Nothing else matters? A nationwide study of microhabitats drivers at the tree scale

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Abstract

Managing forest structure to preserve biodiversity requires a good knowledge of the elements that actually support biodiversity as well as the driving factors of their dynamics. Tree-related microhabitats (cavities, cracks, conks of fungi) are tree-borne features that are reputed to support specific biodiversity, linked to microhabitats for at least a part of their life cycle. While several studies have analysed the drivers of microhabitats number and occurrence at the tree scale, they remain limited to a few tree species located in relatively narrow biogeographical range. Here, we used a nationwide database of forest natural reserves comprising more than 22000 trees where microhabitats have been inventoried since 2005. We analysed the effect of tree diameter and live status (alive or dead) on microhabitat number and occurrence per tree, taking into account biogeoclimatic variables and tree genus.

We confirmed that larger trees as well as dead trees bore more microhabitats than their smaller or alive counterparts, and extended these results to a wider range of tree genus and conditions. Contrary to expectations, these relationships varied neither much with tree genus, with slightly higher accumulation levels for broadleaves than for conifers, nor with biogeographical context. We observed these results both for the total number of microhabitats per tree and for the occurrence of individual microhabitat types. However they were more marked for microhabitats linked with wood decay processes (e.g. dead branches or woodpecker feeding holes) than for other, epixylic, microhabitats such as epiphytes (ivy, mosses and lichens).

Promoting large living and dead trees of several tree species seems a good and quite universal way to promote microhabitats and enhance potential substrates to support specific biodiversity. In addition, a better understanding of the drivers of microhabitats at the tree scale may help to better define them as biodiversity indicators for large scale monitoring.

Introduction

Small natural features are defined as structural habitat elements that have a disproportionate role for biodiversity regarding their actual size [1]. Taking them into account in biodiversity conservation appears as a new frontier in terms of science-based decision making [2]. In forests, delineating such elements is quite challenging since the number and variety of candidate structural features in a tri-dimensional environment is potentially infinite. Small natural features encompass for example large old trees [3] as well as tree-born structures. While large old trees are disappearing at the large scale [4], their importance for biodiversity remains partially unknown, not to speak of the peculiarities they are susceptible to bear (ie. cracks, cavities, epiphytes) that are also known as 'tree-related microhabitats' (hereafter 'microhabitats', [5]). Microhabitats have recently met the interests of scientists and forest managers since they can serve as a substrate for a specific part of forest biodiversity [5,6] and ultimately as forest biodiversity indicators [5,7]. Their conservation in daily forest management has hence become an issue, just like large old trees and deadwood [8,9]. However, our understanding of their dynamics and driving factors, notably at the tree scale, remains incomplete [10]. Tree diameter and live status (alive vs. dead trees) have been shown as key factors for microhabitat presence and number at the tree scale [11-13]: larger trees are likely to bear more microhabitats than smaller trees, as they have experienced more damages and microhabitats-creating events (e.g. woodpecker excavation, storms, snowfalls); similarly, dead trees are likely to bear more microhabitats than living trees, relatively to the decomposition process and their role as habitat and food source for many microhabitat-creating species [14]. The relationships between microhabitats and tree characteristics have nevertheless been demonstrated on a limited number of tree species involving only a maximum of a few thousand observations at the tree level (e.g. [10-12]), and within a limited biogeographical range (see case studies in Mediterranean forests [15], the French Pyrénées [11] or in Germany [16,17]). As a consequence, the question still remains whether the observed relationships between tree characteristics and microhabitats are idiosyncratic or not. Large databases allowing such analysis at a larger scale are currently rare (but see [18]) due mainly to a lack of homogeneity

in the typologies used to inventory microhabitats [5], but also to the scarcity of forest monitoring initiatives that actually inventory microhabitats. Such sources of information are crucial to better understand the potential variations of these relationships with biotic (e.g. tree species) or abiotic (e.g climatic) factors. Since microhabitats are on the potential biodiversity indicator list [7,16,19], it is also important to better understand the factors of influence at various scales, including the tree scale.

In this context, we benefited from a nationwide database issued of forest monitoring in nature reserves, where microhabitats have been inventoried since 2005. Based on this, we analysed the influence of individual tree diameter and living status on the number and presence of microhabitats at the tree level. We expected the number and occurrence of microhabitats per tree to increase with diameter and to be higher on dead than living trees. We assessed the influence of tree species as well as the influence of aggregated biogeoclimatic variables on these relationships, expecting that the microhabitat dynamics (or accumulation rate per tree) would be tree-species dependent and vary with abiotic context. Ultimately, the aim of this study was to provide forest managers with a better – science-based – understanding of the forest ecosystem with a special focus on microhabitats, allowing them to adapt their management to their specific context.

Materials and methods

Database structure

We worked with a nationwide database issued of the monitoring program in French forest reserves. Since 2005, a systematic permanent plot network has been gradually set-up on a voluntary basis in several forest reserves. The main aim was to provide managers with quantitative data on the fluxes of living and dead trees at the site scale, and ultimately delineate guidelines for management plans establishment. The full database currently comprises 107 reserves for a total of 8190 plots (83180 living and 19615 dead trees, snags and stumps).

Forest management in the reserves varies from total abandonment (strict forest reserves) to active management aimed at preserving specific biodiversity (special forest reserves). However, no homogeneous data could be gathered at the plot level for all the reserves in the database. In addition, Vuidot et al. [12] shown that management had a limited effect on microhabitats number and occurrence at the tree level. For these two reasons, we assume that management differences do not play a significant role at the tree scale and did not take into account this source of variation in the analyses (see below).

Stand structure and microhabitat inventories

On each plot, forest stand structure was characterised using a combination of two sampling methods [20]. For all living trees with a diameter at breast height (DBH) higher than 30 cm, we used a fixed angle plot method to select the individuals comprised within a fixed relascopic angle of 3%. Practically, this meant that the sampling distance is proportional to the apparent DBH of a tree: for example, a tree with a DBH of 60 cm was included in the sample if it was comprised within a maximum distance of 20 m from the centre of the plot. This particular technique allows large trees to be more precisely estimated at a small scale. All other variables were measured on fixed-area plots. Within a fixed 10 m (314m2) radius around the plot centre, we measured (i) the diameter of all living trees from 7.5 to 30 cm DBH in lowlands and (ii) snags (standing dead trees with height > 1.30 m, to the exclusion of stumps below this height) with a diameter ≤ 30 cm. Within a 20 m radius (1256 m2), we recorded the diameter of snags with a diameter > 30 cm. All trees, either alive or dead, were determined to species level whenever possible. In the following, tree species were grouped at the genus level to have sufficient representation in terms of tree numbers (namely: Ash, Beech, Chestnut, Fir, Hornbeam, Larch, Maple, Oak, Pine, Poplar and Spruce). By this, we assumed that tree genus, rather than species, did influence the relationships we studied. Undetermined tree species or genus were excluded.

All standing trees selected were visually inspected for microhabitats and the presence of microhabitat was recorded on each tree. Observers were provided with a field guide including pictures for better determination of microhabitats and detailing the criteria of inclusion in the inventories. Although probably imperfect compared with recent developments [5,21], this method has limited the potential observer effect linked with microhabitat inventories [22].

Microhabitat inventories were based on different typologies due to parallel developments and lack of harmonization since 2005. As a consequence, we selected only a part of the data in the database to be as homogeneous a possible and to avoid too much degradation of the original data by grouping microhabitat types to coarser classification grains.

Data selection and biogeoclimatic variables extraction

First, we focused on the microhabitat typology that has been used over the larger number of plots and sites (Table 1). This reduced the dataset to 43 sites comprising 3165 plots. Second, smallest trees (7.5≤DBH≤17.5cm) were the more abundant in the database but also the less likely to bear microhabitats. Since this might cause zero-inflation, we excluded this category from the dataset. Third, among the remaining standing dead trees and snags, some genus were poorly represented (ie. less than 100 occurrences over the whole dataset, Table 2: Ash, Chestnut, Hornbeam, Larch, Maple, Poplar). In order to be able to account for the tree live status in the statistical models (ie. living vs. dead trees, see below), we excluded these groups to conserve only those that were sufficiently represented in the two live status categories (Table 2, but see also Supplementary Materials: Figure S1, for a representation on a larger subset of living trees). The final dataset comprised 2783 plots distributed over 43 sites, for a total of 22307 trees (20312 living and 1995 dead trees).

