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THE COLONIZATION OF COARSE WOODY DEBRIS OF *FAGUS SYLVATICA* BY FOREST HERBS IN BUKOWICA RESERVE (S POLAND)

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ABSTRACT. In the forest nature reserve "Bukowica" (S Poland), dominated by *Fagus sylvatica* vascular plant species were noted on coarse woody debris (CWD). A number of individuals (shoots, leaf rosettes, seedlings) were noted in three distinguished microhabitats: fallen logs, stumps and root plates with remnants of soil. In total 30 species were observed on CWD. Majority of found stumps (75%) and most of root plates (67%) and only 34% of logs were colonized by forest herbs. The highest total species richness and mean number of plants were found on root plates followed by stumps and logs. The study showed that the number of species on fallen logs correlated positively with the class of dead wood decomposition.

KEY WORDS: *Fagus sylvatica*, coarse woody debris, colonization, deciduous forests, forest floor species

INTRODUCTION

Many ecologists, and environmentalists point out the major importance of coarse woody debris (CWD) in functioning of forest ecosystems (Bobiec 2002, Christensen et al. 2005, Holeksa et al. 2006). The deadwood poses a microhabitat for numerous fungi, plants and animals and enhances self-regeneration of tree stands as e.g. *Picea abies* as it was shown by Holeksa (1998). The presence and big amount of dead wood is a signal of "naturalness" of forest and the factor preserving forest health. In Poland it was Faliński (1976, 1978) who first began studies on the role of CWD in forest ecosystems exemplified by Białowieża Primeval Forest. Other later studies concerned function of CWD in regeneration of tree stands especially spruce montane woodlands (Jaworski and Karczmarski 1995, Holeksa 2001, Holeksa and Cybulski 2001). CWD enhance spread and colonization by herb species. Some case studies demonstrated the phenomenon of colonization of CWD by particular species e.g. *Impatiens parviflora* (Piskorz and Klimko 2001). There are still few studies which are concerned with vascular flora colonizing CWD especially in forests located in lowlands. In this study floristic studies focused on dead wood of beech *Fagus sylvatica* exemplified by one of the forest reserve.

The following questions guided this research: What vascular species colonize dead wood of *Fagus sylvatica*? What is the frequency of particular species colonizing deadwood? Are there any differences in species richness between fallen logs, stumps and root plates?

STUDY AREA AND METHODS

The studies were carried out in 2006 and 2007 in "Bukowica" nature reserve. This is a forest reserve situated on Triassic hill in western part of Garb Teńczynski, between Wygiełzów and Zagórze (Jurrasic Upland) (Fig. 1). It occupies an area of 22.76 ha. Since 1987 when the reserve was established its main task is to protect well-preserved fragment of old-growth beech forest, classified as *Dentario glandulosae-Fagetum* Klika 1927 em. Mat. 1964. The old beech tree stand which mainly grows hill, with large limestone outcrops, is surrounded by managed pine woods. Due to not-intensive forest management practices in the nature reserve there is quite a big amount of deadwood when compared to the other forest nature reserves in the region.

Three types of microhabitats of deadwood were distinguished: fallen logs, stumps, and root plates with remnants of soil. Fallen dead trees were both broken and uprooted, thus uprooted trees contained part of deadwood called fallen log and deadwood called root plate. The alone root plates with removed remaining part of deadwood were also included in the studies. The stumps surveyed were of natural origin i.e. they were remaining part of trunk after the fall of tree. The presence and absence of vascular plant species were recorded and density of individuals of species found was counted. These were seedlings, shoots in case of annual species or leaf rosettes in case of grasses and perennials. Each CWD in a given type of the microhabitat was considered a sample. The criterion of division into eight decomposition classes (Table 1) follows Holeksa (1998).

