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Polypore diversity in the herb-rich woodland key habitats of Koli National Park in eastern Finland

Anna-Liisa Sippola [a,*], Mikko Mönkkönen [b], Pertti Renvall [c]

[a] Arctic Centre, University of Lapland, P.O. Box 122, FIN-96101 Rovaniemi, Finland
[b] Department of Biology, University of Oulu, P.O. Box 3000, FIN-90014, University of Oulu, Finland
[c] Kuopio Natural History Museum, Myhkyrinkatu 22, FIN-70100 Kuopio, Finland

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Abstract

Species diversity of polypores (Basidiomycetes) was compared between woodland key habitats (WKHs) and old-growth forest controls in boreal forests in eastern Finland. WKHs, which were set aside for their rich vascular plant flora, turned out not to be hot spots for the species richness of polypores, nor did their species composition represent the overall species richness of the area. Differences in the total volume of CWD, tree species composition and several CWD qualities were reflected as differences in the species assemblages between the groups. The results indicated that only a fraction of the overall polypore diversity was represented in the small-size WKHs (<0.5 ha), and the protection of red-listed and indicator polypores in WKHs was random. However, rare old-growth forest indicators were found even in small-size WKHs, if the CWD quality was appropriate for them. Nevertheless, our study does not answer the question whether the occurrences of rare and red-listed species will survive in small-size WKHs surrounded by altered environments such as clear-cuts, because our study sites were located in undisturbed areas. The results stress the importance to protect typical old-growth forest patches with high CWD volume and quality in boreal forests.

Keywords: Woodland key habitats; Polypores; Biodiversity; Boreal forests; Hot-spots; Coarse woody debris; Dead wood

1. Introduction

Woodland key habitats (WKHs) are defined as habitats, in which rare and red-listed species are likely to occur (Nitare and Norén, 1992), and which are also considered to serve as refugia and dispersal sources for species that are negatively affected by forestry (Snäll and Jonsson, 2001). In practical forestry WKHs are considered to be small-scaled habitats, which are clearly distinguished from the surrounding forest matrix (Gustafsson, 2002). The criteria for selecting WKHs differ both nationally and, to some degree, also regionally. In some countries such as Finland, WKHs have been defined by legislation to include specific habitat types such as surroundings of springs and brooks, herb-rich mesic spruce forests and fens, ravines and gorges, rocks, boulders, sand dunes and small-scale forest patches in the middle of mires (Suomen säädöskokoelma, 1996). In other countries, e.g., Sweden and Latvia, administrators and forestry organizations have developed the practice of defining the sites (Ek et al., 2002; Norén et al., 2002). Identifying of the areas is usually based on physical or structural properties of the sites and the occurrence of indicator species.

Coarse woody debris (CWD) is one of the key elements for biodiversity in boreal forest ecosystem, and it is also used as one of the structural indicators of WKHs (Ek et al., 2002; Norén et al., 2002). It has been estimated that e.g. in Finland 4000–5000 and in Sweden

* Corresponding author.
E-mail addresses: anna-liisa.sippola@ulapland.fi (A.-L. Sippola), mikko.monkkonen@oulu.fi (M. Mönkkönen), pertti.renvall@kuopio.fi (P. Renvall).

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6000–7000 species are saproxylic, i.e., depending on dead woody material at some stage of their life cycles (Siitonen, 2001; Dahlberg and Stokland, 2004). Saproxylic species comprise also a large proportion of the threatened species in the Nordic countries. For instance, of the 1505 threatened species in Finland 285 (19%) are threatened mainly because of the decline of CWD (Rassi et al., 2001).

Polyporous fungi (Polyporaceae s. lato) comprise over 220 species in Finland; most of the species depend directly on dead wood as their living substrate (Niemelä, 2004). Strong decline of CWD in managed forests has influenced the diversity of polypores, and about 24% of polypore species are threatened and 14% near threatened in Finland (Rassi et al., 2001).Polypores are commonly used as one indicator group of WKHs (Ek et al., 2002; Meriluoto and Soininen, 2002; Norén et al., 2002). Many species of the group are strongly specialized in their habitat requirements, giving information on specific features of the forest stands, such as continuity of large-diameter trunks. There is also evidence that polypore diversity can be used as a surrogate of species richness of some other saproxylic groups such as saproxylic beetles (Jonsson and Jonsell, 1999).

One of the key questions in the evaluation of the importance of woodland key habitats for species conservation is whether the selected WKHs really are hot-spots for rare and threatened species of several taxa (Hansson, 2001). Species-rich communities of vascular plants are in many biotopes used as indicators of WKHs and ecologically valuable sites (Norén et al., 2002; Meriluoto and Soininen, 2002). There is, however, contradictory information on the importance of WKHs for threatened vascular plants, and on the co-variation of species richness of vascular plants with other taxa in boreal and hemiboreal zone. Sætersdal et al. (2003) found that in small-size plots in the forest reserves in eastern Norway the species richness of vascular plants correlated with seven species groups of invertebrates and cryptogams, including polypores. Virolainen et al. (2000), on the contrary, found that optimal networks for the species richnesses of beetles, Heteroptera and vascular plants supported relatively well each other, but not sites with high species richness of polypores. Gustafsson (2000) found in her study in south-east Sweden that rare and threatened vascular plants were not optimal indicators of WKHs, and the regional differences in the occurrence of rare vascular plants were greater than the differences between production forests and WKHs within the regions. The purpose of this study was to detect if the woodland key habitats, which had been selected by their rich vascular plant flora, were also hot-spots for polypore species richness. We compared species richness, abundance and community composition in WKHs versus surrounding heath forest controls. More specifically, the study aimed at answering the following questions:

1. Is the species richness of polypores higher in woodland key habitats than in the surrounding old-growth forest matrix as expected by their presumed status as biodiversity hot-spots?
2. What is the effect of WKH size for the preservation of polypore species? Typically, e.g. in Finland, WKHs are rather small (<0.5 ha), and the question is if such small areas are capable of maintaining overall species richness of polypores in boreal forests.
3. How do the species compositions of WKHs and typical old-growth forests in the region differ from each other? That is, if only WKHs are set aside, to what extent overall polypore species richness is protected?
4. What is the importance of WKHs for the preservation of red-listed and old-growth forest species?

Because polypores are dependent on dead wood, we tested if the amount of CWD differed between WKHs and controls, and then controlled the amount of CWD by including it as a covariate in models explaining polypore species richness and abundance. To further increase understanding of factors affecting polypore diversity, we tested both differences in the species richness and abundance of polypores among different substrate types, and differences in the species numbers per substrate unit between WKH and control plots.

2. Materials and methods

2.1. Study sites

The study was conducted in the Koli National Park in eastern Finland, at the transition border of the southern and middle boreal vegetation zones (Ahti et al., 1968). The area is dominated by north–south oriented hill formations. The forests are dominated by Norway Spruce (*Picea abies* (L.) H. Karst.) on the eastern and by Scots Pine (*Pinus sylvestris* L.) on the western slopes of the hills. Deciduous trees (birch (*Betula pubescens* Ehrh.), grey alder (*Alnus glutinosa* (L.) Gaertn.), bird cherry (*Prunus padus* L.) and rowan (*Sorbus aucuparia* L.)) are found especially on the herb-rich sites of the eastern slopes (Hokkanen, 2003).

The sites were selected from the forest inventory data of the Finnish Forest Research Institute (FFRI). Both the WKHs and the control sites were chosen among spruce-dominated stands on the basis of over 50% canopy coverage of spruce and as similar total living tree volumes as possible (the mean volume in the WKHs 301 $m^3\ ha^{-1}$ and in control areas 351 $m^3\ ha^{-1}$). The WKHs were chosen to represent different sizes to detect the effect of WKH size to the species diversity. The size classes were: small (S) = <0.10 ha (6 replicates), medium (M) = 0.15–0.50 ha (5 replicates) and large (L) = >1 ha (4 replicates). The control sites were chosen within the dominating forest matrix surrounding the WKHs, on the basis of their location near the WKH sites. The size of the control sites (C) varied 6–15 ha (5 replicates).

According to the data of the FFRI, the average canopy coverage of spruce in the WKHs was 71% and in the control areas 82%. The coverage of birch was 9% in WKHs and 10% in controls. The respective figures for aspen were 2% vs. 5%, for alder 6% vs. 0% and for rowan 1% vs. 0% (FFRI, forest inventory database of Koli N.P. FFRI, 2000). Because only total timber volumes were available for the sites, the volumes of different tree species could not be tested between the controls and WKHs. The WKHs had been identified within the forests using indicator vascular plants (Meriluoto and Soininen, 2002). The undergrowth vegetation in the WKHs was dominated by ferns (*Athyrium filix-femina* (L.) Roth, G*ymnocarpium dryopteris* (L.) Newman, *Phegopteris connectilis* (Michx.) Watt) and herbs (*Maianthemum bifolium* (L.) F.W. Schmidt, *Oxalis acetosella* L., *Trientalis europaea* L., *Geranium sylvaticum* L., *Rubus idaeus* L.). On the control sites, blueberry (V*accinium myrtillus* L.) was dominating in undergrowth, but with a mixture of *Maianthemum bifolium*, *Oxalis acetosella*, *Rubus saxatilis* L., *Dryopteris expansa* (C. Presl) Frasier-Jenkins & Jeremy) and *Athyrium filix-femina* as other dominant species.

On each study site, CWD and polypores were inventoried on circular study plots with a radius of 10 m. The number of study plots varied 1–8 depending on the size of the study sites. The plots were located along a line with a distance of 25 m from each other. The line was set randomly to the longitudinal direction of the site. Because most of the WKHs were small, and all sites were surrounded by closed forest, no buffer zone was left from the border of the site. Thus, the centre of the first study plot was located 10 m from the border of the site. If it was not possible to place all the plots along one line, another parallel line was established with a distance of 30 m between the lines. The total number of plots in the small WKHs was 8, in medium size WKHs 19 and in large WKHs 30 plots, and on the control sites altogether 35 plots.

2.2. CWD and polypore inventories

The CWD measurements were conducted in July 2000. All CWD with a base diameter >10 cm or with a minimum length of 1 m and base diameter of >5 cm were measured on the study plots. Tree species and position of CWD were recorded, and length and decay stage of each CWD piece were measured. According to position, CWD was classified into logs, entire standing dead trees, snags (>1 m), natural stumps (<1 m) and branches. Near hiking routes, some cut stumps were also recorded. The decay rate was classified into six stages (modified from Renvall, 1995): 1 = Recently died, wood hard, bark and phloem fresh, knife penetrates only a few millimetres into the wood. 2 = Wood hard, most of the bark left, but no fresh phloem present. Knife penetrates 1–2 cm into the wood. 3 = Partly decayed from the surface or in the centre (depending on tree species), usually large pieces of bark loosened or detached (conifers). Knife penetrates 3–5 cm into the wood. 4 = Most of wood soft throughout, usually without bark (conifers). The entire blade of the knife penetrates easily into the wood. 5 = Wood very soft, disintegrates when lifted. Trunk covered by ground-layer mosses and lichens. 6 = Wood very hard and grey, all bark detached. This last category applies mainly to conifers, which have dried out as standing dead trees.