Based on plot locations, we gathered different biogeoclimatic variables:

- Annual mean temperature (bio1) and precipitation (bio12) from the Worldclim2 database [23];

- Elevation, aspect and slope from the national digital elevation model (resolution 30m);
- Plant-bioindicated pH issued from the national forest inventory [24].

Statistical analyses

Following Zuur et al. [25], preliminary data exploration did not reveal any potential variation of the relationship between microhabitat metrics and any of the biogeoclimatic variable mentioned above, apart from elevation. This latter variable was also strongly correlated to the tree species analysed (trivially, only Beech was distributed over the whole elevation gradient while the others were elevation-dependent). To account for these strongly correlated variables, we computed a principal component analysis (PCA) including mean temperature and precipitation, elevation, slope and pH (aspect was excluded as it was quite redundant with elevation) and we kept the first two uncorrelated axes for inclusion in the models detailed below (altogether these axes represented 78% of the overall variance).

We used DBH, live status (alive vs. dead) and genus (Beech, Fir, Oak, Pine and Spruce) as explanatory variables. Second and third order interactions were included as well in the models. Eigenvalues of the PCA calculated above were added as well but without interactions with other variables.

We modelled the total number of microhabitat types per tree as a response variable with generalised linear mixed models (GLMMs, library glmmTMB, [26]) with Poisson error distribution for count data and plot identity nested within site as random variable. The occurrence of each microhabitat type was modelled similarly, but with binomial error distribution for binary data. Differences of microhabitats number and occurrences between living and dead trees were tested using post-hoc multicomparison Tukey tests for a fixed mean DBH (44cm; function cld, library emmeans [27]). Dispersion diagnostics revealed underdispersed model estimations, which may cause a type II error rate inflation [28]. However, since there was no simple way to account for that in a frequentist framework, we kept with

these results, bearing in mind that our results were conservative despite the large number of observations we analysed. In addition, we focused our interpretations on magnitude of the results rather than statistical significance (see e.g. [29]). We processed all the analyses with the R software v. 3.4.3 [30].

Results

Number of microhabitats per tree

Single parameters estimates were significant in the model (apart from PCA second axis coordinates), while second order and third order interactions were less often and less significant (Supplementary Materials, Table S1). All tree genus except Pine had higher microhabitat number on dead than living trees. Overall, the difference was higher for Oak and Pine (resp. 50% and 43% more on dead trees for a mean DBH, Table 3), than for the other genus (around 30% more on dead trees). Globally, number of microhabitats per tree increased with tree diameter both for live and dead trees. However, the accumulation of microhabitat with diameter varied with genus, with higher accumulation levels for broadleaves (Beech and Oak) than for conifers (Fir, Pine, Spruce), but also for dead compared to living trees (except for Pine; Figure 1, Supplementary Materials, Table S2).

Occurrence of microhabitat types per tree

Five microhabitats out of twenty showed generally higher occurrence on standing deadwood than on living trees, but not systematically for all species or for all live status: trunk cavities (broadleaves), woodpecker feeding holes, rot (broadleaves), conks of fungi (except Pine) and bark characteristics (except Pine and Spruce, Table 3 and Appendix S3). Conversely, injuries, dead branches whatever their size, and forks (broadleaves) showed higher occurrence on living trees. The strongest interpretable differences were observed for woodpecker cavities (e.g. they occurred around 300% more often on standing dead Beech, Oak and Pine, for a

mean DBH = 44cm). Magnitudes for microhabitats which occurred more on living trees were smaller, e.g. for small branches or injuries (around 60% to 90% more on living trees, Table 3).

For most microhabitats, probability of occurrence increased with DBH, either for living or dead trees with the remarkable exceptions of woodpecker cavities, cracks and crown skeletons (Supplementary Materials: Figure S2, Table S3). However, the magnitude of the relation varied with tree genus and live status, the increase in occurrence with DBH being higher for dead than for living trees (e.g. 30% more base and trunk cavities on dead Beech, 22 to 44% more woodpecker feeding holes, except on Pine). For living trees, the magnitude was generally smaller, except for occurrence of small and medium branches (e.g. 70% more medium dead branches on living Pine) and to a lesser extent for mosses on Beech and Fir (18% and 23% more respectively). All other magnitudes were smaller, generally below 10%. Note that in some cases, due to the very small occurrence of some microhabitats on some tree genus (e.g. canopy cavities on Spruce), the estimations proved unreliable in these cases (Supplementary Materials: Figure S2, Table S3).

Discussion

Numerous recent studies in various contexts showed that the number of microhabitats per tree, as well as the occurrence of some types increase with tree diameter [10,13,15] and showed higher levels on dead than living trees [11,12] . Our nationwide study based on a large tree database confirmed these relationships and extend them to a larger range of tree species in various biogeographical conditions than before. Indeed, our results concerned at least five tree genus (eleven if we take only living trees into account, Supplementary Materials: Figure S1).

Dead trees bear more microhabitats than living trees

Standing dead trees contribute significantly to the supply of microhabitats, as they overall bore 30 to 50% more microhabitats than their living counterparts in our dataset. Dead trees could even bear a lot more microhabitats than living trees when individual types are analysed (e.g. woodpecker feeding holes or bark characteristics). Previous studies comparing microhabitat number between living and dead trees almost all found higher microhabitats numbers on dead trees (see [17]). However, this difference varied across studies, from 1.2x more microhabitats in Mediterranean forest [15], 2x more in five forests in France [12], to 4x more on habitat trees in south-western Germany [31]. Our results ranged from 1.3x to 1.5x more microhabitats on dead than living trees, which is of a slightly lower order of magnitude than what was observed before, but on a larger geographical gradient. Once dead, standing trees are affected by decomposition processes that initiate and develop microhabitats [14,32,33]. Such trees could also constitute privileged foraging grounds for a number of species [5,7,19], including for example woodpeckers [33,34]. In particular, insect larvae or ants that live below the bark of more or less recently dead trees constitute a non-negligible part of some birds' diet [7,35,36]. As living trees also bear microhabitats, it seems logical that many of them persist when the tree dies and continue to evolve, or even condition the presence of other microhabitats linked with the decay process [14]. Injuries caused by logging, branch break or treefall could slowly rot and evolve in decayed cavities [5,32]. These successions likely explain why these microhabitats are more numerous on dead trees. The only exception to this global pattern concerned epiphytes and forks with accumulated organic matter, that tend to be more numerous on living trees. Ivy, mosses and lichen are likely to benefit from bark characteristics and conditions (e.g. pH, [37]) likely to occur only on living tree. In addition, epiphytes require a relatively stable substrate to grow or anchor, especially when they grow slowly like some species of mosses or lichens [38]. Such property is lost when the tree dies as the bark loosen and falls more rapidly than on living trees, which could cause epiphytic community replacement as well as lower levels of detection due to the absence of individuals. In a nutshell, decay

processes linked to the tree death makes a clear difference between microhabitats that are linked to it (i.e. saproxylic microhabitats, sensu [5]) and those that are not – or less – linked to those phenomena (i.e. epixylic microhabitats).