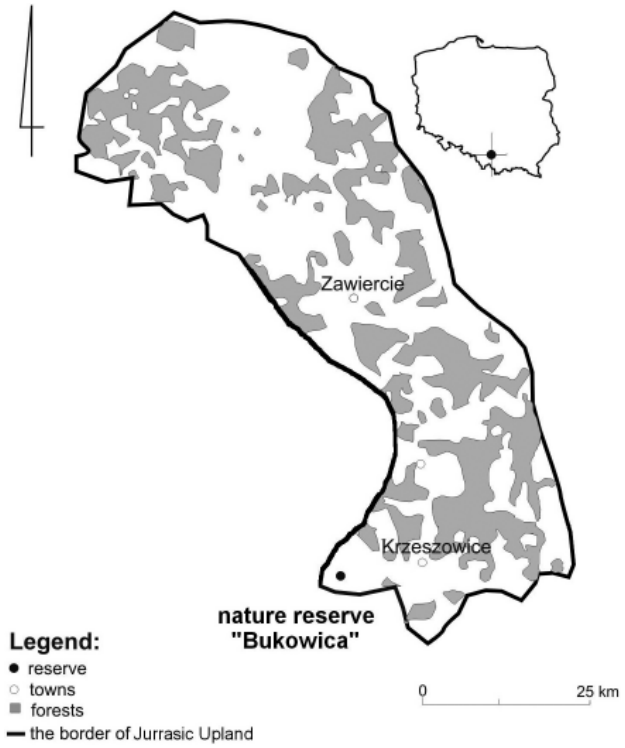

Fig. 1. Situation of the forest nature reserve "Bukowica"

Table 1. Decomposition scale of CWD after Holeksa (1998)

Stage of decomposition	Surface	Shape	Depth of penetration of sharp tool
I	smooth	round	wood hard
II	smooth	round	surface bends under the pressure of knife
III	crevices several millimetre deep	round	to 1 cm
IV	crevices ca. 0.5 mm deep	round	to 3 cm
V	crevices ca. 1 cm deep	round	to 5 cm
VI	several centimetre thick pieces tear off	round	solid only in central part of log
VII	whole log cover with several centimetre deep furrows	distinctly flatten	through
VIII	covered with vegetation	embankment above ground	through

The contingency table (G-test) was employed to test differences in participation of plant colonization (number of colonized samples) vs. non-colonization between deadwood microhabitats. Due to differences in frequency, individuals density of particular species and surface area of fallen logs, stumps and root plates rarefactions of species richness with 1000 iterations (Gotelli and Graves 1996) were used to compare number of species present in three types of CWD. To test relationship between the number of species on fallen logs and class decomposition Spearman's rank correlation coefficient was calculated. Only uprooted logs with plant present on root plates were taken into analyses. It guaranteed that logs lay long enough on forest floor to be theoretically colonized by plants. The analyses were done with R software (R Development... 2007) and EcoSim (Gotelli and Entsminger 2007).

RESULTS

Twenty nine fallen logs were subjected to study and 18 root plates and eight stumps. The highest percentage of stumps (75%) was colonized by plants; however, they are the rarest. Majority of root plates (67%) and minority of fallen logs (34%) were colonized by plants (Fig. 2).

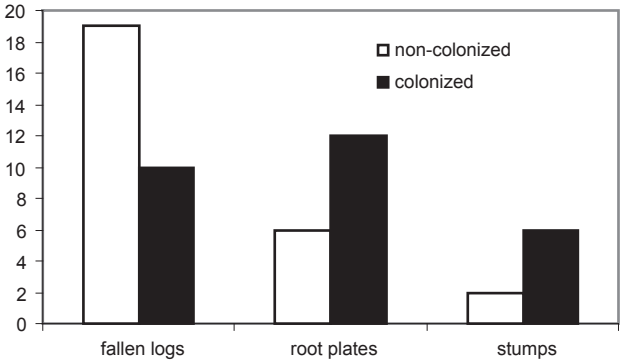

Fig. 2. Comparison of frequency of colonized vs. non-colonized types of coarse woody debris of *Fagus sylvatica* (G = 6.953, P = 0.031)

