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Wood-decay fungi in hazel wood: species richness correlated to stand age and dead wood features

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Abstract

The correlation between species richness of wood-decay fungi, stand age and dead wood features was investigated in eight hazel stands in south-east Sweden. Sampling of fruit-bodies was performed on fallen decomposing hazel stems and a total of 140 species were found, 60 ascomycetes (pyrenomycetes) and 80 basidiomycetes (Aphyllophorales). Total species richness correlated negatively with the age of stands, contrary to results in studies of other forest types. The reason for this is not known, but the possibility of competitive exclusion in old stands is discussed. In sites with a higher concentration of dead wood the number of species per stem was lower. The numbers of Red List species/indicator species were not correlated to stand age or wood decay. We suggest that old age of stands should be used with care as an evaluation criterion for hazel stands important for the protection of fungal biodiversity. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Wood-decay fungi; Species richness; Woody debris; Stand age; *Corylus avellana*

1. Introduction

Dead wood is important for biodiversity in forested ecosystems because it contains many microhabitats for different organisms (Harmon et al., 1986; Samuelsson et al., 1994). Of the many different organism groups dependent on woody debris, wood-decay fungi is one of the most prominent. Wood-decay fungi have key-roles in the ecology of nemoral and boreal forests since they are the major agents of wood decomposition and nutrient cycling (Cromack and Caldwell, 1992). Forestry practices drastically decrease the amount of woody debris in forests (Östlund, 1993; Fridman and Walheim, 2000), and thereby threatens biodiversity.

Several studies of the ecology and conservation of wood-decay fungi have focused on effects of forestry practices in the taiga biome. In these studies, the age of forest stands and large amounts of coarse woody debris are reported to be important variables for a rich wood-decay fungal flora (Bader et al., 1995; Renvall, 1995; Høiland and Bendiksen, 1997; Stokland et al., 1997; Lindblad, 1998). Species richness is also reported to increase with progressive wood decay (Renvall, 1995; Høiland and Bendiksen, 1997). Indicator species (Skogsstyrelsen, 1995) and species on the Swedish Red List for fungi (Larsson, 1997) are often claimed to be particularly sensitive to disturbance, to benefit from late successions and to indicate old-growth characteristics. For instance, Nitare and Norén (1992) stated that "threatened species often co-occur in valuable stands with long forest continuity and a good supply of substrate".

Little is known about how wood-decay fungi react to changes in habitat variables in different deciduous forest types. The wood-associated fungal flora in stands of hazel has been little studied, but is known to be species-rich and to contain many ascomycetes (Nordén et al., 1997) as well as many basidiomycetes. In this study we describe the fungal flora in terms of fruit bodies on fallen wood of hazel *Corylus avellana* L., and test if species richness is correlated with differences in stand age and amount and quality of woody debris. The working hypothesis is that older stands and a large amount of fallen hazel wood affect species richness and number of Red List and indicator species positively. The question of how to preserve and manage fungal biodiversity in this habitat is also addressed.

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2. Methods

Eight hazel stands with different ages and amounts of woody debris were selected among several hazel stands studied by Råberg et al. (1998). The stands are situated in a matrix of deciduous forest, farmland and mires on the island of Öland, south-east Sweden, and have probably arisen on abandoned pasture land. The area, which is called the Mittlandskogen forest, belongs to the temperate mixed forest region (Raven et al., 1992). Typical plants in the ground vegetation are *Hepatica nobilis*, *Sanicula europaea*, *Brachypodium sylvaticum* and *Carex sylvatica*. The bedrock consists of limestone which is covered by a thin layer of calcareous soil. The mean temperature varies between −1°C in January and 15°C in July and the mean annual precipitation is 500 mm/year (Raab and Vedin, 1995). The selected stand areas range from 0.5 to 14 ha and distances between stands vary between 0.8 and 18 km.