Number and occurrence of microhabitats increase with tree diameter

We confirmed that microhabitat number and occurrence increase with tree diameter but, contrary to expectations, tree genus – as well as abiotic factors – had a limited effect on this relationship, with slightly higher microhabitat accumulation levels on broadleaves than conifers ([10-12], but see [13]). At the individual microhabitat level, almost all types showed the same trend, but also with considerable variations in terms of magnitude. Larger (living) trees have a generally longer lifespan than smaller ones, and are consequently more prone to damages due to meteorological events (storms, snowfall), natural hazards (rockfalls) or attacks and use by different tree- and wood-dependent species (woodpeckers, beetles, fungi, e.g. [12,39]). Depending on the studies, for a comparable increase in tree diameter (from 50 to 100cm), number of tree microhabitats was roughly multiplied by two in several studies [12,16,17], but can be multiplied by four [31] up to five [11] in certain cases. Our results showed magnitudes below the lower end of this range (the multiplication coefficient ranged from 1.2 to 1.4). This is probably linked to the fact that the large trees in our dataset may be younger that those in the other studies, especially compared to studies located in near-natural or long-abandoned forests [11,12]. At the individual microhabitat scale, dead branches were more prone to occur on large trees than smaller trees, which seems quite obvious but has rarely been quantified before: larger trees have more, but also larger, branches likely to die from competition with neighbours, especially broadleaves [40]. Indeed, Oak and Beech were the tree genus that showed higher large dead branches accumulation rates in our analyses, while conifers showed almost no large dead branches. Cavity bird and bats are reputed to choose preferentially larger trees to nest or roost [41,42], since larger wood width around the cavity provides buffered and more stable conditions [43]. However, this relationship was not the best shown in our results,

since the accumulation rate of woodpecker cavities with tree diameter was very slow. This absence of relationship between tree diameter and woodpecker cavities seems hard to prove in the context of temperate European forests (see [12] at the tree scale, or [6] at the stand scale) and probably require more targeted examination [33,44]. This could also be linked to non-linear dynamics [10] of this particular microhabitat (some cavities in living trees can close back when they are not used anymore) but also for other microhabitats with specific phenology like conks of fungi [45]. The number and occurrence of microhabitats also increased with diameter of standing dead trees, sometimes at a higher rate than for living trees. In this case, the longer persistence of large dead trees compared to smaller ones [46,47] may combine the effects of increased hazard and damage risks with the decay processes described above. This probably explains the higher accumulation levels we observed in many cases, especially for saproxylic microhabitats (e.g. rot, feeding holes, trunk cavities). Once again, the only exception to this rule was epiphytes: their probability of occurrence tended to increase with tree diameter but in a very noisy and unclear way, both for living and for dead trees. For such epiphytic organisms, larger scale processes and biogeoclimatic (e.g. soil fertility, precipitation) context is probably more important than local tree characteristics [48,49].

<u>Limitations and research perspectives</u>

We showed a limited effect of biogeoclimatic variables on the relationship between microhabitats, tree diameter and living status. However, the way we controlled for them in the models remains rather imperfect. Some specific interactions may exist, especially in the case of epiphytes [49], but could not be detected by our approach with aggregated variables. In addition, it was rather difficult to disentangle the effects of tree genus with that of biogeoclimatic variables, since distribution range of most tree species we analysed is linked to a climatic niche, apart from Beech and more marginally for Pine that occur over larger gradients. Still, the fact that we did not highlight any clear interaction with biogeoclimatic variables during exploratory analyses tend to confirm that the relations we observed are valid for a wide range of species. However, further analyses are required to assess the effects of biogeoclimatic

variables on microhabitat patterns for the species with a large ecological amplitude (especially Beech species, that occur over temperate and Mediterranean Europe and beyond).

Our data is issued from nature reserves with a potentially larger anthropogenic gradient than managed forests. Some of these reserves have not been harvested for several decades and exhibit characteristics of overmature forests (see e.g. [22], who analysed some of the reserves included in this paper), but their overall structure reflects a relatively recent management abandonment – if any – probably marked by previous intensive harvesting and use over the past centuries characteristic of western European forests [50]. This is testified by the relatively rare occurrence of dead standing trees, in particular those with a large diameter, in the dataset we analysed: standing dead trees represented a mere 10% of the total dataset while very large individuals (DBH > 67.5cm) only 1% (Table 2). As a consequence, despite the fact that we worked on an extended management gradient including unmanaged strict reserves, we still lack a part of the elements characteristic of old-growth and overmature forests, especially large dead trees [20,51], which cause our relationships to be truncated and imprecise for the larger diameter categories. Further research on the last remnant of old-growth primeval forests in Europe [52] is thus needed to bridge this gap and better understand microhabitats dynamics over a whole life of a tree.

Compared to recent developments [5,21], the typology we used (Table 1) appears rather coarse and imprecise. But, on the one hand, it allowed us to have a sufficient number of occurrences in each types to analyse the combined effects of diameter and species for almost all microhabitat types in the typology. On the other hand, it is also likely that we were not able to confirm some effects mentioned in the literature due to imprecise distinctions between types, for example different woodpecker cavity types. The current approach should then be viewed as a compromise between sufficient occurrence of each microhabitat type in the dataset and specificity of the typology. Current developments mentioned above [5] will certainly help to homogenize data in a near future and to build larger shared databases on common and comparable bases.

Finally, our models assumed – unrealistically – microhabitat number to increase exponentially with diameter. Recent studies [17], as well as ecological theory (e.g. species-area relationship), tend to rather show a saturated (e.g. logarithmic or sigmoid) relationship between microhabitats and diameter. Models allowing for different link functions – probably within a Bayesian framework – remain to be tested to see whether they perform better than the current ones used (see e.g. [10]).

Implications for forest management and biodiversity conservation

Among small natural features, large and old trees are considered a keystone in forest and agro-pastoral landscapes because of their disproportionate importance for biodiversity relatively to their size [3]. This functional role for biodiversity seems further enhanced by the 'smaller' natural features – microhabitats – they bear. In this large-scale analysis, we confirmed and extended some of the results already observed locally: most microhabitats occur preferentially on living large trees and even more on dead ones. This relationship seems true for several tree species included in this analysis, and across a large gradient of ecological conditions, with minor differences in terms of accumulation rates. As a consequence, conserving and promoting large trees in daily forest management is likely to enhance the structural heterogeneity at the stand scale [20,53], including a variety of tree-borne microhabitats, that could further help to better conserve specific forest biodiversity [5,54]. Despite the fact that the diameter effect seems consistent across different conditions, promoting a variety of large trees of various species may further increase the effect on biodiversity [19], since the succession dynamics of microhabitats as well as their formation speed may vary with tree species [10,12]. Successional patterns and long-term dynamics or microhabitats remains largely unknown [10], long term monitoring at the tree and stand scales are still needed to better understand their dynamics and the underlying processes at play [5]. Ultimately, such knowledge will feed recommendations to managers to better preserve biodiversity on solid scientific grounds.

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Figure 1: Relationship between number of microhabitats (N microhabitats) per tree and Diameter at Breast Height (DBH) by species and live status (living vs. dead standing trees). The line represents the estimation issued from a generalized mixed effect mode with Poisson error distribution. The ribbons represent the 95% confidence interval of the mean. Principal component analysis eigenvalues were hold constant for the representation.