To calculate CWD volumes, the mid-diameter of each CWD piece was measured, and the volume was calculated using the formula for the volume of a cylinder. For entire dead trees, the diameter at breast height (DBH 1.3 m) was measured, and the volume was detected from volume tables separately for each tree species (Laasasenaho and Snellman, 1998) (the volume table of birch was used for all the deciduous trees).

The polypore inventories were carried out in August–September 2000. Polypores were surveyed both on CWD and on living trees up to the height of three meters. A species found on a CWD unit was considered as one record, regardless the number of fruit bodies. The nomenclature of polypores follows Niemelä (2004). The red-listed species include both threatened and near-threatened species (according to Rassi et al., 2001). The old-growth forest indicators are defined according to Kotiranta and Niemelä (1996). The voucher specimens are preserved in the herbarium of the Kuopio Natural History Museum (KUO).

2.3. Data analysis

Student's *t*-test was used to study differences in the timber volumes between WKH means and control sites, and one-way analysis of variance (ANOVA), with a Tukey's test as a post hoc test was used to detect differences between the control sites and different WKH size classes. A logarithmic transformation ($\log 10(S + 1)$) was applied to the CWD data, because they were not normally distributed.

Because the total number of sample plots in WKHs (57) was larger than that of the control plots (35), direct comparison of species richness and abundance was not possible. Therefore, resampling was used to detect differences between the WKHs and control sites. We used bootstrapping (resampling with replacement) to estimate species richness in the sets of 1, 5, 10, 15, 20, 25 and 30 study plots separately for the WKH and control plot data. The cumulative species number as a function of plot number was detected from the resampling data, as well as the cumulative number of species that was common to both WKH and control plots. To test if the total species richness and abundance differed between WKHs and controls we used permutation test, where we randomly drew without replacement 35 plots from WKH data and calculated species numbers and their abundance across selected plots. This procedure was repeated 1000 times. We then calculated how many times the resampled data sets contained equal number or more species and records than was observed in the set of 35 control sites.

Nested multivariate ANOVA was used to model the factors affecting polypore species richness and abundance. CWD volume, species richness and abundance per individual study plot were used in the analysis. Volume of CWD was included into models as a covariate. We entered group (WKHs versus controls) as a fixed factor into the models after CWD to test if there is a difference between WKHs and controls when controlling for CWD. Because study plots within a site are not independent from each other, study site was used as a random variable in the model hierarchically nested into the group.

Kruskall–Wallis non-parametric analysis of variance and Mann and Whitney *U*-test were used to detect differences in the species richness and abundance of polypores growing on different substrates. Species richnesses and abundances per individual study plots were used also in these tests to eliminate the influence of the size of the study site. To detect if the observed differences were due to the differences in the volume of CWD or to some other factor, we tested differences in the species richness per individual CWD unit between WKHs and controls by using Mann and Whitney *U*-test.

Similarity in the species composition between the overall data of WKHs and control areas was explored by percentage similarity index, which also takes account the relative abundance of species (Renkonen, 1938, see also Wolda, 1981):

$$PS = \Sigma \min(p_{1i} \times p_{2i}),$$

where p_{ji}, the proportion of species in sample $j = n_{ji}/N_j$; n_{ji}, the number of individuals of species i in sample j; N_j, the number of individuals in sample j.

3. Results

Even though the mean volumes of living trees did not differ between the WKHs and control areas ($t = -2.43$, df = 18, $p = 0.124$), the total volume of CWD was significantly higher on the control sites than on the WKHs (67 vs. 41 m^3 ha^{-1}, Table 1). The volume of logs was about double on the control sites compared with WKHs, and higher CWD volumes on the control sites were detected in the diameter class 20–29 cm and in the decay class 3 (partly decayed) (Table 1). The volume of natural stumps was on average higher on the WKHs than on the control sites. The CWD volumes varied considerably within and between the WKH size classes. Random large aggregates of CWD on some sample plots contributed to the large mean volume of CWD in the smallest WKH size class, but the difference to the other WKH size classes was not significant. The volumes of alder CWD were significantly higher in the medium and large size WKHs than in the small WKHs and control sites. The volume of smallest-diameter CWD (<10 cm) was lower in the small WKHs than in the larger ones (Table 1).

Altogether 597 polypore records were made on the study sites (Table 2). The total area of all 92 sample plots was 2.9 ha, which hosted 56 species. In the bootstrapped data (35 plots from both groups) the mean number of species in WKHs was 29.8 (53% of detected total species richness) and 34.3 in control sites (61% of detected total species richness) (Fig. 1). In permutation test, probability to observe equal number or more species on randomly selected 35 WKH plots than on 35 control plots was 0.039, which means that the species number on control plots was significantly higher than on WKHs when the sample sizes were equal. The mean number of species on a WKH sampling plot was 2.98 and on a control plot 5.57. The total number of species increased, as expected, with increasing sampling area, but the control plots consistently fostered more diverse polypore assemblages (Fig. 1). On the basis of this study, a 0.2-ha size WKH hosted about 19% of detected total (WKHs and controls combined) polypore species richness, and a 0.5-ha size WKH about 36%.