The frequency of lying dead hazel stems was measured in three random 10 m^2 squares per stand. Only stems thicker than 3 cm were counted and measured. The decay class was recorded for each stem with a method modified after Renvall (1995), using the following three decay classes: (1) wood hard, knife penetrates max. 2 mm by force of hand; (2) wood penetrability intermediate, knife penetrates easily 2–20 mm by force of hand, and (3) wood soft, knife penetrates easily through the whole stem. If a stem was unevenly decayed, the knife was inserted in the two ends and the middle of the stem, and the mean decay class for the whole stem was noted. Each stand was surveyed for the largest hazel stool and its diameter was used as a relative measure of the age of the stands. According to investigations by Håkan Slotte (personal communication) and Oliver Rackham (personal communication) hazel stool genets can reach several hundred years in age, stools with a diameter of 1 m being about 100 years old, and stools with a diameter of 2 m being more than 200 years old. No old maps or archival data of hazel occurrence in the area were available. Stool diameter could potentially be a function of soil fertility as well as of age. Therefore, we tested if stool diameter was correlated to mean stem diameter, stand height (Råberg et al., 1998), amount of dead wood or decay class, but the result was negative. Mean stem diameter was estimated from 20 stems in five randomly selected 5×5 m squares in each stand. For each stand the occurrence of fruitbodies of Aphyllophorales including resupinate Tremellales, and Pyrenomycetes were registered. Seventy-five metres of fallen hazel stems with a stem width greater than 3 cm were randomly sampled in each stand. Sampling was conducted between 4 and 10 November 1996.

Correlations between species richness, stand age and dead wood features were tested, as well as the correlation between the number of wood-decay Red List/indicator species and the number of Red List ground floor macrofungi (Råberg et al., 1998) found in the same stands. The variables did not have equal variances, and the correlations were tested with the non-parametric Spearman Rank Correlation (Daniel, 1995). The nomenclature follows Eriksson (1992) for pyrenomycetes and Hansen and Knudsen (1997) for basidiomycetes.

3. Results

A total of 140 species of wood-decay fungi were found (Appendix A), of which 60 were pyrenomycetes and 80 basidiomycetes (67 corticioid species and 13 polypore species). The number of species varied from 36 (Site 4) to 58 (Site 8). Seventeen pyrenomycetes were new to Sweden compared to Eriksson's findings (1992). Ten other pyrenomycete species were not found in the literature and may be undescribed species. Five Red List species and three indicator species were found. Sixty species were found at only one study site and 46 species were found at three study sites. Only five species were found at all eight study sites: the pyrenomycetes *Nemania serpens*, *Hypoxylon fuscum* and *Chaetosphaeria myriocarpa* and the basidiomycetes *Postia subcaesia* and *Trechispora confinis*. Species accumulation curves indicate that 70-90% of all species present on hazel wood in the whole forest during the sampling period were encountered (Fig. 1).

Data on habitat characteristics of all stands are given in Table 1. The number and thickness of stems varied greatly between stands as did the size of the largest stools.

Fig. 2 shows relationships between structural variables and species richness. Total species richness was

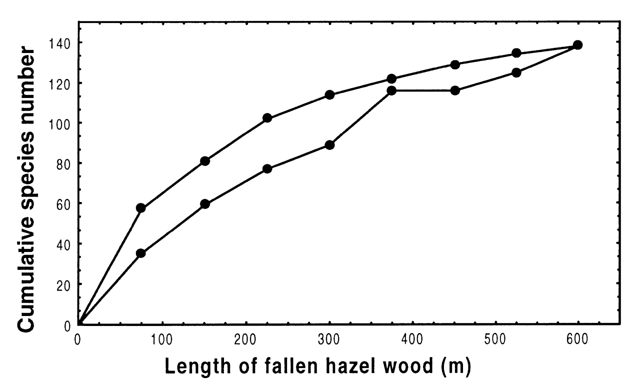

Fig. 1. Species accumulation curves for wood-decay fungi on hazel wood. The curves are based on the number of species on 75 m lying dead hazel wood in eight stands. For the upper curve the species richest stand was added first and the species poorest last. The lower line shows the opposite, i.e. the species poorest stand is added first and the species richest last. The slopes of the curves indicate that 70–90% of all species present on hazel in the whole forest during the sampling period were encountered.