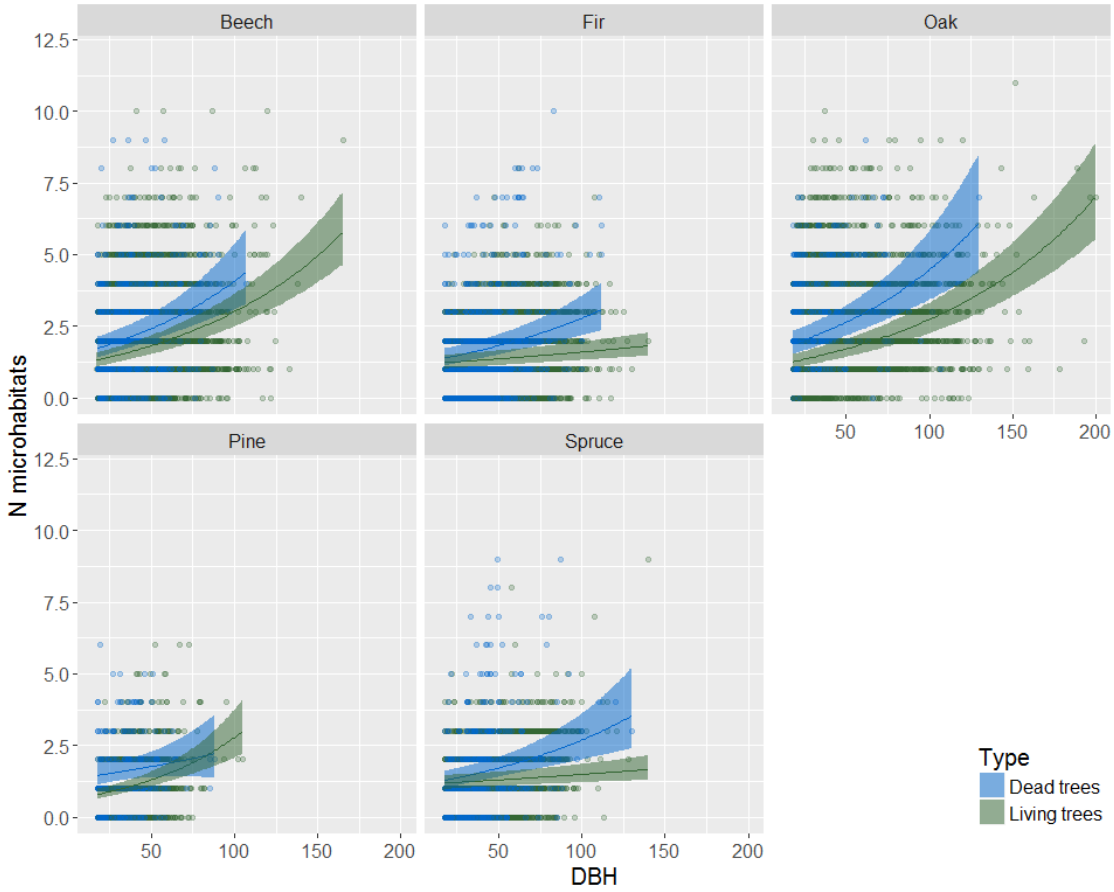


Table 1: Typology of microhabitats

Microhabitat	Description	Occurrence (%, n=22307)
Base Cavity	Non-woodpecker cavity located at a height < 1.3m, large enough to host small mammals	9.2
Trunk Cavity	Non-woodpecker cavity located at a height comprised between 1.3m and the first main branch	4.5
Canopy cavity	Non-woodpecker cavity located on canopy branches (unhealed)	1.0
Woodpecker cavity	Nesting cavity of a woodpecker, minimum diameter 2cm	1.4
Crack	Crack in the wood with a width >1cm and deep enough to host bat species	3.1
Woodpecker feeding hole	Feeding hole dug by a woodpecker	4.6
Rot	Presence of wood rot	3.3
Injury	Fresh injury, minimum diameter 10cm.	12.1
Conk of fungi	Conk of perennial polypore	4.0
Bark characteristic	Bark loosened affecting >50% of the surface of a given part of the tree (base, trunk, canopy)	3.1
Bryophyte (>50)	Epiphytes with a cover >50% of a given part of the tree (base, trunk, canopy)	53.5
Lichen (>50)		31.9
Ivy (>50)		7.9
Small branches (5-10cm)	Dead branches with a diameter comprised between 5 and 10cm and a length higher than 1m	28.4
Medium branches (10-30cm)	Dead branches with a diameter comprised between 10 and 30cm and a length higher than 1m	13.3
Large branches (>30cm)	Dead branches with a diameter higher than 30cm and a length higher than 1m	1.5
Crown skeleton	Noted when the sum of small, medium and large branches is higher than 10 individuals	2.3
Fork	Fork with suspected presence of organic matter or rainwater	12.8
Broken stem	Broken or dry main stem	7.1

Table 2: Distribution of the data by genus and Diameter at Breast Height (DBH) classes: small trees (ST: 17.5 < DBH ≤ 30), medium trees (MT, 30 ≤ DBH < 47.5cm), large trees (LT, 47.5 ≤ DBH < 67.5cm) and very large trees (VLT, DBH ≥ 67.5cm). Genus in grey were excluded from the main analyses due to small occurrences among dead trees (see Supplementary Materials: Figure S1).

	Living trees					Dead trees				
Genus	ST	MT	LT	VLT	Total	ST	MT	LT	VLT	Total
Ash	300	292	93	25	710	25	11	3	0	39
Beech	1743	3382	1811	600	7536	117	213	100	37	467
Chestnut	71	154	87	26	338	42	14	4	3	63
Fir	807	1440	1339	698	4284	126	348	155	54	683
Hornbeam	223	156	30	2	411	8	4	1	0	13
Larch	114	312	243	79	748	6	11	2	0	19
Maple	375	472	140	19	1006	21	10	3	0	34
Oak	1259	1549	1043	925	4776	79	89	38	33	239
Pine	363	783	273	33	1452	83	115	25	5	228
Poplar	66	124	50	18	258	12	11	6	2	31
Spruce	540	850	544	330	2264	87	198	70	26	381
Total	5861	9514	5653	2755	23783	606	1024	407	160	2197

Table 3: Percentage of difference between living and dead trees for a mean Diameter at Breast Height (DBH = 44cm) calculated as [(Microhabitat living trees – Microhabitats dead trees) / Microhabitat living trees]. * indicate significant differences based on post-hoc Tukey tests for a mean DBH. Differences lower than -1000% correspond to cases where a given microhabitat was almost absent from living trees. In these cases, the percentage was considered uninterpretable (although significant).

Microhabitats	Beech	Fir	Oak	Pine	Spruce
All	-31.0*	-30.2*	-53.3*	-43.2*	-27.2*
Base cavities	-58.1	-83.3	-6.8	-227.4	52.1
Trunk cavities	-168.7*	-581.4*	-198.1*	-595*	< -1000*
Canopy cavities	34.5	-5.8	-45.2	100	< -1000
Woodp. cavities	-692.4*	-145.6	-363.5*	-380.5	-77.3
Cracks	-83.9*	-141	-978.4*	56.8	-260.5*
Woodp. feeding holes	< -1000*	< -1000*	< -1000*	< -1000*	< -1000*
Rot	-129.1*	-67.6	< -1000*	< -1000*	-853.9*
Injuries	83.7*	91.4*	79.1*	74.8*	93.0*
Conks of fungi	< -1000*	< -1000*	< -1000*	< -1000*	< -1000*
Bark characteristics	< -1000*	< -1000*	< -1000*	< -1000*	< -1000*
Moss cover >50%	27.3*	55.4*	69.1*	-249.6	-15.5
Lichen cover > 50%	83.2*	83.1*	46.6	37.6	86.1*
Ivy cover >50%	18.1	60.3	-3.3	-43.1	33.4
Small branches	90.8*	68*	94*	90.6*	60.7
Medium branches	74.3*	< -1000*	74.9*	57.5	63.3
Large branches	-90.8	-129.3	68.7	-223.4	100.0
Crown skeleton	< -1000*	-355.3	< -1000*	-659.4*	< -1000*
Forks	97.4*	83.6*	67.4	88.8	80.5*
Broken stem	-17.6	-7.3	1.3	29.5	3.4

Supplementary materials

Table S1: Model scaled estimations for number of microhabitat types per tree issued from a generalised linear mixed model with Poisson error distribution and plot nested in site as a random effect. DBH: Diameter at Breast Height; PC1 and PC2: eigenvalues for the first two axes of a principal component analysis on biogeoclimatic variables (see main text); SE: standard error of the mean: p = p value; ***p<0.001; **p<0.01; *p<0.05.

Parameter	Estimate	SE	p	
Intercept(Beech)	0.804	0.096	<0.001	***
DBH	0.209	0.036	<0.001	***
Fir	-0.302	0.046	<0.001	***
Oak	0.220	0.050	<0.001	***
Pine	-0.316	0.078	0.0001	***
Spruce	-0.406	0.053	<0.001	***
Living trees	-0.270	0.032	<0.001	***
PC1	-0.064	0.018	<0.001	***
PC2	0.033	0.025	0.1963	ns
DBH:Fir	-0.040	0.047	0.3986	ns
DBH:Oak	0.002	0.048	0.9728	ns
DBH:Pine	-0.090	0.089	0.3158	ns
DBH:Spruce	-0.028	0.054	0.6094	ns
DBH:Living	-0.008	0.0370	0.8284	ns
Fir:Living	0.006	0.0480	0.8984	ns
Oak:Living	-0.157	0.049	0.0014	**
Pine:Living	-0.089	0.079	0.2605	ns
Spruce:Living	0.029	0.055	0.5959	ns
DBH:Fir:Living	-0.098	0.049	0.0478	*
DBH:Oak:Living	-0.014	0.049	0.7714	ns
DBH:Pine:Living	0.195	0.097	0.0458	*
DBH:Spruce:Living	-0.118	0.057	0.0389	*

Table S2: Accumulation levels of microhabitat per tree (number of microhabitats and occurrence) for a Diameter at Breast Height (DBH) increment from 50cm to 100cm.