The number of species per plot was dependent both on the volume of decaying wood and on the group (nested ANOVA model for decaying wood $F = 4.455$, df = 1, $p = 0.038$ and for the group $F = 11.526$, df = 1, $p = 0.002$). Thus, both the volume of CWD and the group influenced the species richness. The number of observations per plot, on the contrary, depended only on the volume of decaying wood (nested ANOVA model for decaying wood $F = 10.396$, df = 1, $p = 0.002$).

The species composition of WKHs differed considerably from the species composition of control sites. In all data (57 vs. 35 plots) the overall percentage similarity between controls and WKHs was 67. When equal sample sizes were compared, the proportion of shared species was 33.6% of the total number of species found in the study, and 54.8% of species found on the 35 control plots (Fig. 1). The most remarkable differences were found on polypore species growing on different tree species. In all data, about 35% of species in WKHs were growing on coniferous CWD and 65% on deciduous CWD, whereas the majority (53%) of species in the control areas were growing on coniferous CWD (Table 3). The difference was still higher in the number of records: in the control areas 58% of specimens were growing on

Table 1
The mean volumes of CWD (m^3 ha^{-1} ± SD) in woodland key habitats and control areas

	Woodland key habitats					
	Small	Medium	Large	WKHs mean	Control	*p*
CWD by tree species						
Pine	0	0	0	0	0.3 ± 0.7	0.368
Spruce	49.4 ± 67.7	19.1 ± 33.1	8.4 ± 5.1	28.4 ± 47.9	38.7 ± 23.7	0.429
Birch	4.7 ± 8.7	6.4 ± 8.1	5.8 ± 4.9	5.6 ± 7.2	17.1 ± 20.1	0.142
Aspen	0.2 ± 0.4	0.4 ± 0.9	0	0.2 ± 0.6	2.9 ± 0.6	0.117
Alder	0.3 ± 0.3	4.7 ± 3.5	6.2 ± 3.1	3.3 ± 3.5	1.0 ± 0.8	0.143
Goat willow	0	0.3 ± 0.5	0	0.1 ± 0.3	0.4 ± 0.8	0.252
Rowan	0	0.3 ± 0.5	0.5 ± 0.5	0.3 ± 0.4	0.4 ± 0.8	0.776
Unknown	5.3 ± 9.7	1.6 ± 1.4	1.5 ± 1.1	3.0 ± 0.4	0.4 ± 0.8	0.157
CWD by quality						
Logs	43.3 ± 55.6	23.8 ± 36.1	13.6 ± 2.8	28.9 ± 40.6	57.3 ± 21.0	**0.028**
Standing dead trees	4.5 ± 10.6	1.4 ± 1.1	2.7 ± 2.7	3.0 ± 6.7	3.7 ± 2.7	0.257
Snags	0.1 ± 0.2	4.0 ± 5.9	2.1 ± 1.3	1.9 ± 3.6	4.3 ± 4.1	0.066
Natural stumps	6.6 ± 4.9	3.6 ± 1.6	3.5 ± 2.2	4.8 ± 3.6	1.4 ± 0.9	**0.022**
Branches	0	0	0	0	0.2 ± 0.4	0.255
Cut stumps	0.6 ± 1.0	0	0.5 ± 0.7	0.4 ± 0.8	0.3 ± 0.7	0.913
Cut butts and branches	4.8 ± 11.4	0	0	1.9 ± 7.2	0	0.578
CWD by diameter						
⩽10 cm	1.2 ± 1.2	3.4 ± 1.8	4.1 ± 0.6	2.7 ± 1.8	2.4 ± 1.1	0.951
10–19 cm	6.8 ± 4.3	8.4 ± 6.8	7.2 ± 1.3	7.4 ± 4.6	11.9 ± 3.3	0.621
20–29 cm	19.4 ± 35.7	12.0 ± 24.2	4.3 ± 2.9	12.9 ± 25.8	28.0 ± 8.7	**0.000**
30–39 cm	17.8 ± 27.7	6.8 ± 11.9	4.6 ± 4.8	10.6 ± 18.9	18.3 ± 12.4	0.055
40–49 cm	12.0 ± 11.9	1.9 ± 2.3	1.2 ± 1.5	5.8 ± 9.0	6.0 ± 7.3	0.649
50–59 cm	1.2 ± 2.3	0.2 ± 0.3	0.9 ± 0.9	0.8 ± 1.5	0.1 ± 0.1	0.057
⩾60 cm	1.5 ± 3.7	0	0.1 ± 0.3	0.6 ± 2.3	0.5 ± 1.2	0.826
CWD by decay stage						
Hard, with fresh phloem	0	0	0.3 ± 0.3	0.1 ± 0.2	0.7 ± 1.4	0.379
Hard, no fresh phloem	10.6 ± 11.7	13.4 ± 19.0	10.4 ± 2.6	11.5 ± 12.5	17.4 ± 5.3	0.107
Partly decayed	16.1 ± 15.6	8.5 ± 9.4	6.3 ± 3.3	11.0 ± 11.6	26.3 ± 16.6	**0.035**
Soft throughout	21.1 ± 31.4	7.7 ± 6.5	4.3 ± 2.2	12.1 ± 20.6	17.0 ± 8.4	0.109
Covered by mosses, disintegrates	7.7 ± 15.7	2.8 ± 5.1	1.1 ± 0.9	4.3 ± 10.2	3.7 ± 2.5	0.356
Very hard, without bark (conifers)	4.4 ± 10.6	0.4 ± 1.0	0	1.9 ± 6.7	2.2 ± 3.0	0.356
CWD, total mean	59.9 ± 74.5	32.8 ± 40.5	22.4 ± 6.2	40.9 ± 52.3	67.2 ± 20.4	**0.039**