Table 1
Maximun stool diameter and dead wood features in eight hazel stands on the island Öland, southeast Sweden

Site	Site No.	Max. stool diameter (m)	Mean stem diameter (cm±S.E.)	Wood frequency (number/100 m^2±S.E.)	Total wood length (m/100 m^2±S.E.)	Wood-decay class 1 (m/75 m)	Wood-decay class 3 (m/75 m)
Törnbotten	1	1.45	4.2±0.1	37.7±2.8	6.4±1.7	40.8	15.0
N. Gråborg	2	1.40	5.2±0.2	17.3±2.7	11.5±2.6	33.7	13.6
S. Gråborg	3	1.50	5.2±0.2	20.5±4.7	28.0±8.1	40.2	8.5
N. Bäck	4	0.80	4.9±0.1	21.0±8.8	5.7±1.3	38.9	13.2
Vanserum	5	1.40	5.2±0.2	22.0±2.2	20.2±4.6	47.4	10.0
Kritmossen	6	1.90	4.0±0.1	22.0±5.7	9.5±3.2	56.8	6.4
Åstad	7	1.48	3.7±0.1	46.7±11.6	14.8±2.9	33.9	14.6
Gärdslösa	8	2.00	5.4±0.2	17.7±5.0	33.0±0.6	38.6	11.7

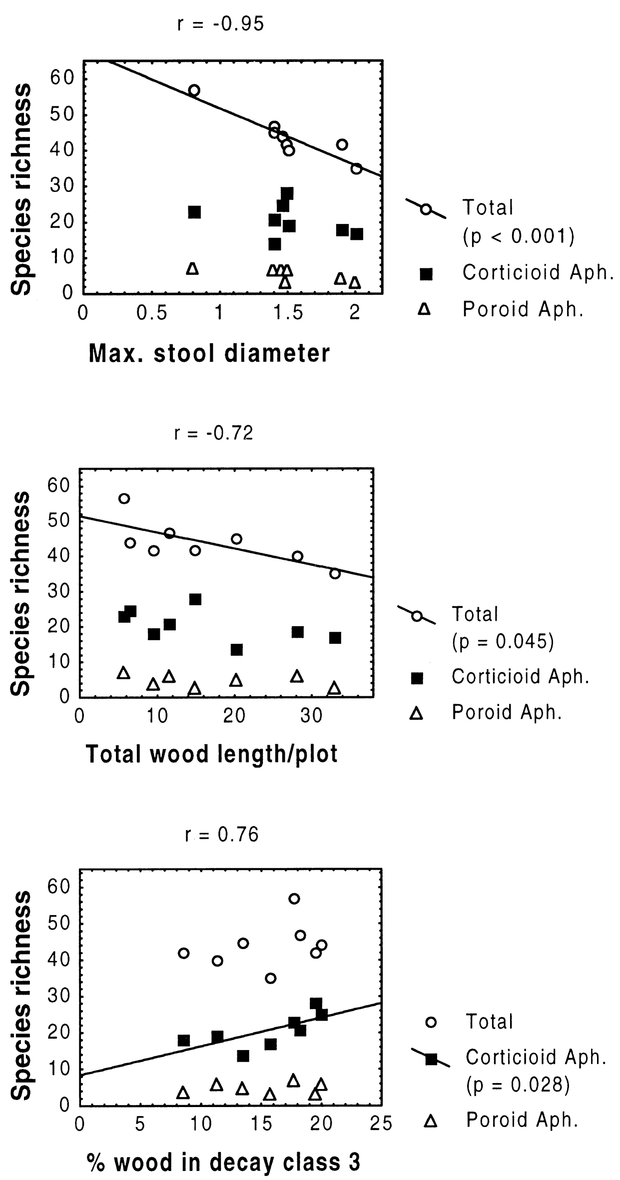

Fig. 2. Relationships between species richness of wood-decay fungi on hazel and stand age, total length of fallen hazel wood per stand and proportion highly decayed wood (Spearmann Rank correlation).

highest in young hazel stands ($r=-0.95$, $n=8$, $P<0.001$) and in stands with a low concentration of woody debris ($r=-0.72$, $n=8$, $P=0.045$). After these results were obtained, the number of cord-forming species was tested against stand age, but no such trend was found. Total species richness showed an increasing trend with increasing percentage of well-decayed wood in the stands, but the increase was only significant for corticioid Aphyllophorales ($r=0.76$, $n=8$, $P=0.028$).