	Living trees					Dead trees				
Microhabitats	Beech	Fir	Oak	Pine	Spruce	Beech	Fir	Oak	Pine	Spruce
All	1.185	0.235	1.027	1.487	0.191	1.653	0.960	1.824	0.614	0.979
Base cavities	0.154	0.065	0.036	0.099	0.1	0.335	0.077	0.041	-0.005	0.222
Trunk cavities	0.056	0.013	0.033	0.05	0.017	0.323	0.068	0.262	0.013	0.048
Canopy cavities	0.017	0.001	0.016	0.004	0	0	0.065	0.014	0	0.009
Woodp. cavities	0.01	0.002	0.012	0.083	0.017	0.041	0.032	0.009	0.075	0.026
Cracks	0.032	0.001	0.018	0.02	0.009	0.078	-0.004	0.012	-0.002	-0.003
Woodp. feeding holes	0.029	0.003	0.036	0.027	0.005	0.441	0.285	0.392	0.063	0.223
Rot	0.018	0.012	0.005	0.016	0	0.255	0.009	0.239	0.082	-0.02
Injuries	0.048	-0.009	0.049	0.021	-0.021	-0.005	-0.003	0.006	0.012	-0.004
Conks of fungi	0.04	0.006	0.011	0.005	-0.001	0.154	0.245	0.136	-0.01	0.277
Bark characteristics	0.007	0.001	0.003	0.002	0	0.045	0.087	0.155	0.04	-0.036
Moss cover >50%	0.178	0.228	-0.011	-0.017	0.112	0.087	0.179	0.009	0.722	0.315
Lichen cover > 50%	0.067	0.126	0.021	0.068	-0.031	-0.013	0.006	0.007	-0.036	0.009
Ivy cover >50%	0.001	0.002	0.02	0	0.003	0.001	0	0	0.013	0
Small branches	0.138	0.363	0.209	0.283	0.465	-0.005	0.055	-0.015	-0.023	0.011
Medium branches	0.32	0.117	0.528	0.688	0.064	0.018	0.024	0.01	-0.019	0.016
Large branches	0.049	0.001	0.078	0.145	0.004	0.023	0.006	0.001	0.244	0
Crown skeleton	0	0.002	0	0.026	0.003	0	0	0.001	0.065	-0.004
Forks	0.244	0.005	0.07	0.159	0.002	-0.002	0.018	0.001	-0.001	0.038
Broken stem	0.016	-0.024	-0.005	-0.028	-0.015	0.12	0.021	0.063	-0.021	0.045

Table S3: Model scaled estimations for occurrence of microhabitat types per tree issued from a generalised linear mixed model with binomial error distribution and plot nested in site as a random effect. DBH: Diameter at Breast Height; PC1 and PC2: eigenvalues for the first two axes of a principal component analysis on biogeoclimatic variables (see main text); SE: standard error of the mean: p = p value; ***p<0.001; **p<0.01; *p<0.05.

	Base cavities				Trunk cavities				Canopy cavities				Woodpecker cavities				Cracks				Woodpecker feeding holes			
	Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p	
Intercept	-2.66	0.34	0.00	***	-2.50	0.26	0.00	***	-6.76	1.02	0.00	***	-3.48	0.32	0.00	***	-3.54	0.32	0.00	***	-0.95	0.29	0.00	**
DBH	0.85	0.21	0.00	***	0.77	0.19	0.00	***	-0.12	1.18	0.92	ns	0.36	0.25	0.16	ns	0.52	0.22	0.02	*	0.77	0.19	0.00	***
Fir	-1.11	0.33	0.00	**	-1.19	0.28	0.00	***	-1.34	1.94	0.49	ns	-1.67	0.52	0.00	**	-1.09	0.35	0.00	**	0.43	0.23	0.07	.
Oak	-1.10	0.35	0.00	**	-0.54	0.32	0.09	.	0.76	1.07	0.48	ns	-0.48	0.45	0.28	ns	0.44	0.36	0.22	ns	0.35	0.27	0.19	ns
Pine	-2.09	0.59	0.00	***	-1.29	0.50	0.01	*	-10.38	14.62	0.48	ns	-0.54	0.59	0.36	ns	-2.51	0.72	0.00	***	-0.94	0.36	0.01	*
Spruce	-1.50	0.32	0.00	***	-2.07	0.41	0.00	***	-2.05	2.06	0.32	ns	-2.12	0.60	0.00	***	-0.56	0.37	0.13	ns	-0.58	0.26	0.03	*
Living	-0.48	0.19	0.01	*	-1.04	0.17	0.00	***	0.42	0.97	0.66	ns	-2.10	0.28	0.00	***	-0.62	0.19	0.00	**	-4.72	0.23	0.00	***
PC1	-0.34	0.11	0.00	**	-0.28	0.09	0.00	**	0.14	0.17	0.43	ns	0.01	0.10	0.95	ns	-0.09	0.10	0.39	ns	0.25	0.10	0.01	*
PC2	-0.10	0.17	0.55	ns	0.02	0.15	0.87	ns	0.00	0.26	0.99	ns	-0.22	0.16	0.17	ns	0.04	0.17	0.83	ns	-0.12	0.17	0.46	ns
DBH:Fir	-0.32	0.32	0.31	ns	-0.30	0.28	0.28	ns	2.09	1.41	0.14	ns	0.35	0.43	0.42	ns	-0.70	0.39	0.07	.	-0.30	0.23	0.19	ns
DBH:Oak	-0.30	0.30	0.32	ns	0.19	0.26	0.48	ns	0.74	1.23	0.55	ns	-0.21	0.39	0.60	ns	-0.40	0.32	0.21	ns	0.23	0.27	0.41	ns
DBH:Pine	-1.07	0.63	0.09	.	-0.62	0.53	0.24	ns	-9.16	11.85	0.44	ns	0.23	0.59	0.69	ns	-1.41	0.73	0.06	.	-0.56	0.35	0.11	ns
DBH:Spruce	0.10	0.32	0.75	ns	-0.22	0.35	0.54	ns	1.67	1.40	0.23	ns	0.41	0.42	0.33	ns	-0.59	0.36	0.10	.	-0.28	0.26	0.27	ns
DBH:Living	-0.19	0.21	0.36	ns	-0.34	0.19	0.08	.	0.98	1.19	0.41	ns	0.14	0.27	0.59	ns	-0.09	0.23	0.70	ns	0.06	0.21	0.76	ns
Fir:Living	-0.13	0.35	0.70	ns	-0.90	0.34	0.01	**	-0.48	2.14	0.82	ns	1.20	0.57	0.04	*	-0.26	0.39	0.50	ns	-0.56	0.35	0.11	ns
Oak:Living	0.42	0.35	0.23	ns	-0.09	0.31	0.79	ns	-0.80	1.07	0.46	ns	0.55	0.47	0.24	ns	-1.80	0.38	0.00	***	0.47	0.30	0.11	ns
Pine:Living	-0.71	0.58	0.22	ns	-0.92	0.53	0.09	.	9.82	14.63	0.50	ns	0.51	0.59	0.39	ns	1.46	0.65	0.02	*	1.11	0.42	0.01	**
Spruce:Living	1.24	0.32	0.00	***	-1.58	0.61	0.01	*	-10.06	105.3	0.92	ns	1.52	0.63	0.02	*	-0.67	0.42	0.11	ns	0.10	0.36	0.78	ns
DBH:Fir:Living	0.27	0.33	0.41	ns	0.37	0.32	0.24	ns	-2.48	1.55	0.11	ns	-0.65	0.48	0.17	ns	0.38	0.42	0.36	ns	-0.25	0.31	0.42	ns
DBH:Oak:Living	0.17	0.31	0.59	ns	-0.06	0.27	0.82	ns	-0.82	1.24	0.51	ns	0.20	0.40	0.62	ns	0.66	0.33	0.05	.	-0.54	0.29	0.06	.
DBH:Pine:Living	1.64	0.70	0.02	*	1.14	0.64	0.07	.	8.95	11.87	0.45	ns	0.39	0.67	0.57	ns	1.53	0.75	0.04	*	0.53	0.48	0.27	ns
DBH:Spruce:Living	-0.29	0.33	0.38	ns	0.81	0.44	0.07	.	-1.73	69.75	0.98	ns	-0.10	0.46	0.83	ns	0.55	0.39	0.16	ns	-0.01	0.33	0.98	ns

Table S3 (continued)