Statistics denote differences in the volumes between WKH means and control sites by Student's *t*-test.

coniferous CWD, but in the WKHs only about 25%. The importance of logs as a substrate was pronounced in the control areas, whereas the proportions of species growing on standing dead trees, snags and natural stumps were higher on the WKHs than in the control areas. In general, more species in the WKHs were growing on small-diameter CWD and in earlier decay stages than in the control areas, where the majority of species were found on mid-diameter CWD and mid-decay stages (Table 3).

The influence of the quality of CWD for species richness was detected by testing the differences in the mean numbers of species growing on different substrates. A significantly higher number of species was found on spruce CWD on the control plots than in the WKHs, and also on spruce CWD in small WKHs compared with the large ones (Fig. 2(a)). Higher species numbers on alder CWD were found in the middle and large size WKHs compared with the control areas (Fig. 2(a)). Of the other CWD qualities, significantly higher species numbers on the control plots were found on logs (Fig. 2(b)), in the diameter classes 10–39 cm (Fig. 2(c)) and in the decay stage 3 (Fig. 2(d)). When testing the number of species per CWD unit, a higher mean number per log was found on the spruce logs of control plots (mean 1.63 species) than on WKHs (1.22 species) (Mann–Whitney $U = 153.5$, $Z = -3.62$, $p = 0.00$), whereas no differences per substrate unit were found on alder CWD. A higher number of species per log on controls was also detected in the diameter class <20 cm ($U = 67.0$, $Z = -2.24$, $p = 0.025$) and in the mid-decay stage ($U = 80.0$, $Z = -2.22$, $p = 0.027$), but the difference in the diameter class >20 cm was not significant ($U = 128.0$, $Z = -1.82$, $p = 0.069$).

Three red-listed and nine old-growth forest indicator species were found in the study (Table 2). One of the red-listed species (*Antrodia mellita*) was recorded from a small WKH and two (*Antrodia sitchensis* and *Protomerulius caryae*) from the control plots. All nine old-growth forest indicators (57 records) were found in the

Table 2
Polypore (Basidiomycetes) species detected from the woodland key habitats (WKH) and the control sites (C)

Species	No. of records		Host CWD
	WKH	C	
Antrodia macra (Sommerf.) Niemelä	1	0	D
Antrodia mellita Niemelä & Penttilä * T	1	0	D
Antrodia serialis (Fr.) Donk	6	23	C
Antrodia sinuosa (Fr.) P. Karst.	1	4	C
Antrodia sitchensis (Baxter) Gilb. & Ryvarden * T	0	2	C
Antrodiella faginea Vampola & Pouzar	2	0	D
Antrodiella semisupina (Berk. & M.A. Curtis) Ryvarden	1	1	D
Bjerkandera adusta (Pers.: Fr.) P.Karst.	4	3	D
Byssoporia mollicula (Bourdot) Larsen & Zak	0	3	C
Ceriporia reticulata (H. Hoffm.: Fr.) Domański	4	0	D
Ceriporiopsis resinascens (Romell) Domański	1	0	D
Cerrena unicolor (Bull.: Fr.) Murrill	3	0	D
Datronia mollis (Sommerf.) Donk	8	0	D
Fomes fomentarius (L.: Fr.) Fr.	66	56	D
Fomitopsis pinicola (Sw.: Fr.) P. Karst.	66	65	B
Fomitopsis rosea (Alb. & Schwein.: Fr.) P. Karst. *I, NT	0	6	C
Ganoderma lipsiense (Batsch) G.F. Atk.	3	3	D
Gloeophyllum sepiarium (Wulfen: Fr.) P. Karst.	0	4	C
Gloeoporus dichrous (Fr.: Fr.) Bres.	0	1	D
Hapalopilus rutilans (Pers.: Fr.) P. Karst.	3	0	D
Hyphodontia radula (Pers.: Fr.) E. Langer & Vesterholt	1	0	D
Inonotus obliquus (Pers.: Fr.) Pilát	1	7	D
Inonotus radiatus (Sowerby:Fr.) P. Karst.	0	1	D
Ischnoderma benzoinum (Wahlenb.: Fr.) P. Karst.	1	2	C
Junghuhnia nitida (Pers.: Fr.) Ryvarden	1	0	D
Leptoporus mollis (Pers.: Fr.) Quél. *I	1	1	C
Oligoporus sericeomollis (Romell) Pouzar *I	0	2	C
Phellinus chrysoloma (Fr.) Donk *I	4	3	C
Phellinus ferrugineofuscus (P. Karst.) Bourdot *I, NT	0	9	C
Phellinus igniarius (L.: Fr.) Quél.	19	10	D
Phellinus laevigatus (P. Karsten) Bourdot & Galzin	0	3	D
Phellinus lundellii Niemelä*I	6	3	D
Phellinus nigrolimitatus (Romell) Bourdot & Galzin *I	2	14	C
Phellinus populicola Niemelä	0	1	D
Phellinus punctatus (P. Karst.) Pilát	1	0	D
Phellinus tremulae (Bondartsev) Bondartsev & Borisov	21	12	D
Phellinus viticola (Schwein. ex Fr.) Donk *I	3	18	C
Piptoporus betulinus (Bull.: Fr.) P. Karst.	8	9	D
Polyporus tubaeformis (P. Karst.) Ryvarden & Gilb.	2	0	D
Porpomyces mucidus (Pers.: Fr.) Jülich	1	1	B
Postia alni (Velen.) Niemelä & Vampola	6	0	D
Postia caesia (Schrad.: Fr.) P. Karst.	2	5	C
Postia fragilis (Fr.) Jülich	1	2	C
Postia stiptica (Pers.: Fr.) Jülich	1	0	C
Postia tephroleuca (Fr.) Jülich	0	1	C
Protomerulius caryae (Schwein.) Ryvarden * T	0	1	D
Pycnoporellus fulgens (Fr.) Donk *I	0	1	C
Rigidoporus corticola (Fr.) Pouzar	1	2	D
Skeletocutis biguttulata (Romell) Niemelä	1	0	C
Skeletocutis kuehneri A. David	1	0	C
Trametes hirsuta (Wulfen: Fr.) Pilät	1	0	D
Trametes ochracea (Pers.) Gilb. & Ryvarden	8	5	D
Trametes pubescens (Schumach.: Fr.) Pilät	1	1	D
Trametes velutina (Fr.) G. Cunn.	1	0	D
Trechispora hymenocystis (Berk. & Broome) K-H. Larsson	4	1	B
Trichaptum abietinum (Pers.: Fr.) Ryvarden	15	26	C

