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Comparative study of the *Fomes fomentarius* and *Trametes gibbosa* beetle communities in Hidegvíz Valley, Sopron Mts., Hungary

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Abstract: The forest, which is exposed to fewer anthropogenic impacts, has a rich and complex community. In Hungary, the quantity of dead wood has an ever-increasing significance in the forests. The decomposition of wood starts with the xylophagous insects, followed by the appearance tinder fungus, which transforms the wood into a form suitable for decomposers. Fungus beetles decompose most of the fungus. Therefore, besides consumer organizations, demolition organizations also play an essential role in building the forest ecosystem. In Central Europe, we have a little information about the beetle communities of tinder fungi. During our research, we investigated the beetle communities of *Fomes fomentarius* and *Trametes gibbosa*, which were collected from the Sopron-mountains in West Hungary. In *F. fomentarius,* the most common beetle species that we found was *Bolitophagus reticulatus* with about 100 individuals in four fruiting bodies, while in *T. gibbosa*, *Cis boleti* had the largest number of individuals with more than 5300 in four specimens. The beetle communities in the two tinder fungi were different, the difference probably caused by the structure and the nutritional value of the fungi.

Nomenclature: Fauna Europaea (2017) for beetles, MycoBank (2016) for tinder fungi.

Introduction

Tinder fungi are natural inhabitants of the forests. The insect community of mushrooms is already known in Hungary (Dely-Draskovits 1974). However, the knowledge of tinder fungi insect community in literature is not complete up to now. In natural forests, dead wood and tinder fungi are important elements in maintaining biodiversity. Biodiversity is key element in sustainable forest management (Rollinson 2003). Natural forests are key habitats for many species, e.g. mammals, birds, invertebrates, lichens and fungi (Christensen et al. 2005). The demolition process of tinder fungi has not been thoroughly investigated but this knowledge is also important to discover the whole process of tinder digestion and to know the complete forest ecosystem. In the food chain, the saproxylic insects have an important role because they consume dead wood. They accelerate the wood decomposition process. Tinder fungi appear on wood and fungus feeders appear on the tinder fungi. The xylophagous insects, followed by bracket fungi, start the demolition process of the wood. These fungi transform the wood into forms that can be used by the decomposing organisms. Fungi beetles also decompose bracket fungi (Andrési 2015). The beetles develop in a protected area inside the fungi which means they have a hidden lifestyle, which makes them difficult to examine. In Hungary, in addition to our own investigations earlier studies of insect species associated with various tinder fungi were done (Domboróczki 2006, Csóka 2011, Lakatos et al. 2014). In the Scandinavian literature, this topic has been already investigated for a long time, so the insect community of tinder fungi of that region has already been explored (Økland 1995, Jonsell et al. 1999, Komonen 2001). The mycophagous insects were thought to be polyphagous, but there are also species, which associated with only one tinder fungus (Hackman and Meinander 1979, Lacy 1984, Hanski 1989). The mycophagous invertebrate fauna group is also an indicator of the naturalness of forests (Franc 1997). The most common insect groups that were found in the Polyporaceae are beetles, flies and butterflies (Hammond and Lawrence 1989). This statement is supported by our results too but in this research, we only focused on beetles.

