Nutrient richness of wood mould in tree hollows with the Scarabaeid beetle *Osmoderma eremita*

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Abstract

Nutrient richness of wood mould in tree hollows with the Scarabaeid beetle Osmoderma eremita.— Trunk hollows with wood mould harbour a rich invertebrate fauna with many threatened species, and it has been suggested that the beetle *Osmoderma eremita* (Coleoptera, Scarabaeidae) is a keystone species in this community. We estimated the amount of nitrogen and phosphorus in wood mould and compared the coarse fraction which constitutes frass of *O. eremita* with the finer fraction of wood mould, and found that the nutrient richness was higher in frass. *O. eremita* larvae have a fermentation chamber that harbours nitrogen fixing bacteria. As the levels of absorbable nitrogen are a limiting factor in insect growth, an increase in nutrient richness is one of several possible explanations why the species richness of saproxylic beetles is higher in hollow oaks where *O. eremita* is present in relation to similar trees where the beetle is absent.

Key words: Nitrogen, Oak, Phosphorous, Scarabaeoidea, Wood decay.

Resumen

Riqueza en nutrientes del mantillo de la madera en cavidades arbóreas donde está presente el escarabeideo Osmoderma eremita.— Las cavidades de los troncos con mantillo de la madera albergan una rica fauna de invertebrados, entre los que se incluyen numerosas especies amenazadas. Se ha sugerido que *Osmoderma eremita* (Coleoptera, Scarabaeoidea) constituye una especie clave de esta comunidad. Se estimó la cantidad de nitrógeno y fósforo presentes en el mantillo de la madera, y se comparó la fracción gruesa formada por las deyecciones de *O. eremita* con la fracción más fina del mantillo de la madera y se vió que la riqueza en nutrientes era más elevada en la fracción gruesa. Las larvas de *O. eremita* contienen una cámara de fermentación que alberga el nitrógeno fijado por las bacterias. Puesto que los niveles de nitrógeno absorbible constituyen un factor limitador del crecimiento de insectos, un aumento de la riqueza en nutrientes es una de las posibles explicaciones del porqué la riqueza en especies de los escarabajos saproxílicos es más elevada en los robles huecos donde *O. eremita* está presente que en otros árboles similares donde está ausente.

Palabras clave: Nitrógeno, Roble, Fósforo, *Scarabaeoidea,* Descomposición de la madera.

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Introduction

When deciduous trees age, hollows with wood mould often form in the trunks. Wood mould is loose wood colonised by fungi, often with remains from bird nests and insects. Trunk hollows with wood mould harbour a specialised fauna, mainly consisting of beetles, flies, mites and pseudoscorpions (Dajoz, 2000; Ranius, 2002a). Among these species, the Scarabaeid beetle *Osmoderma eremita* has received much attention in the last few years because it is among those species with the highest priority in the European Union's Habitats Directive (Luce, 1996). Species richness of beetles associated with tree hollows is considerably higher in tree hollows with *O. eremita* present than in those hollows where it is absent (Ranius, 2002b). This may be because several species have similar habitat requirements and thus prefer the same trees (Ranius, 2002c). To some extent it may also be because they are all limited by the spatio–temporal structure of suitable trees in a similar way, and therefore have colonised the same trees. A third possibility is that *O. eremita* improves the habitat for other species. Up to 100 adult *O. eremita* beetles emerge from a suitable tree hollow every year (Ranius, 2001), implying that there may be several hundreds of larvae present. *O. eremita* larvae eat large amounts of rot wood, thereby increasing the volume of the trunk hollow. As their frass is often a dominant content of tree hollows (Martin, 1993), it has been suggested that *O. eremita* is a keystone species which influences a whole community of species associated with tree hollows (Ranius, 2002b). *O. eremita* increases the size of the hollow, and its frass also changes the structure of the wood mould by making it more grainy. Moreover, larvae of *O. eremita* have a fermentation chamber which harbours nitrogen fixing bacteria (Wiedemann, 1930). Because levels of absorbable nitrogen are a limiting factor in insect growth (Haack & Slansky, 1985; Dajoz, 2000), it is possible that *O. eremita* improves the habitat for other species by increasing the nutrient richness of the rot wood.