The number of wood-decay Red List/indicator species correlated positively with the number of Red List ground floor macrofungi found in the same sites by Råberg et al. (1998; $r=0.73$, $n=8$, $P=0.038$; Fig. 3), but did not correlate with stand age or amount of woody debris.

4. Discussion

Total species richness was strongly negatively correlated to the age of stands, contrary to results in studies of other forest types. The reason for this is not known,

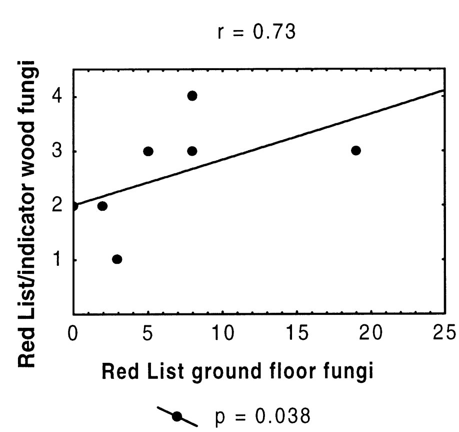

Fig. 3. Relationship between the number of Red List/indicator species of wood-living fungi on hazel wood and the number of Red List ground floor macrofungi found in an inventory made by Råberg et al. (1998) (Spearmann Rank correlation).

but one possibility could be increased competition in old stands due to mycelial spread of competitive non-unit-restricted fungi. Disturbances may act on communities to prevent competitive exclusion (Palmer, 1994), giving ruderal species better chances of finding patches free from competitors (Lei and Hanski, 1998).

In disturbed areas, such as burned forests, ruderal wood-decay fungi have been observed to increase in number, while competitive species decrease (Penttilä and Kotiranta, 1996). Individuals of some wood-decay basidiomycetes, e.g. species of the corticioid genus *Phanaerochaete*, are not restricted to single resource units but can extend across the forest floor via mycelial cords. These individuals cover large expanses of ground, are capable of quick colonisation of fallen wood, and are often highly competitive (Thompson, 1984; Boddy, 1993, 1999). However, no increasing trend in the number of cord-forming species, as judged from presence of basidiomata, could be seen. This could either indicate that some other factor was responsible for the reduction in species richness, or could have to do with the sampling technique.

Judging species presences from the presence of fruit-bodies will lead to an underestimation of the number of species, since species may be present as active mycelia in wood and litter but not produce basidiomata. Strongly competitive species may be suspected to produce basidiomata less often than ruderal species (Dix and Webster, 1995), and are therefore likely to be overlooked. To be able to test the hypothesis that non-unit-restricted fungi increase with stand age, identification of sterile mycelia in wood and litter should be performed.

In stands with high concentrations of dead wood, the sampled wood covered a larger area of the forest floor. The negative correlation between species richness per metre and concentration of dead wood may be due to the fact that less concentrated dead wood covers a greater variation of microclimates and edaphic conditions.

Total species richness showed an increasing trend with wood decay, but the increase was only significant for corticioid basidiomycetes. Corticioid species are common at all decay stages, but at the same time some instances are known where the corticioid flora is very species rich in strongly decayed wood (Renvall, 1995; Nordén et al., 2000). Strongly decayed wood have high water-holding capacity (Boddy, 1986), which may possibly favour corticioid species with thin and soft, and presumably desiccation sensitive, fruit bodies.

The conclusions drawn here are of course dependent on the sample properly representing the species occurring in the area. Judging from Fig.1, most species present in the area during the sampling period were found, but considering the sporadic fructification of many fungi it must be remembered that the sampling was performed over a short period of time and that species fructifying earlier or later in the season were overlooked.