Species with asterisk are threatened species (T), near threatened (NT) or old-growth forest indicators (I). Host CWD (according to Niemelä, 2004): C = coniferous, D = deciduous, B = both coniferous and deciduous.

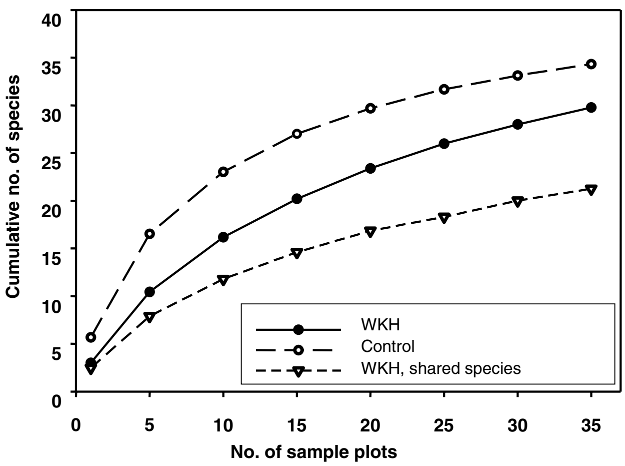

Fig. 1. The cumulative species number per study plot in the resampling data in woodland key habitats and control areas, and the cumulative number of shared species.

control areas, and four species (16 records) in the WKHs (Table 2). The combined species number of indicator and red-listed species, as well as their number of records, was significantly higher per control plot than per WKH plot (Fig. 3). On the contrary of expectations, the highest number of indicator and red-listed species per plot among WKHs was found in the small areas, and the lowest in the large areas (Fig. 3).

4. Discussion

The results show that herb-rich woodland key habitats in the Koli area were not hot-spots for polypore diversity. This supports earlier observations that the diversity of polyporous fungi is not connected with the fertility of the forest site type, but with the amount and quality of CWD (Sippola et al., 2004). Several

Table 3
Total numbers and proportions of polypore species and records for different categories of CWD in WKHs and old-growth forests (controls)

CWD category	Species				Records			
	WKHs		Controls		WKHs		Controls	
	Number	%	Number	%	Number	%	Number	%
Tree species								
Spruce	15	34.9	20	52.6	70	24.5	182	58.3
Pine	0	0	1	2.6	0	0	1	0.3
Birch	13	30.2	17	44.7	102	35.8	98	31.4
Aspen	12	27.9	9	23.7	37	13.0	24	7.7
Alder	18	41.9	4	10.5	63	22.1	7	2.3
Rowan	7	16.3	0	0	10	3.5	0	0
Bird cherry	1	2.3	0	0	1	0.4	0	0
Goat willow	2	4.7	0	0	2	0.7	0	0
CWD quality								
Logs	36	83.7	36	94.7	177	62.1	256	82.1
Standing dead trees	10	23.3	6	15.8	33	11.6	14	4.5
Snags	8	18.6	6	15.8	40	14.0	16	5.1
Natural stumps	12	27.9	6	15.8	27	9.5	15	4.8
Branches	3	7.0	3	7.9	6	2.1	11	3.5
Cut stumps	2	4.7	0	0	2	0.7	0	0
CWD diameter								
⩽10 cm	23	53.5	8	21.1	71	24.9	21	6.7
10–19 cm	20	46.5	27	71.1	95	33.3	91	29.2
20–29 cm	18	41.9	19	50.0	57	20.0	70	22.4
30–39 cm	14	32.6	27	71.1	42	14.7	100	32.1
40–49 cm	9	20.1	9	23.7	18	6.3	20	6.4
50–59 cm	1	2.3	5	13.2	1	0.4	8	2.6
⩾60 cm	1	2.3	2	5.3	1	0.4	2	0.6
Decay stage								
Hard, with fresh phloem	2	4.7	2	5.3	3	1.0	2	0.6
Hard, no fresh phloem	34	79.0	20	52.6	122	42.8	85	27.2
Partly decayed	25	58.1	28	73.7	90	31.6	158	50.6
Soft throughout	12	27.9	19	50.0	45	15.8	49	15.7
Covered by mosses, disintegrates	2	4.7	4	10.5	4	1.4	8	2.7
Very hard, without bark	0	0	1	2.6	0	0	1	0.3
Living trees	5	11.6	4	10.5	21	7.4	9	2.9
Total no. of species/records	43		38		285		312	

Note that the proportions of species do not sum up to 100% in different CWD categories, because the same species can grow on several different substrates.