	Rot				Injuries				Conks of fungi				Bark characteristics				Moss (>50%)				Lichen (>50%)			
	Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p	
Intercept	-3.39	0.34	0.00	***	-4.49	0.40	0.00	***	-0.37	0.22	0.09	.	-2.65	0.35	0.00	***	0.05	0.63	0.93	ns	-4.03	0.73	0.00	***
DBH	0.88	0.21	0.00	***	-0.36	0.36	0.32	ns	0.25	0.15	0.08	.	0.22	0.19	0.25	ns	0.14	0.19	0.46	ns	-0.37	0.27	0.17	ns
Fir	-0.80	0.31	0.01	*	-0.67	0.45	0.13	ns	-0.69	0.20	0.00	***	-0.19	0.30	0.54	ns	-1.75	0.25	0.00	***	0.63	0.29	0.03	*
Oak	1.54	0.32	0.00	***	-0.18	0.53	0.74	ns	-2.01	0.26	0.00	***	1.81	0.29	0.00	***	-1.10	0.28	0.00	***	1.37	0.42	0.00	**
Pine	-0.62	0.59	0.29	ns	-0.31	0.48	0.52	ns	-2.47	0.53	0.00	***	-0.15	0.46	0.75	ns	-2.30	0.52	0.00	***	1.25	0.44	0.01	**
Spruce	-0.19	0.32	0.55	ns	-0.64	0.59	0.28	ns	-1.45	0.26	0.00	***	0.47	0.30	0.12	ns	-2.45	0.29	0.00	***	-0.62	0.30	0.04	*
Living	-0.85	0.22	0.00	***	1.87	0.30	0.00	***	-4.47	0.17	0.00	***	-2.98	0.21	0.00	***	0.82	0.16	0.00	***	1.88	0.21	0.00	***
PC1	-0.23	0.11	0.03	*	0.06	0.07	0.41	ns	0.32	0.09	0.00	**	0.10	0.14	0.49	ns	0.16	0.15	0.28	ns	-0.76	0.18	0.00	***
PC2	0.18	0.17	0.31	ns	-0.30	0.12	0.01	*	0.53	0.15	0.00	***	-0.10	0.22	0.64	ns	-0.21	0.20	0.30	ns	0.80	0.25	0.00	**
DBH:Fir	-0.72	0.28	0.01	*	-0.35	0.54	0.52	ns	0.17	0.19	0.36	ns	0.18	0.26	0.48	ns	0.27	0.27	0.33	ns	0.41	0.34	0.23	ns
DBH:Oak	-0.29	0.27	0.28	ns	0.52	0.51	0.30	ns	0.09	0.22	0.69	ns	0.03	0.27	0.90	ns	-0.12	0.28	0.65	ns	0.52	0.46	0.26	ns
DBH:Pine	-0.25	0.55	0.65	ns	0.66	0.55	0.23	ns	-0.44	0.61	0.47	ns	0.00	0.47	1.00	ns	1.32	0.66	0.05	*	0.03	0.52	0.95	ns
DBH:Spruce	-1.26	0.33	0.00	***	-0.42	0.73	0.56	ns	0.37	0.25	0.13	ns	-0.46	0.29	0.11	ns	0.65	0.31	0.03	*	0.50	0.37	0.19	ns
DBH:Living	-0.58	0.21	0.01	**	0.59	0.36	0.10	.	0.37	0.16	0.02	*	0.17	0.21	0.40	ns	0.38	0.19	0.05	.	0.58	0.28	0.04	*
Fir:Living	0.33	0.33	0.32	ns	0.65	0.45	0.15	ns	-0.49	0.35	0.16	ns	-1.00	0.39	0.01	*	0.25	0.25	0.33	ns	0.08	0.29	0.79	ns
Oak:Living	-2.23	0.33	0.00	***	-0.27	0.53	0.61	ns	1.75	0.27	0.00	***	-2.21	0.31	0.00	***	1.87	0.28	0.00	***	-1.19	0.41	0.00	**
Pine:Living	-1.88	0.66	0.01	**	-0.47	0.46	0.31	ns	0.97	0.89	0.28	ns	-1.32	0.68	0.05	.	-2.15	0.55	0.00	***	-1.37	0.47	0.00	**
Spruce:Living	-1.43	0.39	0.00	***	0.88	0.59	0.14	ns	0.33	0.45	0.46	ns	-2.06	0.48	0.00	***	-0.98	0.30	0.00	**	0.16	0.30	0.61	ns
DBH:Fir:Living	0.71	0.30	0.02	*	0.05	0.55	0.93	ns	-0.23	0.27	0.40	ns	-0.26	0.33	0.43	ns	-0.41	0.28	0.15	ns	-0.40	0.35	0.26	ns
DBH:Oak:Living	0.26	0.28	0.36	ns	-0.49	0.51	0.34	ns	-0.42	0.24	0.08	.	-0.19	0.28	0.51	ns	-0.43	0.28	0.12	ns	-0.51	0.47	0.27	ns
DBH:Pine:Living	0.90	0.72	0.22	ns	-0.72	0.57	0.20	ns	0.47	1.22	0.70	ns	0.03	0.96	0.98	ns	-2.39	0.72	0.00	**	-0.02	0.57	0.97	ns
DBH:Spruce:Living	0.98	0.37	0.01	**	0.04	0.74	0.96	ns	-1.42	0.45	0.00	**	-0.12	0.44	0.79	ns	-0.72	0.33	0.03	*	-0.79	0.39	0.04	*

Table S3 (continued)

	Ivy (>50%)				Small branches				Medium branches				Large branches				Crown skeleton				Forks			
	Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p		Estimate	SE	p	
Intercept	-6.61	0.62	0.00	***	-4.36	0.43	0.00	***	-4.49	0.35	0.00	***	-5.95	0.60	0.00	***	-5.76	1.02	0.00	***	-6.14	0.80	0.00	***
DBH	0.22	0.39	0.57	ns	-0.19	0.35	0.58	ns	0.37	0.34	0.28	ns	0.79	0.50	0.11	ns	-0.01	0.30	0.99	ns	-1.40	0.77	0.07	.
Fir	-0.65	0.56	0.24	ns	1.00	0.35	0.01	**	1.60	0.33	0.00	***	-1.83	1.49	0.22	ns	-1.98	0.70	0.01	**	0.36	0.77	0.64	ns
Oak	1.14	0.46	0.01	*	0.38	0.43	0.38	ns	1.35	0.36	0.00	***	-0.23	0.84	0.79	ns	-0.12	0.40	0.77	ns	2.24	0.85	0.01	**
Pine	0.32	0.91	0.72	ns	1.19	0.48	0.01	*	1.51	0.50	0.00	**	1.33	0.82	0.11	ns	-0.02	0.52	0.96	ns	0.38	1.03	0.72	ns
Spruce	0.42	0.51	0.42	ns	0.65	0.45	0.14	ns	-1.69	1.32	0.20	ns	-39.07	49109.68	1.00	ns	1.32	0.46	0.00	**	0.22	0.80	0.78	ns
Living	0.20	0.39	0.61	ns	2.52	0.29	0.00	***	1.39	0.27	0.00	***	-0.65	0.55	0.24	ns	-4.95	0.50	0.00	***	3.73	0.73	0.00	***
PC1	0.87	0.19	0.00	***	0.10	0.08	0.18	ns	0.07	0.08	0.41	ns	0.14	0.14	0.31	ns	0.44	0.16	0.01	**	-0.56	0.10	0.00	***
PC2	-0.95	0.28	0.00	**	0.02	0.13	0.91	ns	-0.07	0.13	0.59	ns	0.35	0.22	0.11	ns	-0.19	0.32	0.55	ns	0.62	0.13	0.00	***
DBH:Fir	0.02	0.47	0.96	ns	0.60	0.40	0.13	ns	-0.21	0.40	0.60	ns	0.23	0.95	0.81	ns	-0.03	0.80	0.97	ns	1.96	0.81	0.02	*
DBH:Oak	-0.21	0.44	0.63	ns	-0.84	0.51	0.10	.	-0.29	0.41	0.49	ns	-0.71	0.74	0.34	ns	0.07	0.35	0.84	ns	1.43	0.87	0.10	ns
DBH:Pine	0.61	1.19	0.61	ns	-1.13	0.54	0.04	*	-0.60	0.58	0.30	ns	0.62	0.84	0.46	ns	1.25	0.45	0.01	**	1.30	1.10	0.24	ns
DBH:Spruce	-0.38	0.52	0.47	ns	0.36	0.45	0.42	ns	0.45	0.79	0.57	ns	-21.37	39120.97	1.00	ns	-0.71	0.49	0.15	ns	2.14	0.81	0.01	**
DBH:Living	0.04	0.39	0.93	ns	0.53	0.35	0.13	ns	0.56	0.34	0.10	ns	0.48	0.51	0.34	ns	0.09	0.43	0.84	ns	2.00	0.77	0.01	*
Fir:Living	0.73	0.54	0.18	ns	-1.30	0.35	0.00	***	-3.86	0.38	0.00	***	-0.18	1.72	0.92	ns	3.44	0.83	0.00	***	-1.90	0.77	0.01	*
Oak:Living	-0.23	0.46	0.61	ns	0.63	0.43	0.15	ns	0.13	0.36	0.71	ns	1.81	0.86	0.03	*	0.53	0.57	0.36	ns	-2.57	0.85	0.00	**
Pine:Living	-0.56	0.96	0.56	ns	0.36	0.47	0.45	ns	-0.46	0.49	0.35	ns	-0.53	0.89	0.55	ns	2.92	0.58	0.00	***	-1.51	1.04	0.15	ns
Spruce:Living	0.21	0.52	0.69	ns	-1.55	0.46	0.00	**	-0.39	1.36	0.78	ns	33.54	49109.68	1.00	ns	1.95	0.65	0.00	**	-2.08	0.80	0.01	**
DBH:Fir:Living	0.19	0.48	0.70	ns	-0.15	0.40	0.71	ns	0.51	0.42	0.22	ns	-0.73	1.06	0.49	ns	1.14	0.89	0.20	ns	-2.50	0.81	0.00	**
DBH:Oak:Living	0.21	0.44	0.63	ns	0.85	0.51	0.09	.	0.30	0.41	0.47	ns	0.33	0.74	0.66	ns	0.58	0.48	0.23	ns	-1.46	0.87	0.10	.
DBH:Pine:Living	-1.04	1.28	0.42	ns	1.27	0.55	0.02	*	1.03	0.60	0.09	.	-0.32	0.93	0.73	ns	0.27	0.57	0.63	ns	-1.18	1.11	0.29	ns
DBH:Spruce:Living	0.63	0.54	0.24	ns	0.38	0.46	0.41	ns	-0.42	0.82	0.61	ns	22.46	39120.97	1.00	ns	1.52	0.63	0.02	*	-2.71	0.82	0.00	**