This study estimated the nutrient richness (content of nitrogen and phosphorus) in wood mould, comparing hollows with and without *O. eremita*. When *O. eremita* was present, we compared the fraction of wood mould consisting of *O. eremita* frass with the finer fraction.

Material and methods

The content of nitrogen and phosphorus was measured in samples with wood mould taken from trunk hollows in 20 oaks *Quercus robur*. The possibility to obtain large sample sizes is restricted because hollow oaks are a rare habitat and many tree hollows are out of reach, even by ladder. The oaks had a trunk circumference of 2.2–4.8 m and were situated at half–open or regrown pasture woodlands on the island Hallands Väderö, southern Sweden. The age of oaks at Hallands Väderö has been measured by counting tree rings and almost all very old oaks are between 280 and 350 years old (Lannér, 2003). Probably all the trees in our study were this age. Brown rot was unmistakably the dominant rot type in the hollows. Only in five of twenty hollows there was also wood decayed by white rot, but this was not the dominating rot type in any tree. All hollows contained a sufficient amount of wood mould for larval development of *O. eremita* (at least 10 litres, according to data in Hedin & Mellbrand [2003]). Frass of *O. eremita* was found in 15 of the hollows, while it was absent in five. Samples were taken from each tree 10 cm below the wood mould surface. When frass of *O. eremita* was present, it was separated from the finer fraction of wood mould by sieving. The finer fraction consists of rotten wood which has become pulverized, possibly due to activity by insects other than *O. eremita* (for instance, beetles and ants). It may also contain pulverized frass from *O. eremita*. Larval frass can be present for a long time after the species has disappeared from the tree (Martin, 1993; Ranius & Nilsson, 1997), which suggests that the sampled frass may have been years old.

For the chemical analyses, about 60 mg of the dried samples were used. Samples were ground to a fine powder and oven–dried at 60°C for five days. Samples were digested by a micro–Kjeldahl digestion (boiled at 415°C in 2 ml concentrated sulphuric acid plus a catalyser until the sample turned clear, taking approximately 1h). The digested material was diluted to 100 ml with distilled water and analysed for N (organic plus ammonical) and P using a Flow Injection Analyzer (FIA; Tecator, Höganäs, Sweden). FIA carries out an automatized colorimetric assessment of N and P by measuring absorbance of the sample at 540 nm and 650 nm respectively.

Results

The content of N and P was significantly higher in larval frass than in the finer fraction of wood mould (fig. 1). This was analysed with the paired sample t-test (for N: $p < 0.001$, for P: $p = 0.001$). There was no significant difference in nutrient richness in wood mould with *O. eremita* absent in comparison with the finer fraction of wood mould in trunks where *O. eremita* was present (for N: $p = 0.404$, for P: $p = 0.151$).

Discussion

A study by Kelner–Pillault (1974) in chestnut trees, revealed that the level of organic nitrogen was higher in wood mould (0.79–0.97%) than in other kind of wood (healthy wood – 0.24%; dry rotten – 0.31%; damp rotten wood – 0.47%). In our study, we found an N concentration of about 1% dry mass in wood mould with no *O. eremita* present, which means that the level of N concentration was similar to the wood mould studied by Kelner–Pillault (1974). Viejo Montesinos et al. (1996) measured an N concentration of between 0.5 and 0.8% dry mass in rotten wood of different *Quercus* species.

Frass of *O. eremita* was N and P enriched when compared to the finer fraction of wood mould. A similar finding has been reported for the longhorn beetle *Phymatodes maaki* (Ikeda, 1979). The enrichment is probably due to the nitrogen fixing bacteria which occur in the fermentation chamber of *O. eremita* larvae. Another less likely explanation is that *O. eremita* larvae selectively feed on a certain fraction of the rotten wood with a much higher nutrient richness than the rest. However, in many trees almost all loose material consists of *O. eremita* frass, which suggests that *O. eremita* larvae eat on the inner walls without leaving any fraction of the rot wood. When Kelner–Pillault (1974) studied the content of the wood mould and frass of the Scarabaeid beetle *Gnorimus variabilis* in chestnut trees, there was a trend towards a higher level of organic nitrogen in the frass in comparison to the wood mould (1.17% in comparison to 1.09%).