In total 30 vascular plant species were found (Table 2). Twenty two species on root plates, 15 on stumps and 12 on fallen logs were detected. On the basis of rarified number of species, number of species on root plates vs. fallen logs amounts to 19.45 and 20.6 vs. stumps respectively. Whereas rarified species richness of stumps vs. fallen logs was estimated at 14.3. The highest mean number of species per sample was recorded on root plates (5.4 ±2.7) lower on stumps (4.5 ±2.8) and the lowest on fallen logs (2.8 ±1.1) (Fig. 3). The Spear-

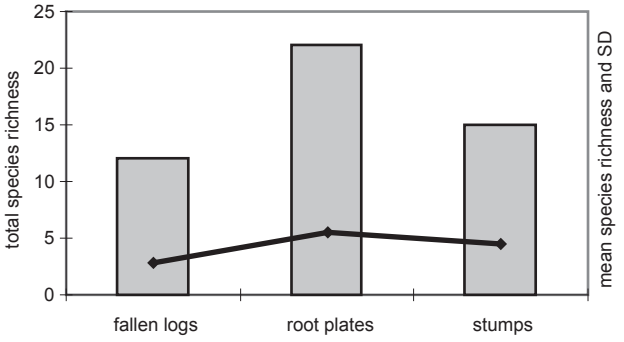

Fig. 3. The total and mean with standard deviation of species richness of colonized coarse woody debris types in *Fagus sylvatica*

Table 2. The frequency and abundance of species observed in coarse woody debris of *Fagus sylvatica*

Species	Frequency (%)			Total number of plants		
	fallen logs	root plates	stumps	fallen logs	root plates	stumps
Aegopodium podagraria	–	–	12.5	–	–	20
Ajuga reptans	–	16.7	12.5	–	17	10
Athyrium felix-femina	–	16.7	12.5	–	3	1
Betula pendula	3.4	–	–	1	–	–
Carex digitata	–	5.6	–	–	2	–
Chamaenerion angustifolium	–	16.7	–	–	3	–
Chelidonium majus	–	5.6	–	–	3	–
Convallaria maialis	–	5.6	–	–	3	–
Cruciata glabra	–	11.1	–	–	13	–
Dryopteris filix-mas	3.4	–	–	2	–	–
Eupatorium cannabinum	–	–	12.5	–	–	1
Fagus sylvatica	24.1	38.9	25	29	28	3
Galium odoratum	10.3	22.2	25	15	41	11
Geranium robertianum	3.4	11.1	–	2	3	–
Hedera helix	3.4	5.6	–	3	3	–
Impatiens parviflora	13.8	55.6	75	88	121	101
Lathyrus vernus	3.4	–	–	2	–	–
Luzula pilosa	–	–	12.5	–	–	2
Melica nutans	–	–	12.5	–	–	5
Mercurialis perennis	20.7	22.2	25	19	64	22
Moehringia trinervia	–	–	12.5	–	–	3
Mycelis muralis	3.4	16.7	12.5	1	10	2
Pinus sylvestris	–	5.6	–	–	1	–
Poa nemoralis	–	11.1	25	–	5	3
Rubus idaeus	–	11.1	37.5	–	4	12
Sambucus racemosa	–	5.6	–	–	1	–
Taraxacum officinale	3.4	16.7	–	2	8	–
Tussilago farfara	–	11.1	–	–	5	–
Veronica officinalis	–	11.1	–	–	14	–
Viola reichenbachiana	3.4	11.1	25	1	16	25

man rank correlation revealed significant and positive relationship ($r_s = 0.65$, $p < 0.01$) between class decomposition and number of species encountered on fallen logs. Amongst 30 total species found on CWD only six were present in each type of microhabitat. These were: *Galium odoratum*, *Fagus sylvatica*, *Impatiens parviflora*, *Mercurialis perennis*, *Mycelis muralis*, *Viola reichenbachiana* (Table 2). Overall highest density was revealed by *Impatiens parviflora* which was the most frequent and most abundant, especially on stumps. Other quite frequent and abundant species were *Fagus sylvatica* and *Mercurialis perennis*. Seven species were present in two types of CWD-microhabitats e.g. *Ajuga reptans*, *Athyrium filix-femina*, *Geranium robertianum*, *Hedera helix*, *Rubus idaeus* and *Taraxacum officinale*. The remaining 16 species were noted only in one type of microhabitat and usually at small densities (Table 2).