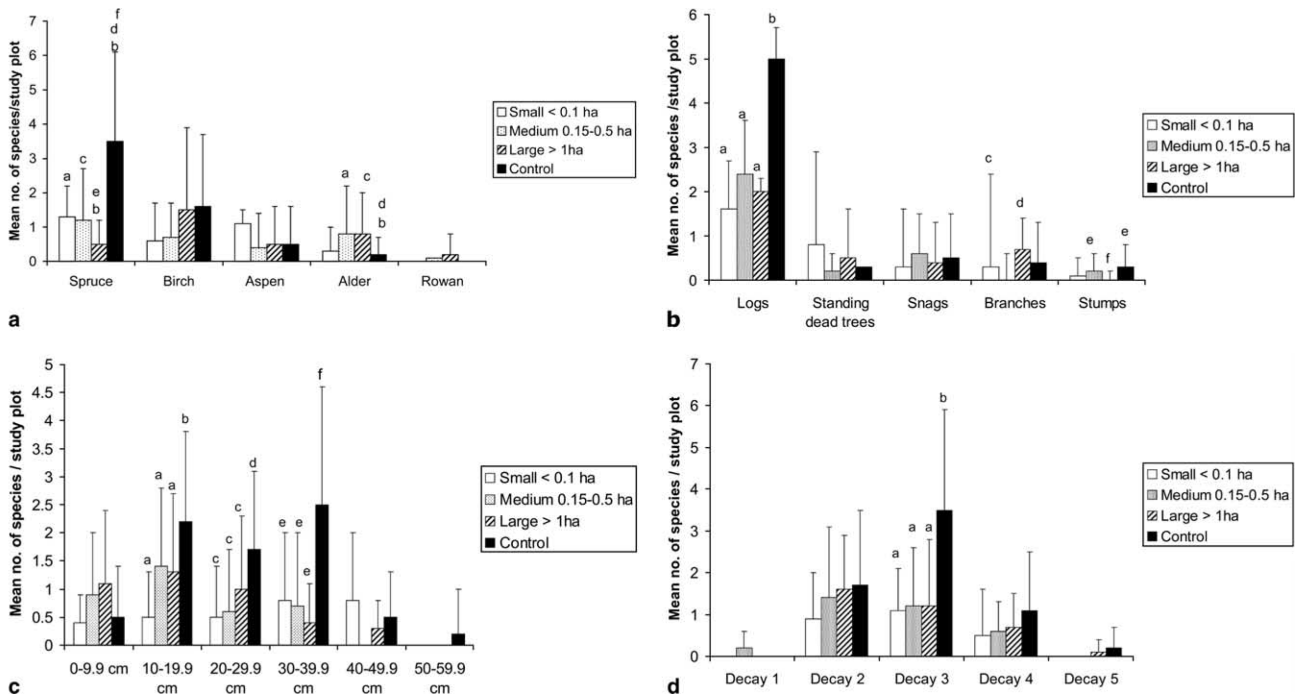

Fig. 2. (a) The mean numbers of species and records per study plot by tree species in different WKH size categories and control areas. Column pairs indicated by a–b, c–d and e–f denote significant differences in the numbers of species at the level $p < 0.05$ (Kruskall–Wallis non-parametric test). (b) The mean numbers of species and records per study plot by CWD quality in different WKH size categories and control areas. Column pairs indicated by a–b, c–d and e–f denote significant differences in the numbers of species at the level $p < 0.05$ (Kruskall–Wallis non-parametric test). (c) The mean numbers of species and records per study plot by diameter class in different WKH size categories and control areas. Column pairs indicated by a–b, c–d and e–f denote significant differences in the numbers of species at the level $p < 0.05$ (Kruskall–Wallis non-parametric test). (d) The mean numbers of species and records per study plot by decay stage in different WKH size categories and control areas. Column pairs indicated by a–b denote significant differences in the numbers of species at the level $p < 0.05$ (Kruskall–Wallis non-parametric test).

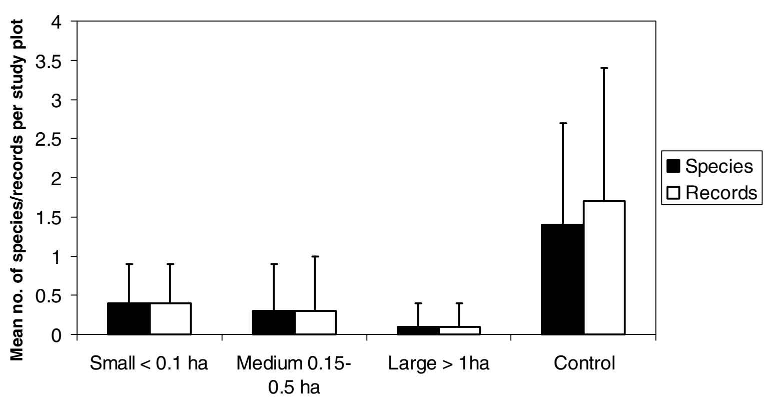

Fig. 3. The mean number of species and records of indicator and red-listed species per study plot in different size classes of WKHs and in control areas. Both the number of species and records on the control plots differ significantly from respective numbers on the WKH plots in all size classes (Mann–Whitney non-parametric test).