To conclude, it appears that results from research on other forest types, such as coniferous forests, should not be applied uncritically to the management of fungal biodiversity in hazel stands. Differences in natural disturbance regimes of forest types, and species composition and life history strategies of fungi, probably mean that management for biodiversity needs to differ between different forest types. The presence of a higher number of species in younger stands and the lack of correlation between Red List/indicator species and stand age indicates that hazel stands at relatively early stages of succession may be just as important as old ones for biodiversity of wood-decay fungi. These therefore need to be created repeatedly in the landscape, perhaps at intervals in accordance with a traditional coppice management regime. In addition, the correlation between the numbers of Red List/indicator species of wood-decay and ground-floor fungi indicates that there may be other factors defining the 'hotspots' for fungi in hazel stands than those measured in this study.

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Appendix A. List of recorded species

Species name (R, Red List species; I, Indicator species; N, New to Sweden	Number of records in different decay classes			Number of records (stands)
	1	2	3	
Ascomycetes				
Bertia moriformis (Tode: Fr.)De Not.	3	3	0	5
Camarops lutea (Alb. & Schw.: Fr.) R	0	1	0	1
Capronia chlorospora (Ellis & Everh.)Barr N	1	0	0	1
Capronia pilosella (Karsten)E. Müller et al.	4	6	4	6
Capronia cf. pulcherrima (Munk)E. Müller et al.	1	1	2	3
Capronia sp.	0	1	0	1
Ceratosphaeria subferruginea (Fuckel)Munk	0	0	1	1
Ceratostomella ampullasca (Cooke)Sacc. N	2	0	4	5
Ceratostomella investita (Schwein.)Starb. N	1	0	0	1
Ceratosphaeria rhenana (Auersw.)Winter	0	0	2	2
Chaetosphaeria inaequalis (Grove ex Berl. &Vogl.)W. Gams & Hol.-Jech. N	0	0	1	1
Chaetosphaeria myriocarpa (Fr.: Fr.)Booth	5	7	6	8
Chaetosphaeria cf. pulviscula (Currey)Booth	2	0	0	2
Coniochaeta pulveracea (Ehrh.: Fr.)Munk	0	1	0	1
Creopus gelatinosus (Tode: Fr.)Link	1	1	0	2
Diatrypella verruciformis (Ehrh.: Fr.)Nitschke	1	0	0	1
Endoxyla cirrhosa (Pers.: Fr)Arx & E. Müller	0	0	1	1
Eutypa sp.	1	0	0	1
Gloniopsis curvata (Fr.)Sacc.	1	1	0	2
Helminthosphaeria odontiae Höhnel N	4	3	0	5
Helminthosphaeria corticiorum Höhnel N	2	2	1	2
Helminthosphaeria hyphodermiae Samuels, Candoussau & Magni N	1	0	0	1
Helminthosphaeria sp.	0	2	4	4
Hypocrea citrina (Pers.: Fr.)Fr.	0	1	0	1
Hypoxylon fuscum (Pers.: Fr.)Fr.	8	7	8	8
Hypoxylon rubiginosum (Pers.: Fr.)Fr.	2	1	0	3
Hypoxylon udum (Pers.: Fr.)Fr.	1	2	1	3
Hysterium pulicare Pers.: Fr.	0	0	1	1
Kirschteiniothelia aethiops (Berk. & Curtis)D. Hawksw.	2	1	0	3
Lasiosphaeria canescens (Pers.: Fr.)Karsten	3	0	0	3
Lasiosphaeria strigosa (Alb. & Schw.: Fr.)Sacc.	1	0	1	1
Lentomita hirsutula Bres. N	0	2	1	2
Linostomella sphaerosperma (Fuckel)Petrak N	0	1	0	1
Lophiotrema boreale Mathiassen	1	0	0	1
Melanomma pulvis-pyrius (Pers.: Fr.)Fuckel	4	1	0	5
Nemania sp. A Granmo, Laessøe & T. Schumach. N	0	1	0	1
Nemania prava Granmo, Laessøe & T. Schumach. N	3	4	4	6
Nemania serpens (Pers.: Fr.)Gray	2	6	5	8
Neorehmia aurea (v. Hoehn.)Munk N	1	0	0	1
Neorehmia ceratophora v. Hoehn. N	1	0	0	1
Porosphaerella cordanophora Müller & Samuels N	0	0	1	1
Pseudotrichia mutabilis (Pers.Fr.)Wehm.	1	0	0	1
Sillia ferruginea (Pers.: Fr.)Karsten	5	1	0	6
Trichosphaerella decipiens Bomm., Rouss. & Sacc. N	2	0	0	2
Trichosphaeria cf. melanostigmoides (Feltgen)Munk N	0	1	0	1
Trichosphaeria notabilis Mouton N	2	4	3	6
Tubeufia cf. cerea (Berk. & Curtis)Höhnel	3	0	0	3
Xylaria hypoxylon (L.: Fr.)Grev.	3	0	0	3
Zignoëlla cf. fallax Sacc.	0	3	2	4
Zignoëlla sp.	0	1	0	1
Species 1	0	2	0	2
Species 2	0	1	0	1
Species 3	1	0	0	1
Species 4	1	0	0	1
Species 5	0	1	1	2
Species 6	0	0	2	2
Species 7	0	1	0	1
Species 8	1	1	1	1
Species 9	0	1	0	1