Table S3 (continued)

	Broken stems			
	Estimate	SE	p	
Intercept	-3.66	0.36	0.00	***
DBH	0.72	0.24	0.00	**
Fir	0.28	0.30	0.36	ns
Oak	-0.23	0.43	0.59	ns
Pine	-0.09	0.49	0.85	ns
Spruce	-0.08	0.34	0.81	ns
Living	-0.17	0.26	0.53	ns
PC1	-0.14	0.09	0.11	ns
PC2	-0.22	0.14	0.10	.
DBH:Fir	-0.53	0.29	0.07	.
DBH:Oak	-0.12	0.33	0.72	ns
DBH:Pine	-1.57	0.50	0.00	**
DBH:Spruce	-0.33	0.31	0.28	ns
DBH:Living	-0.49	0.24	0.04	*
Fir:Living	0.09	0.31	0.76	ns
Oak:Living	0.18	0.44	0.68	ns
Pine:Living	0.53	0.49	0.28	ns
Spruce:Living	0.20	0.36	0.57	ns
DBH:Fir:Living	-0.39	0.30	0.18	ns
DBH:Oak:Living	-0.26	0.34	0.45	ns
DBH:Pine:Living	0.70	0.53	0.19	ns
DBH:Spruce:Living	-0.31	0.33	0.35	ns

Figure S1: Relationship between total number of microhabitats per tree and Diameter at Breast Height (DBH) by species and live status (living vs. dead standing trees). The line represents the estimation issued from a generalized mixed effect mode with Poisson error distribution. The ribbon represents the 95% confidence interval of the mean. Principal component analysis eigenvalues were hold constant for the representation.