Trees with *O. eremita* generally have a higher species richness than those without *O. eremita*, and several explanations have been suggested (see Introduction). This study adds another possible explanation: higher nutrient richness may improve the situation for decomposing invertebrates, and increase the total species richness of invertebrates in the tree hollow. However, one weakness of this explanation is that we do not know the decomposition rate of the frass and to what extent it is actually utilised by the invertebrate community in tree hollows. Some observations indicate that larval frass of *O. eremita* may remain in tree hollows, for instance in old stumps, for several decades after *O. eremita* has disappeared. However, we do not know whether it is only a very small proportion that remains after a few decades or if the volume of frass is more or less intact after that time. Therefore, studies of decomposition rate of frass and wood mould should be carried out, as well as experimental studies on the effect of *O. eremita* frass on the abundance of other invertebrates.

Present knowledge on habitat requirements of invertebrates in tree hollows is mainly based on correlations observed between presence/absence of species and easily measurable variables reflecting the quality of tree hollows (Ranius 2002a; 2002c). This study suggests that to go one step further, and understand the mechanism behind the correlation patterns, analyses oh how wood mould forms and decomposes are required, based on studies both in the field and in the laboratory. During the successional change of a tree hollow, the wood mould habitat also changes. The volume of wood–mould in known to change (Kelner–Pillault, 1974), but the physical and chemical characteristics likely change as well, and this may affect the invertebrate community. The present study shows that invertebrates such as *Osmoderma eremita* may affect the rotten wood habitat not only physically, but also chemically.

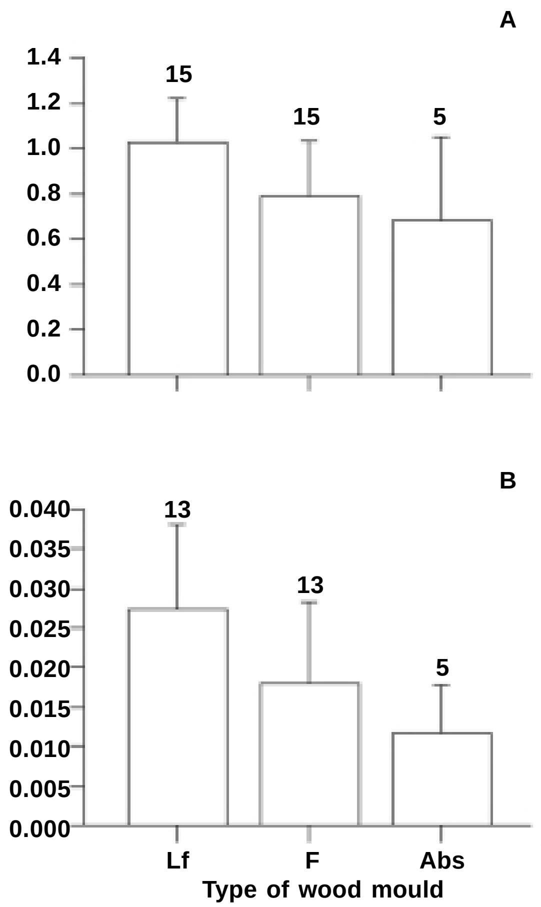

Fig. 1. Concentration of nitrogen (organic + ammoniacal) (A) and phosphorus (B) (mean and standard deviation, units in mmol per g) in three types of dried wood mould: Lf. Larval frass; F. Finer wood mould; Abs. Wood mould taken from trunk hollows with *O. eremita* absent. (Lf and F are fractions taken from the same trees.)

Fig. 1. Concentración de nitrógeno (orgánico + amoniacal) (A) y fósforo (B) (media y desviación estándard, en mmol por g) en tres tipos de mantillo de la madera seca: Lf. Deyecciones larvales; F. Mantillo más fino en la madera; Abs. Mantillo de la madera tomado de cavidades formadas en troncos sin presencia de O. eremita. (Lf y F *son fracciones tomadas de los mismos árboles.)*

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