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Appendix A. (*continued*)

Species name (R, Red List species; I, Indicator species; N, New to Sweden	Number of records in different decay classes			Number of records (stands)
	1	2	3	
Species 10	0	0	1	1
Basidiomycetes				
Amphinema byssoides (Pers.: Fr.)J. Erikss.	3	1	3	3
Antrodiella americana Ryvarden & Gilb.	2	0	2	4
Antrodiella onychoides (Egeland)Niemelä	1	0	0	1
Antrodiella emisupina (Berk. & M.A. Curtis)Ryvarden	2	0	0	2
Athelia arachnoidea (Berk.)Jülich	1	0	0	1
Athelia epiphylla Pers. : Fr.	5	3	3	6
Athelopsis glaucina (Bourdot & Galzin)Parmasto	0	2	0	2
Basidiodendron caesiocinereum (Höhn. & Litsch.)Luck-Allen	1	1	2	2
Botryobasidium laeve (J. Erikss.)Parmasto	1	0	0	1
Botryobasidium botryosum (Bres.)J. Erikss.	1	0	0	1
Brevicellicium olivascens (Bres.)K.-H. Larss. & Hjortstam	0	2	0	2
Ceraceomyces serpens (Tode: Fr.)Ginns	6	4	3	6
Ceriporia reticulata (Hoffm.: Fr.)Domanski	2	1	1	4
Cristinia gallica (Pilát)Jülich R	1	0	0	1
Cristinia helvetica (Pers.)Parmasto	3	4	4	6
Dichomitus campestris (Quél.)Domanski & Orlicz I	1	5	1	6
Eichleriella deglubens (Berk. & Broome)D.A. Reid	5	1	0	5
Fomes fomentarius (L.: Fr.)Fr.	1	0	0	1
Fomitiporia punctata (P. Karst.)Pilát	1	3	1	3
Galzinia incrustans (Höhn. & Litsch.)Parmasto	1	0	0	1
Gloeocystidiellum porosum (Berk. & M.A. Curtis)Donk	1	1	0	2
Gloeoporus dichrous (Fr.: Fr.)Bres.	0	1	0	1
Hymenochaete fuliginosa (Pers.)Bres. R	3	1	1	3
Hymenochaete cinnamomea (Fr.)Bres.	4	4	1	6
Hymenochaete tabacina (Fr.)Lév.	1	1	0	2
Hyphoderma cf. cremeoalbum (Höhn. & Litsch.)Jülich	1	0	0	1
Hyphoderma pallidum (Bres.)Donk	0	1	0	1
Hyphoderma praetermissum (P. Karst.)J. Erikss. & Å. Strid	1	2	0	2
Hyphoderma puberum (Fr.)Wallr.	0	2	0	2
Hyphodontia aspera (Fr.)J. Erikss.	3	3	2	6
Hyphodontia crustosa (Pers.: Fr.)J. Erikss.	4	2	0	6
Hyphodontia paradoxa (Schrad: Fr.)E. Langer & Vesterholt	0	0	1	1
Hyphodontia pruni (Lasch)J. Erikss. & Hjortstam	2	3	1	5
Hyphodontia quercina (Pers.: Fr.)J. Erikss.	1	0	0	1
Hyphodontia rimosissima (Peck)Gilb.	1	1	1	1
Hyphodontia subalutacea (P. Karst.)J. Erikss.	2	1	1	3
Hypochnicium geogenium (Bres.)J. Erikss.	0	0	1	1
Inonotus radiatus (Sowerby: Fr.)P. Karst.	2	0	0	2
Kavinia himantia (Schwein.: Fr.)J. Erikss. R	1	0	0	1
Peniophora cinerea (Pers.: Fr.)Cooke	2	2	0	3
Phanerochaete sordida (P. Karst.)J. Erikss. & Ryvarden	2	1	0	2
Phanerochaete velutina (DC: Fr.)P. Karst.	2	0	3	4
Phlebia lilascens (Bourdot)J. Erikss. & Hjortstam	0	0	1	1
Phlebiella sulphurea (Pers.: Fr.)Ginns & Lefebvre	2	1	0	2
Phlebiella tulasnelloidea (Höhn. & Litsch.)Oberw.	2	2	2	4
Piloderma byssinum (P. Karst.)Jülich	1	1	1	1
Piloderma lanatum var. bisporum (Parmasto)J. Erikss. & Hjortstam	1	1	0	2
Plicatura crispa (Pers.: Fr.)Rea I	2	0	0	2
Postia subcaesia (David)Jülich	7	4	1	8
Radulomyces confluens (Fr.: Fr.)M.P. Christ.	2	0	1	3
Resinicium bicolor (Alb. & Schwein.: Fr.)Parmasto	0	0	1	1
Scopuloides rimosa (Cooke)Jülich	5	4	2	6
Sistotrema biggsiae Hallenb.	1	1	0	2
Sistotrema brinkmannii (Bres.)J. Erikss.	3	1	0	4
Sistotrema oblongisporum M.P. Christ. & Hauerslev	1	0	0	1
Sistotremastrum niveocremeum (Höhn & Litsch.)J. Erikss.	0	1	0	1
Skeletocutis nivea (Jungh.)Keller R, I	4	4	0	6
Steccherinum fimbriatum (Pers.: Fr.)J. Erikss.	2	1	2	4