This study investigated two different fungal species (*Fomes fomentarius* (Fig. 1, Fig. 2) and *Trametes gibbosa* (Fig. 3)). The purpose of the study was to produce a model for further research; therefore, a sample test was made on the beetle communities of perennial and annual tinder fungi with this preliminary examination. In the future, this study will be improved with larger tinder fungi sample sizes, and fungi will be collected from different locations in the country. They were collected from the same sampling sites in the Hidegvíz Valley, which is situated in the western part of the Sopron Mountains, in Hungary (Király 2004) (Fig. 4). Both fungus species belong to the Polyporaceae family. *F. fomentarius* has a perennial fruiting body, mostly single, sessile and ungulate. *Fomes* infects weakened beech, and other hardwoods, or it is a saprophyte (Breitenbach and Kränzlin 1986). On the contrary, *T. gibbos*a is an annual species, rather durable, semicircular-plate-shaped, and sometimes zoned with distinct umbo, occasionally occurring in groups. *T. gibbosa* is widespread and rarely infect weakened trees (Breitenbach and Kränzlin 1986). Both fungi cause white rot of wood and usually both species are found on beech (*Fagus sylvatica*) (Domanski et al. 1973, Igmándy 1991). The *Trametes* sp. can appear on trunks, on dead wood, on stored wood logs and on the construction wood. It causes serious economic loss (Zabel and Morrell 1992). On the other hand, *Trametes* sp. has an important role in forests as a biomass-decomposing organism (Boddy 1991; Boddy and Watkinson 1995). *F. fomentarius*, in our country, may occur on the following species: *Acer*, *Aesculus*, *Alnus*, *Betula*, *Carpinus*, *Fagus*, *Fraxinus*, *Juglans*, *Populus*, *Prunus*, *Quercus*, *Salix*, *Tilia*, *Ulmus* sp. In dead wood, this species has white mycelia plates, which are a few millimetres thick and longer than 1 m (Igmándy 1991). *T. gibbosa* is a common saprophyte tinder fungus, commonly found except in a woody-steppe climate. Typical host plants: *Fagus*, *Carpinus*, *Tilia*, *Quercus*, but we can find it on *Abies* and *Picea*, but it does not like *Robinia*. After logging, it appears in almost every stump. It does not cause significant damage inside timber (Igmándy 1991).

One of our purposes in this research was to identify what kind of beetle community is related to *Fomes fomentarius*

Figure 1. Undamaged, healthy *Fomes fomentarius* on a tree (left) and its cross section (right).

Figure 2. *Fomes fomentarius* with emergence holes and with the fruiting body consumed by beetles (left) an its cross section (right).

Figure 3. Healthy, intact *Trametes gibbosa* (left) and the fungi consumed by beetles (right).

and *Trametes gibbosa*. The other aim of this study was to compare the beetle community of a perennial (*F. fomentarius*) and an annual (*T. gibbosa*) tinder fungi, which were collected from trees in the same location. Finally, the main objective of the study was to make a model with this preliminary examination of the beetle communities in perennial and annual tinder fungi.

As an assumption, we have established that two fungi differ in structures and characteristics. *F. fomentarius* is perennial and the *T. gibbosa* is annual tinder fungi. We aimed to find out whether these unique characteristics can cause any differences between their beetle communities.

Material

Tinder fungi, *F. fomentarius* and *T. gibbosa* were collected from different beech trees from the same area. The altitude of the Hidegvíz Valley ranges between 390-550 m above sea level. It belongs to the watershed of the Rák stream. Several springs of the stream are located in the area. Thanks to these conditions, its mesoclimate has a subalpine character. The area of the sampling site was 150.036 ha. It covered those beech forests in the Hidegvíz Valley (Fig. 4) in which at least 30% of the trees in the mixed forest are beech. The Hidegvíz Valley forest reserve is situated inside the sampling site. The total area of the reserve was 56.9 ha with a core area of 19.7 ha and the buffer zone is 37.2 ha. In this area, the average annual precipitation is 750-900 mm. The average temperature in January is –2°C, and in July is 19°C (Király 2004).

F. fomentarius is a common species in Hungarian forests. It is a facultative necrophyte, but it can also live for a long time as saprophyte on dead wood (Folcz and Papp 2014). In Hungary, it is found everywhere from the plains to the mountains, only missing from black locust plantations. The trama is tough and light brown with concentric zones. The mycelial core is soft. *F. fomentarius* has a pleasantly fungoid smell and a bitter taste. The surface of pileus is smooth, glabrous with hard, dark brown crust, 0.5-2.0 mm thick. The margin is obtuse and rounded. The structure is flexible, and corky-woody. Its pores are more or less circular with a diameter of 0.2-0.3 mm. The flesh is thinner than the tubular part. The hyphal system is trimetric. Spores are oblong-ellipsoid with thin hyaline walls. Its spore is light yellow, and it is obtainable only in spring, from mid-April to mid-June. It is widespread in the Holarctic Flora Empire (Domanski et al. 1973, Breitenbach and Kränzlin 1986, Igmándy 1991).

