</tr>
<tr>
<td><strong>Margarinotus ventralis</strong> (Marseul, 1854)</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td><strong>Onthophilus punctatus punctatus</strong> Müller, 1776</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><strong>Onthophilus striatus striatus</strong> (Forster, 1771)</td>
<td>206</td>
<td></td>
</tr>
<tr>
<td><strong>Saprinus aeneus</strong> (Fabricius, 1775)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Saprinus planticusculus</strong> Motschulsky, 1849</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td><strong>Saprinus semistriatus</strong> (Scriba, 1790)</td>
<td>4671</td>
<td></td>
</tr>
<tr>
<td><strong>Saprinus subnitescens</strong> Bickhardt, 1909</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>8,906</td>
<td></td>
</tr>
</tbody>
</table>
Statistical analyses were performed only on pitfall trap material and only for the most abundant species (Margarinotus brunneus, M. marginatus, M. striola succicola, M. ruficornis, M. ventralis, Saprinus semistriatus, S. planiusculus and Onthophilus striatus). Significance of the season and forest effects on species abundance was tested with two-way analysis of variance (ANOVA). Fisher least significant difference procedure (LSD procedure) was used. In all analyses 5% level of significance was accepted. Figs 9 and 10 show the abundance of particular species expressed as a mean number of specimens per carcass (a total number of specimens collected on all 12 carcasses, in particular date, divided by the number of carcases). If the samples consist of specimens collected during two days or more, the first step was to calculate the daily mean abundance. Abundance of larvae showed in the Table 2 was calculated as a sum of larvae collected with traps and manually. Calculations were conducted using Statistica 7.1 (StatSoft, Inc. 1984–2005).

3. RESULTS

During the study 21 species of histerid beetles from 8 genera were collected (Table 1). The most abundant were S. semistriatus, M. striola succicola, and M. brunneus. We collected also 114 larvae of Margarinotus and 74 larvae of Saprinus (Table 2).

Season had significant effect on abundance of all species (ANOVA, season effect, $P<0.05$; Figs 1–8). The highest abundances of M. brunneus, M. marginatus, M. ruficornis, M. striola succicola, M. ventralis, O. striatus and S. planiusculus were in the spring.

Table 2. Total numbers of Margarinotus and Saprinus larvae collected (numbers represent larvae collected from all carcasses and all forests in particular season).

<table>
<thead>
<tr>
<th>Species</th>
<th>Total</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Margarinotus sp.</td>
<td>114</td>
<td>102</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Saprinus sp.</td>
<td>74</td>
<td>19</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>188</td>
<td>121</td>
<td>67</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 1. Abundance (mean number of individuals collected per one carcass with 0.95 confidence intervals) of Margarinotus brunneus in different seasons and forests. Different letters denote significant differences between experimental groups in pairwise comparisons ($P<0.05$). POF – pine-oak forest, HOF – hornbeam-oak forest, AF – alder forest.
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*M. niusculus* were observed in spring. In summer abundance decreased markedly and in autumn most species were not recorded. Abundance of *S. semistriatus* was found to be similar both in spring and summer (Fig. 8). For *M. brunneus* and *S. semistriatus* we found no statistically significant preference for any forest (ANOVA, forest effect, *P* > 0.05; Figs 1, 8). For *M. marginatus*, *M. ruficornis* and *M. striola succicola*, a clear preference for hornbeam–oak forest was found (ANOVA, forest effect, *P* < 0.05; Figs 2–4). *Margarinotus ventralis* preferred

![Graph](image)

Fig. 2. Abundance (mean number of individuals collected per one carcass with 0.95 confidence intervals) of *Margarinotus marginatus* in different seasons and forests. Different letters denote significant differences between experimental groups in pairwise comparisons (*P* < 0.05). POF – pine-oak forest, HOF – hornbeam-oak forest, AF – alder forest.

![Graph](image)

Fig. 3. Abundance (mean number of individuals collected per one carcass with 0.95 confidence intervals) of *Margarinotus ruficornis* in different seasons and forests. Different letters denote significant differences between experimental groups in pairwise comparisons (*P* < 0.05). POF – pine-oak forest, HOF – hornbeam-oak forest, AF – alder forest.
Fig. 4. Abundance (mean number of individuals collected per one carcass with 0.95 confidence intervals) of Margarinotus striola succicola in different seasons and forests. Different letters denote significant differences between experimental groups in pairwise comparisons ($P < 0.05$). POF – pine-oak forest, HOF – hornbeam-oak forest, AF – alder forest.

Fig. 5. Abundance (mean number of individuals collected per one carcass with 0.95 confidence intervals) of Margarinotus ventralis in different seasons and forests. Different letters denote significant differences between experimental groups in pairwise comparisons ($P < 0.05$). POF – pine-oak forest, HOF – hornbeam-oak forest, AF – alder forest.
pine-oak forest (ANOVA, forest effect, $P<0.05$; Fig. 5) whereas *Onthophilus striatus* showed a clear preference for both pine-oak forest and hornbeam-oak forest (ANOVA, forest effect, $P<0.05$; Fig. 6). In *S. planiusculus* results indicate its preference for pine-oak forest and alder forest (LSD procedure, $P<0.05$), although forest effect was not significant (ANOVA, forest effect, $P>0.05$; Fig. 7).