DISCUSSION

The importance of CWD to forest biodiversity has been focused in some case studies for several organism groups. Majority publications are devoted to mainly lichens, bryophytes and fungi (e.g. Bader et al. 1995, Crites and Dale 1998, Kruys et al. 1999, Humphrey et al. 2002, Caruso and Thor 2007) or saproxylic invertebrates, especially beetles (Jonsell et al. 2004, Lindhe and Lindelöw 2004). Few studies concern the occurrence of vascular plant species (Lee and Sturgess 2001, Zielonka and Piątek 2004, Åström et al. 2005). The herbs encountered in three types of CWD differ in frequency and abundance as well as in ecological responses to the biotopic conditions associated with specific microhabitat of CWD. Taking into account of small amount of CWD subjected to the presented stud-

ies obtained number of vascular species is relatively high when compared to other researches. For instance Zielonka and Piątek (2004) observed 20 vascular species on 285 logs and stumps of Norway spruce *Picea abies* in subalpine zone of Polish Tatra Mountains. Such a high species richness in the present study resulted mainly from taking root places into analyses where 22 plant species were found. This part of deadwood contain remains of soil and litter between roots, therefore there are the most favourable conditions for growth of herb species. However, 21 species, occurring together on logs and stumps, were observed. As in the study of Zielonka and Piątek (2004) the species found on logs and stumps are usually plants very frequent in the herb layer of the forest floor. Such a species was *Vaccinium myrtyllus* and in this study the most frequent is *Impatiens parviflora*. These species are completely different in terms of growth form, dispersal and origin. This suggests that the process of colonization of dead logs is rather stochastic in nature than determined by special plant traits of colonizers. As to *Impatiens parviflora,* the obtained results confirm observations by Piskorz and Klimko (2001) on high tendency of this species to colonize deadwood. They noted high frequency of *Impatiens parviflora* on decayed logs of oak and hornbeam and no individuals on dead Pine trees. In "Bukowica" reserve mainly beech trees constitute tree stand, however, probably it can be inferred that small balsam easier colonizes deciduous trees than coniferous ones because intensity of decaying of these tree species is different. Small balsam was found almost as the only one on logs of first decay class – in holes in bark. Another frequent species was *Mercurialis perennis*; this plant is very abundant in the herb layer of forest in the reserve. The seedlings of *Fagus sylvatica* were quite frequent in all type of deadwood but no saplings of the species were observed. The coarse woody debris of beech do not play equivalent role in regeneration of the tree as in case of *Picea abies* (Holeksa 1998).

The research proves that fallen logs, stumps and root plates are incomparable in relation to microhabitat conditions. As it was said before, root plates due to soil presence and higher humidity, as well as occurrence of mosses, enhanced colonization and persistence of herbs because it most resembled conditions occurring in the ground layer of forest interior. Whereas, top surface of stumps – remnants of broken trees – is a place where processes of decaying are faster than on logs and layer of mosses and humus is formed what facilitates herbs to spread. The study confirmed relationship between the degree of decomposition of tree e.g. logs and species richness. Such a result was obtained by Zielonka and Piątek (2004) who found that first species colonized dead logs at III decomposition class (Table 1).

Further research is needed to test whether other characteristics of CDW as age, volume, position on slope – in case of logs, and ground pits after tree fall influence species richness and diversity of colonizing vascular flora. The changes in colonization require temporal studies both between years and during the vegetation season what is important in relation to annual forbs.

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