The upper part of the *Trametes gibbosa* pileus is mostly flat and densely pubescent. At times it is tomentose. It is white, greyish and greenish at the base. The margin is rufous-brown, obtuse and later thin. *T. gibbosa* has a homogenous structure with up to 30 mm central part and with 2-3 mm thick margin. Its pores are longitudinal and radially arranged. The flesh is tough and elastic, white and cream-colored. The tubes have thick partitions, 5-10 (15) mm long. The hyphal system is trimetric; the generative hyphae are thin-walled; the skeletal hyphae are thick-walled and the binding hyphae are branched. Its spores are white and ellipsoid with thin hyaline walls. Its sporulation is in May. It is also widespread in the Holarctic Flora Empire (Domanski et al. 1973, Breitenbach and Kränzlin 1986, Igmándy 1991).

Methods

Fungi were collected randomly in April 2013, near the western border of Hungary from Hidegvíz Valley. Each fruiting body was packed in a paper sack. It was important to conserve this complex assemblage. Therefore, the fungi were collected without bark and not cleaned. During the sample collection process, the place and time of collection, the host plant, the quality of the tree, the name and age of the specimen were recorded.

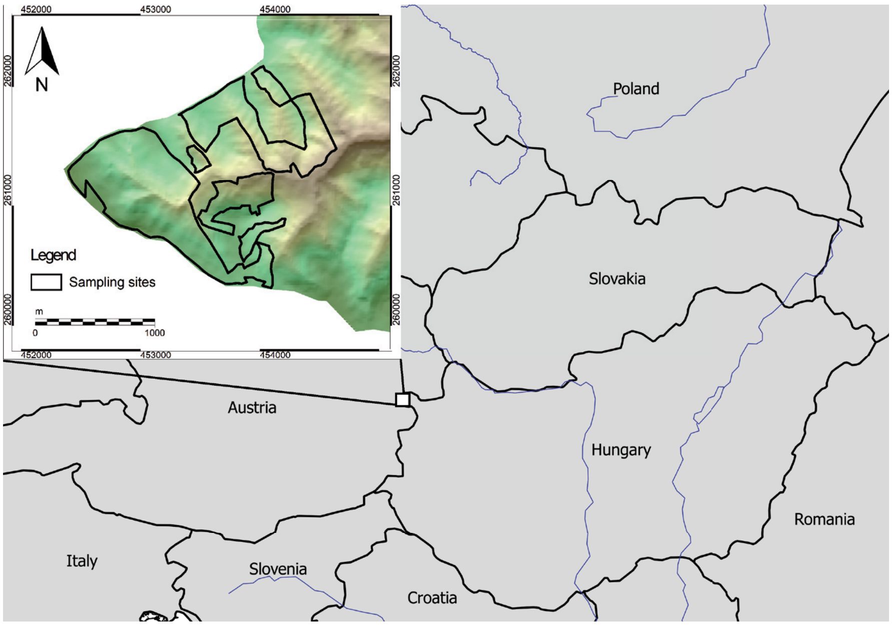

Figure 4. The location of the study site, Hidegvíz Valley in the Sopron Mountains, Hungary.

Table 1. Numbers of beetle individuals in *Fomes fomentarius* samples (1-4).

	Beetles	Family	Sample 1.	Sample 2.	Sample 3.	Sample 4.	∑
1.	*Cis castaneus*	Ciidae	3	0	1	0	4
2.	*Octotemnus glabriculus*		3	0	0	0	3
3.	*Sulcacis nitidus*		0	1	0	0	1
4.	*Bolitophagus reticulatus*	Tenebrionidae	0	94	0	3	97
		∑	6	95	1	3	105

Table 2. Numbers of beetle individuals in *Trametes gibbosa* samples (1-4).