Changes in abundance during decomposition follow different pattern in representatives of *Saprinus* and *Margarinotus*. A clear peak in abundance of *S. semistriatus* occurred, whereas abundance of *Margarinotus* species was relatively constant and low (Figs 9, 10). Both species of *Margarinotus* had longer presence period on carrion than *S. semistriatus* (Figs 9, 10).

![Fig. 6. Abundance (mean number of individuals collected per one carcass with 0.95 confidence intervals) of *Onthophilus striatus* in different seasons and forests. Different letters denote significant differences between experimental groups in pairwise comparisons ($P<0.05$). POF – pine-oak forest, HOF – hornbeam-oak forest, AF – alder forest.](image1)

![Fig. 7. Abundance (mean number of individuals collected per one carcass with 0.95 confidence intervals) of *Saprinus planiusculus* in different seasons and forests. Different letters denote significant differences between experimental groups in pairwise comparisons ($P<0.05$). POF – pine-oak forest, HOF – hornbeam-oak forest, AF – alder forest.](image2)
Fig. 8. Abundance (mean number of individuals collected per one carcass with 0.95 confidence intervals) of *Saprinus semistriatus* in different seasons and forests. Different letters denote significant differences between experimental groups in pairwise comparisons ($P < 0.05$). POF – pine-oak forest, HOF – hornbeam-oak forest, AF – alder forest.

Fig. 9. Patterns of residency on carrion in *Margarinotus striola succicola* (MS), *Margarinotus brunneus* (MB), and *Saprinus semistriatus* (SS) in spring. Abundance is expressed as a mean number of individuals per carcass in particular sampling date.
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Fig. 10. Patterns of residency on carrion in *Margarinotus striola succicola* (MS), *Margarinotus brunneus* (MB), and *Saprinus semistriatus* (SS) in summer. Abundance expressed as a mean number of individuals per one carcass in particular sampling date.

4. DISCUSSION

Dominance of species of *Saprinus* and *Margarinotus* is a characteristic feature of histerid beetle communities in island-like distributed, unstable microhabitats, such as carcasses, dung or decaying plants (Mazur 1981, Koch 1989). Although, many species from both genera are eurytopic and inhabit various microhabitats, our results suggest that some species may prefer carcasses more than other unstable habitats. *Margarinotus striola succicola* is considered as a saprophilous species inhabiting carcass and animal dung (Koch 1989). In our material *M. striola succicola* was one of the most numerous species. Interestingly, it has not been collected in cow dung (Bajerlein 2009). Similarly, *Saprinus semistriatus* was highly abundant on pig carcasses, whereas in cow dung it was accidental (Bajerlein 2009).

Our study has confirmed previous observations on seasonality of histerid beetles (Kočárek 2003). Their abundance is the highest in spring, decreases markedly in summer and in autumn most of species are not present. Only *Saprinus semistriatus* is characterized by high abundance both in spring and summer. Recent study has shown that *S. semistriatus* is highly useful for the succession-based estimation of PMI (Matuszewski et al. 2010a). Accordingly, it may serve as an indicator of PMI both in spring and summer.

Our study has shown that abundance of particular species differs according to the forest type. Temperature is a key environmental factor influencing distribution of insects. In case of histerid beetles, soil properties are also important, as their whole development takes place in the soil. The studied forest types differ in both temperature near forest floor and soil properties. In hornbeam-oak forest, which was preferred by most species of *Margarinotus*, the air near the forest floor is cold and humid. In pine-oak forest the soil is sandy and dry, and the air near forest floor is dry and hot. Alder forest is characterized by peat soil of high humidity and the temperature of air is close to that of pine oak forest. Its humidity is higher than in pine-oak forest and hornbeam oak forest. It is known that histerids prefer sandy and light soil (Mazur 1981), what explains their rareness in alder forest. Soil of high humidity makes digging of chambers difficult and is unsuitable for larval development. Therefore, one should expect that histerid beetles will be...
most abundant in pine-oak forest, because of favourable environmental conditions; however, in this study only *M. ventralis* reached its highest abundance in pine-oak forest.

Similar residency periods on carrion of *Saprinus* and *Margarinotus* were observed by Kočárek (2003). On the other hand this author observed first adults much earlier as compared to our results. It may result from the fact that Kočárek studied beetle succession on rat carrion, which decomposes differently comparing to pig carrion.

Different patterns of residency on carrion in *Margarinotus* and *Saprinus* probably resulted from differences in release patterns of volatile organic compounds (VOCs) attracting these genera. One can suppose that a short presence period on carrion in *Saprinus semistriatus* resulted from short release period of VOCs attracting this species. On the contrary, species of *Margarinotus* are probably attracted by compounds which have longer periods of release. Other possible explanation is that different patterns of residency in *Margarinotus* and *Saprinus* result from different nutritional preferences. It can be assumed that preys on which *Margarinotus* feeds are present for almost the entire decomposition a long time, whereas *Saprinus* is more specialized and feeds on larvae which occur on carcass only for a short time.

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Histerid beetles visiting exposed pig carrion


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