earlier studies show that co-variation between vascular plant and polypore species richenesess is weak, and the correlations in species richnesses vary according to the scale and region (Jonsson and Jonsell, 1999; Virolainen et al., 2000; Berglund and Jonsson, 2001; Similä et al., 2002; Siitonen et al., 2003; Sætersdal et al., 2003). For instance, Jonsson and Jonsell (1999) found a significant correlation between vascular plant and indicator polypore richness at the larger (1 ha) scale, but not at the small scale (0.25 ha). Sætersdal et al. (2003), on the contrary, found correlation between plants and polypores at the small (0.25 ha) hectare scale, but the correlation was weakest among the studied seven taxa. Varying correlations in the species richnesses among different taxa indicate that different species groups have different habitat and substrate requirements, and the species richnesses overlap either if the requirements of the studied taxa overlap, or if the diverse requirements of the studied taxa are fulfilled at the same sites.

According to our results several structural characteristics of forests influenced the diversity of polypores. Relatively small differences in the tree species composition affected remarkably the composition of polypore species. Many polypores are confined either to coniferous or deciduous CWD, and the differences in the tree species compositions are reflected in their species diversity (Sippola et al., 2004). In our study, the higher total volume of CWD on the control areas influenced the higher species number. However, because also the number of species per substrate unit were higher on spruce on the control plots, probably also some other factors affected the result (see below).

The differences in species richness were found in the number of species growing on spruce logs, on mid-diameter CWD and on CWD in mid-decay stage. The results are accordant with several earlier studies, where, besides of the volume, also the quality of CWD has been found to be crucial to the diversity of polypores (e.g., Bader et al., 1995; Renvall, 1995; Lindblad, 1998; Sippola and Renvall, 1999). The highest species richnesses of lignicolous fungi have been recorded on logs and on CWD in mid- and advanced decay stages (Bader et al., 1995; Renvall, 1995; Høiland and Bendiksen, 1997). Earlier studies also indicate that relatively small changes in the CWD quantity and quality may influence on the species diversity of polypores, as shown for instance in selectively logged areas by Bader et al. (1995) and Sippola et al. (2001). The higher number of species per spruce log on the control sites suggests that a high frequency of logs with appropriate decay stage promotes creation of a diverse polypore community within a CWD unit. This may be connected with the distribution ability of species: a high frequency of suitable substrate probably enhances the colonization of those spruce-confined species which are poor dispersers, whereas on the sites with lower frequency of spruce substrate, such as the WKHs in our study area, the distribution of poor dispersers is restricted. However, there may also be other factors, such as microclimate or competition, which affect the result.

Polypore assemblages of herb-rich WKHs did not represent the overall species composition of old-growth forests in the Koli area. In equal sample sizes, the proportion of shared species was about 55%, and in all data the similarity in species composition was less than 70%. Thus, based on this study, 30–45% of the species composition of old-growth forests would be lost, if only WKHs are set aside for protection.

The results indicate that the smaller the area, the more random is its importance for the protection of lignicolous fungi. In our data, an area of 0.2 ha hosted only about 20% of the total species richness found in the study, and an area of 0.5 ha about 40%. In reality, these proportions are still lower, because our sampling effort undoubtedly did not cover the whole polypore diversity of the spruce-dominated stands. The mean size of WKHs, even by definition, is relatively small (Meriluoto and Soininen, 2002). For instance in Finland, the mean size of WKHs left uncut in forestry operations during 1996–1999 was 0.35 ha in the state-owned forests, and 0.28 ha in the private forests (Hänninen, 2001). Our results suggest that the increase of the mean size to 0.5 ha would remarkably improve the overall protection of polypores, provided that the protected sites have high CWD content and quality.

It is not possible to make far-reaching conclusions on the importance of WKHs for red-listed polypores with these small data. The results indicate, however, that the protection of red-listed polypores in WKHs selected by vascular plant diversity is random. The occurrence of many near-threatened species and old-growth forest indicators, which have strongly declined in commercial forests, was concentrated in the control areas with large volume of spruce logs in mid-decay stage. This is consistent with the results of Berg et al. (2002), who found, when analyzing the habitat preferences of red-listed fungi and bryophytes in WKHs, that woody substrates (mainly logs, snags and old and large trees) were the most important variables which explained the occurrence of red-listed species. However, some small WKHs, which contained relatively large volumes of large-diameter spruce logs, hosted larger numbers of indicator species than medium or large-size WKHs, showing that even small-size sites may be important for the protection of rare polypores, provided that the CWD quality is appropriate for them. Nevertheless, our study is not providing an answer whether the occurrences of rare or red-listed species will survive in small-size WKHs surrounded by altered environments such as clear-cuts, because our study sites were located in undisturbed areas, where the WKHs surrounded by closed forest. The results emphasize the importance to protect, in addition to WKHs, typical old-growth forest patches with large volumes of coniferous CWD in boreal zone. Further studies are needed to detect whether the results apply to WKHs in other regions.

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