	Beetles	Family	Sample 1.	Sample 2.	Sample 3.	Sample 4.	∑
1.	*Cis boleti*	Ciidae	300	1901	2914	254	5369
2.	*Cis micans*		8	130	7	66	211
3.	*Octotemnus glabriculus*		376	1115	317	2734	4542
4.	*Rhopalodontus perforatus*		0	0	0	1	1
5.	*Sulcacis fronticornis*		2	0	0	0	2
6.	*Sulcacis nitidus*		287	465	107	8	867
7.	*Dacne pontica*	Erotylidae	0	0	0	5	5
8.	*Rhizophagus bipustulatus*	Monotomidae	0	1	0	0	1
		∑	973	3612	3345	3068	10998

The tinder fungi were stored in the laboratory of the Institute of Silviculture and Forest Protection at 20±1 °C,with 60% humidity and 16 hours of lighting and 8 hours of darkness. During spring 2013 and winter 2014, the insects were collected from the bags every 8th week, they were removed with pincers from the paper sack five times.

For those insects that we could not remove from the fungal debris, detergent was used. During this process, the fungal debris was submerged in water. Detergent was poured into the water to reduce surface tension of the water. Thus, the insects floated on the surface of the water while the debris submerged.

The beetle samples were stored in plastic tubes. To avoid mould formation, silica gel was used. Until their identification, the tubes were stored in the freezer. Individual beetles were separated and identified with a microscope.

The individuals of species were counted manually. When the number of individuals was greater than 1000, a sampling method was used. Two hundred specimens were counted manually. The weight of 200 specimens was measured after that the entire sample was measured with a laboratory scale, and this quantity was divided by the weight of the 200 specimens. The number of beetles is estimated as 200*(weight of entire sample)/(weight of 200 beetles).

The weight and volume of the fruiting bodies were measured. The volume of tinder fungus was measured by immersion in water with 1 cm^3 precision. The purpose of this measurement was to calculate the average space, which is needed for a beetle in a fungus. The aim of the examination was to determine a fungus beetle's required foraging space and territory.

During the evaluation of the beetle community, the histogram and descriptive statics were calculated. The standard t-test was used for statistical hypothesis test to determine if the two sets of data are significantly different from each other.

Results and discussion

Four samples were collected from *Fomes fomentarius* and four from *Trametes gibbosa*. There were 105 beetle specimens in the *F. fomentarius* samples (Table 1), while the *T. gibbosa* samples had a hundred times more, 10998 beetles (Table 2). Four beetle species were identified from *F. fomentarius*, and eight species from *T. gibbosa*. *Octotemnus glabriculus* and *Sulcacis nitidus* were found in both fungus species. The largest number of individual beetles in a *F. fomentarius* specimen was 95 and the average number of individuals in a fruiting body was 26. The reason for this high number of specimens is that 94 specimens of *Bolitophagus reticulatus*, were found in sample 2, which is typically associated with the tinder conk. The highest number of species was two, the average number of species was 1.5. The highest number of *T. gibbosa* individuals was 3612, while the average number in a single fungus was 2749.5. The maximum number of species was six, while the average was five (Table 3).

We observed that the average volume of *F. fomentarius* is 288.6 cm^3, so an individual of adult fungus beetle had 10.99 cm^3 of space. In contrast, the average volume of a *T. gibbosa* is 102.2 cm^3; thus an adult fungus feeding beetle could only use 0.04 cm^3 of space on average (Table 4). According to our results, the larger beetles are usually in *F. fomentarius*, while the smaller beetles are in *T. gibbosa*. The fruiting bodies of the two species have a different structure. *T. gibbosa* has a

Table 3. The number of individuals and number of species in *F. fomentarius* and *T. gibbosa.*

	Fomes fomentarius	*Trametes gibbosa*
Number of fungus specimens	4	4
Maximum number of individuals per fungus	95.00	3612.00
Minimum number of individuals per fungus	1.00	973.00
Average number of individuals per fungus	26.25	2749.50
Standard deviation	45.879	1204.98
Maximum number of species per fungus	2.00	6.00
Average number of species per fungus	1.50	5.00

Table 4. The mean weight and the mean volume of the two tinder fungi.