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Appendix A. (*continued*)

Species name (R, Red List species; I, Indicator species; N, New to Sweden	Number of records in different decay classes			Number of records (stands)
	1	2	3	
Steccherinum ochraceum (Fr.)Gray	1	2	0	3
Steccherinum separabilimum (Pouzar)Vesterholt	1	1	0	1
Stereum hirsutum (Willd.: Fr.)Gray	1	0	0	1
Thanatephorus fusisporus (J. Schroet.)P. Roberts & Hauerslev	2	1	1	3
Tomentella bryophila (Pers.)M.J. Larsen	4	2	3	6
Tomentella cinerascens (P. Karst.)Höhn. & Litsch.	0	0	1	1
Tomentella fibrosa (Berk. & M.A. Curtis)Kõljalg	0	0	1	1
Tomentella lateritia Pat.	0	0	1	1
Tomentella lilacinogrisea Wakef.	0	1	0	1
Tomentella punicea (Alb. & Schwein)J. Schröt	1	0	0	1
Tomentella radiosa (P. Karst.)Rick	0	0	1	1
Tomentella sublilacina (Ellis & Holw.)Wakef.	1	3	1	3
Tomentella viridula Bourdot & Galzin	0	1	0	1
Tomentellopsis echinospora (Ellis)Hjortstam	1	0	1	2
Trechispora confinis (Bourd. & Galz.)Liberta	6	5	4	8
Trechispora farinacea (Pers.: Fr.)Liberta	0	2	1	2
Trechispora mollusca (Pers.: Fr.)Liberta	1	3	4	5
Trechispora nivea (Pers.)K.-H. Larss.	0	0	2	2
Trechispora stellulata (Bourdot & Galzin)Liberta	1	0	0	1
Trechispora stevensoni (Berk. & Broome)K.-H. Larss.	1	1	1	2
Vesiculomyces citrinus (Pers.)Hagström	2	0	1	2
Vuilleminia coryli Boidin, Lanquetin & Gilles	1	1	0	2

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