	Average weight (g)	Average volume (cm^3)	Fungus volume/beetle specimen
Fomes fomentarius	212.00	288.59	10.99
Trametes gibbosa	57.20	102.20	0.04

Figure 5. Degradation process of *Fomes fomentarius* (healthy, left), early stage of consumption (middle), fungal debris (right).

Figure 6. Degradation process of *Trametes gibbosa* (healthy, left), early stage of consumption (middle), fungal debris (right).

thinner fruiting body of both the trama and hymenium than *F. fomentarius*. However, tinder conk provides more space and nutrition for species. Both fungi were examined regarding which part of fruiting body was preferred by beetles. In *Fomes*, the beetles began to consume under the crust and then proceeded to the tubular part. *Trametes* was consumed between the trama and the tubular part. Presumably, beetles eat in both directions simultaneously. It is interesting that the beetles consumed the hymenium and the trama first and foremost only after that they fed at the umbo of the fungi.

The beetle community of the *Fomes fomentarius* consists of four beetle species: *Bolitophagus reticulatus*, *Cis castaneus*, *Octotemnus glabriculus* and *Sulcacis nitidus*. In the samples, there were a total of 105 individuals. In *Fomes, B. reticulatus* was the most frequent with 97 individuals. The chewing of the beetles in the *F. fomentarius* is very noticeable, because two large Tenebrionidae beetles often connected with it (Merkl 2016). One of those is *B. reticulatus*, which typically associated with *F. fomentarius* (Hurka 2005). They are typical mycophage beetles because they grow in the fruiting body (Stokland et al. 2012).

The four *Trametes gibbosa* specimens had eight different beetle species, which were *Cis boleti*, *C. micans*, *Dacne pontica*, *Octotemnus glabriculus*, *Rhizophagus bipustulatus*, *Rhopalodontus perforatus*, *Sulcacis fronticornis* and *S. nitidus*. There were a total of 10998 individuals in the *Trametes* fruiting bodies. Except for one species, they were typical mycophage beetles. The exception is *R. bipustulatus*, which lives under the bark of broadleaf trees, and consumes the mycelia of the fungi. Sometimes they can consume species from the family of Bostrichidae (Hurka 2005). In *T. gibbosa* we found 6 beetle species from Ciidae family. The largest and one of the most common species is *Cis boleti* (Merkl 2016). In our research, the most frequent species were *C. boleti* with 5356 individuals and *O. glabriculus* with 4542 individuals.

Despite the fact that the tinder samples were collected at the same time and same location from *Fagus sylvatica* trees, *Fomes fomentarius* and *Tramates gibbosa* had a different number of beetle species and specimens. Statistical analysis was performed with the Wilcoxon-Mann-Whitney (WMW) test, which proved statistically significant at $\alpha = 0.05$ ($P_{calculated} = 0.03$) between the number of individuals. This test also proved statistically significant ($P_{calculated} = 0.0027$) between species numbers. The differences could be caused by the structure of fruiting bodies and secondary metabolites. *T. gibbosa* has a thinner fruiting body than *F. fomentarius,* (*T. gibbosa* is about 1/3 of *F. fomentarius*) (Fig. 5, Fig. 6). In spite of this *T. gibbosa* provides more nutrition for species. *Fomes* has a harder fruiting body. It can be consumed only by a few beetle species. The spread of the fungus beetles is influenced by the conditions of their habitat, such as the presence of substrate (Southwood 1977). The sample site was a forest reserve; therefore, it had more dead wood and tinder fungi than in a managed forest. Dead wood and tinder fungi can have a positive effect for distribution strategy of the tinder fungi consumers. Important properties of natural forests, such as coarse woody debris, decaying wood, dead wood and fungi, assist in maintaining the diversity of saproxylic and mycophagous species (Harmon et al. 1986). These factors increase the diversity and at the same time, they reduce the local disappearance of species, or the risk of harmful gene loss (Brakefield 1991).

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