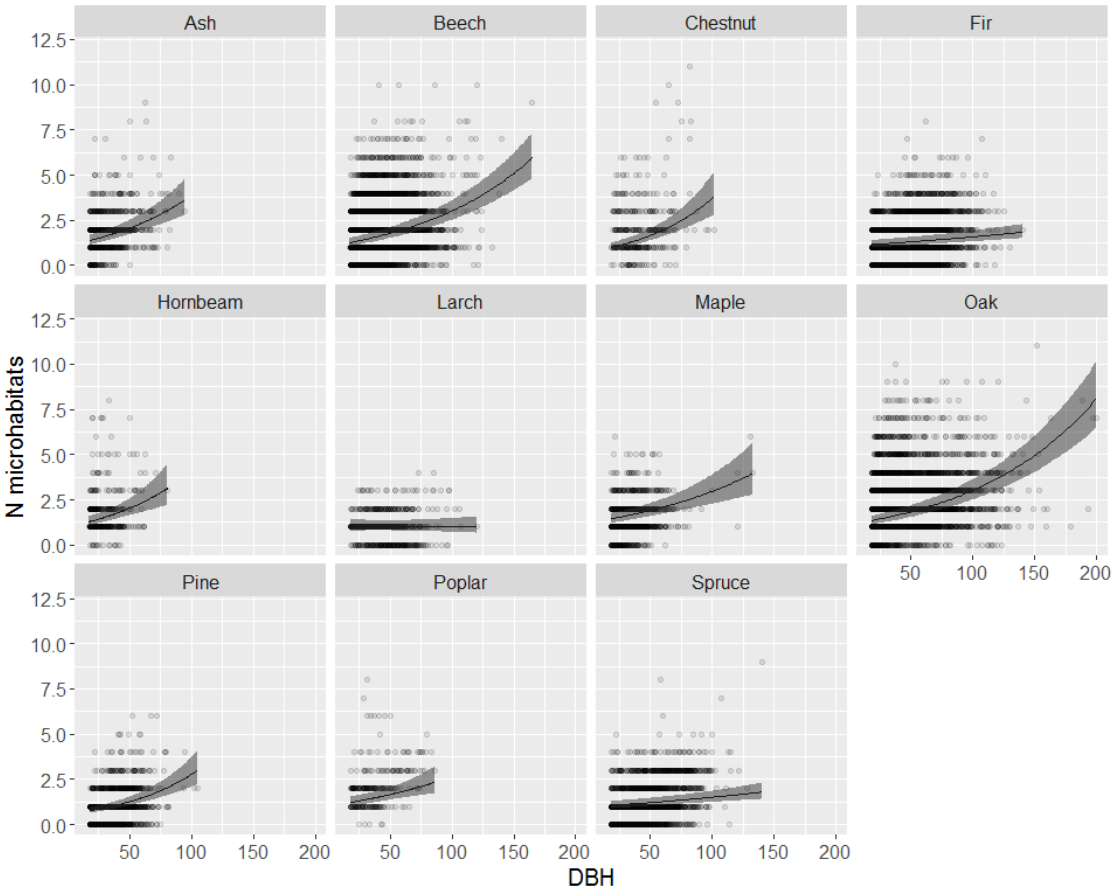
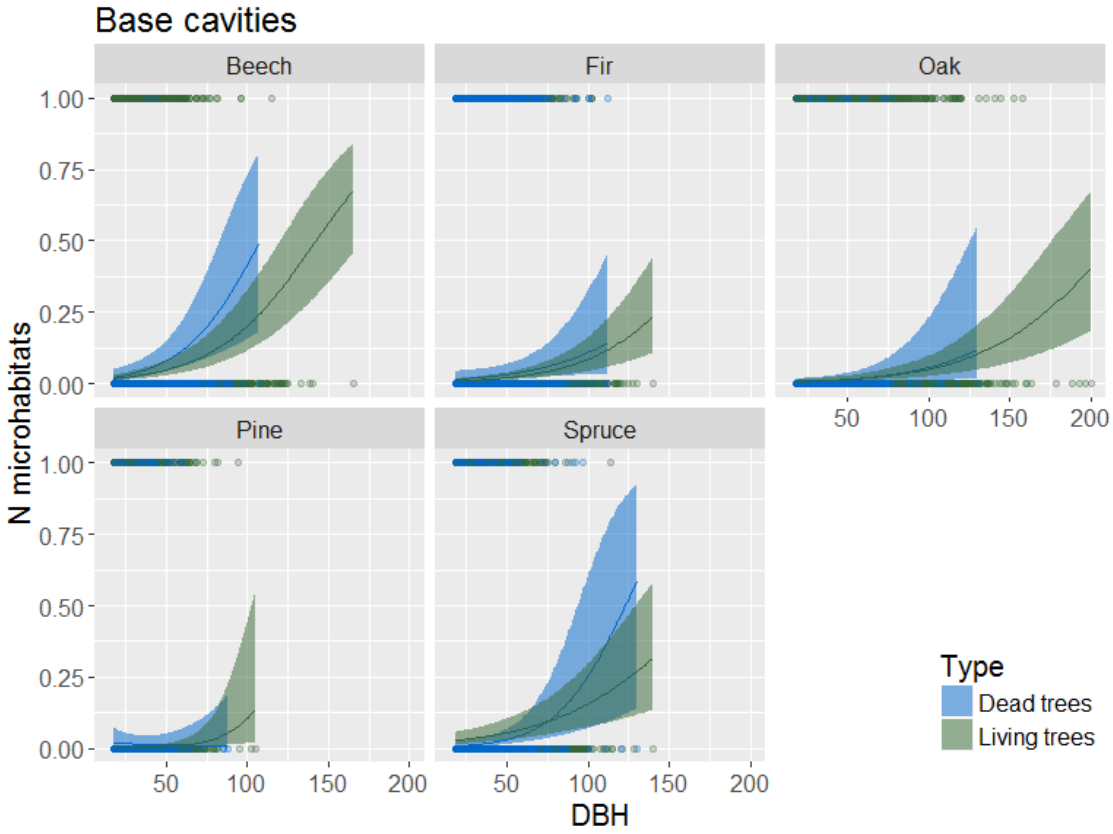
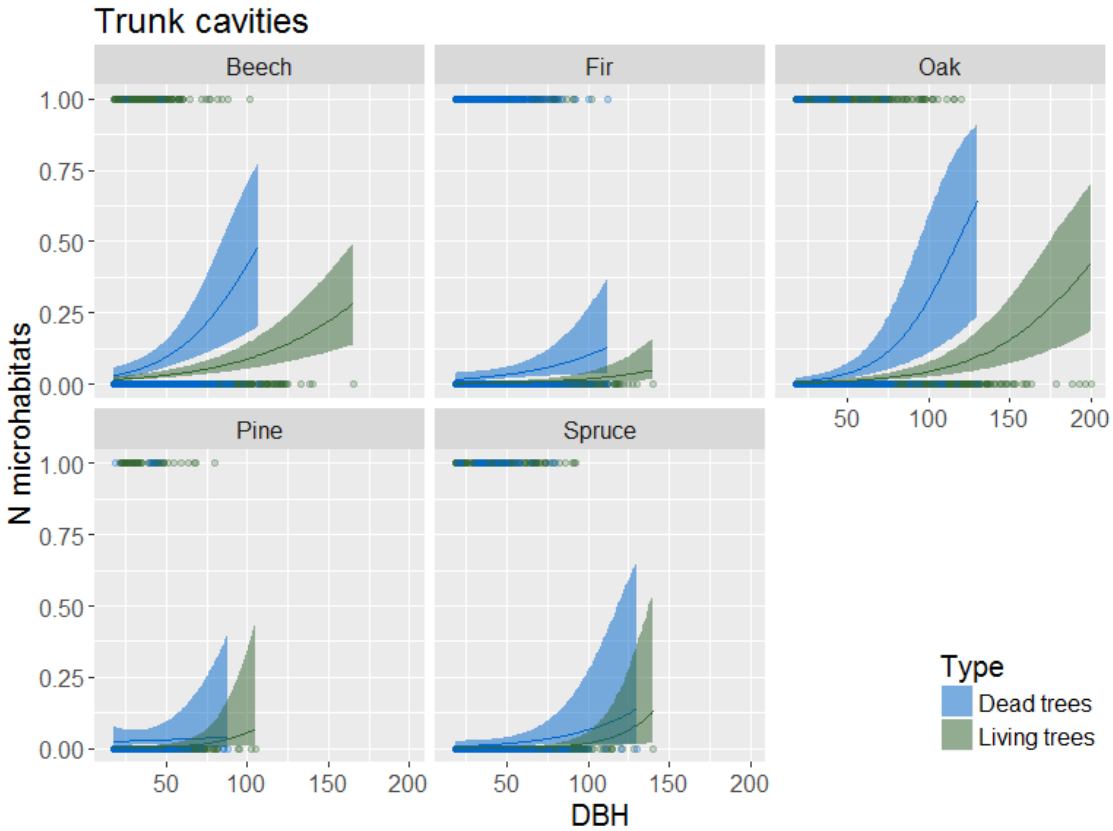
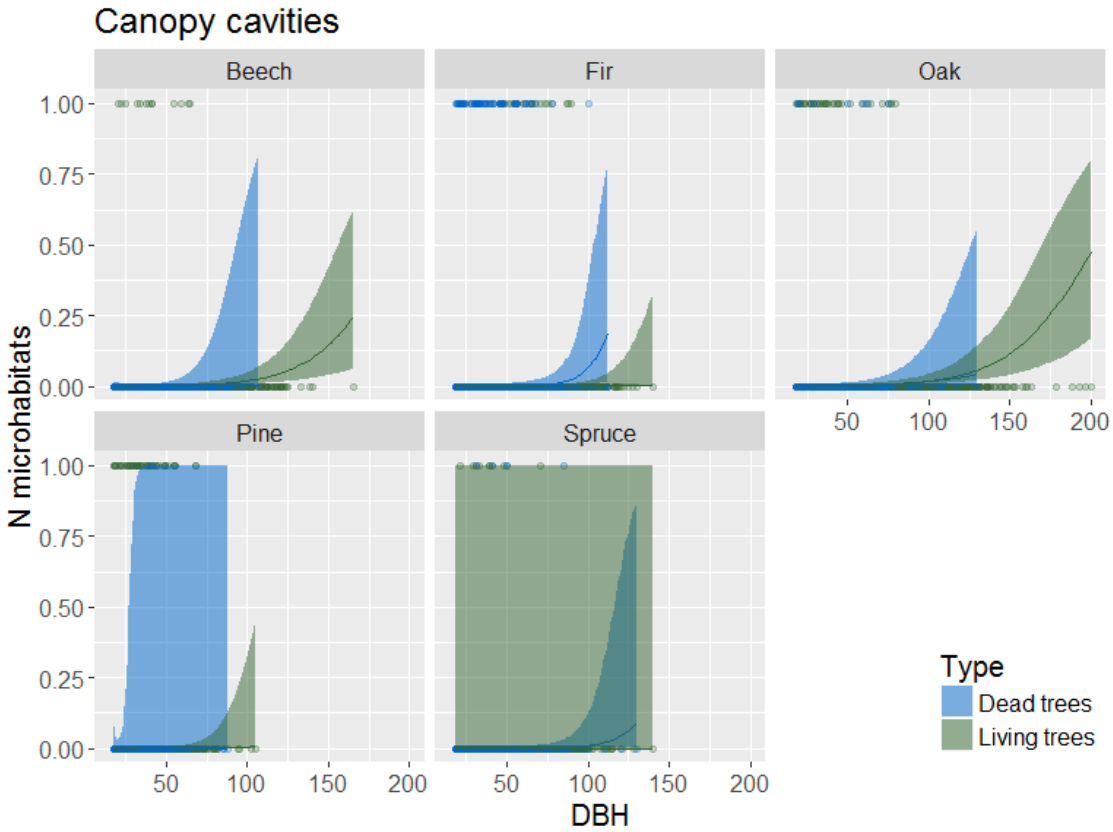


Figure S2: Relationship between occurrence of microhabitats per tree and Diameter at Breast Height (DBH) by species and live status (living vs. dead standing trees). The line represents the estimation issued from a generalized mixed effect mode with Binomial error distribution. The ribbons represent the 95% confidence interval of the mean. Principal component analysis eigenvalues were hold constant for the representation.

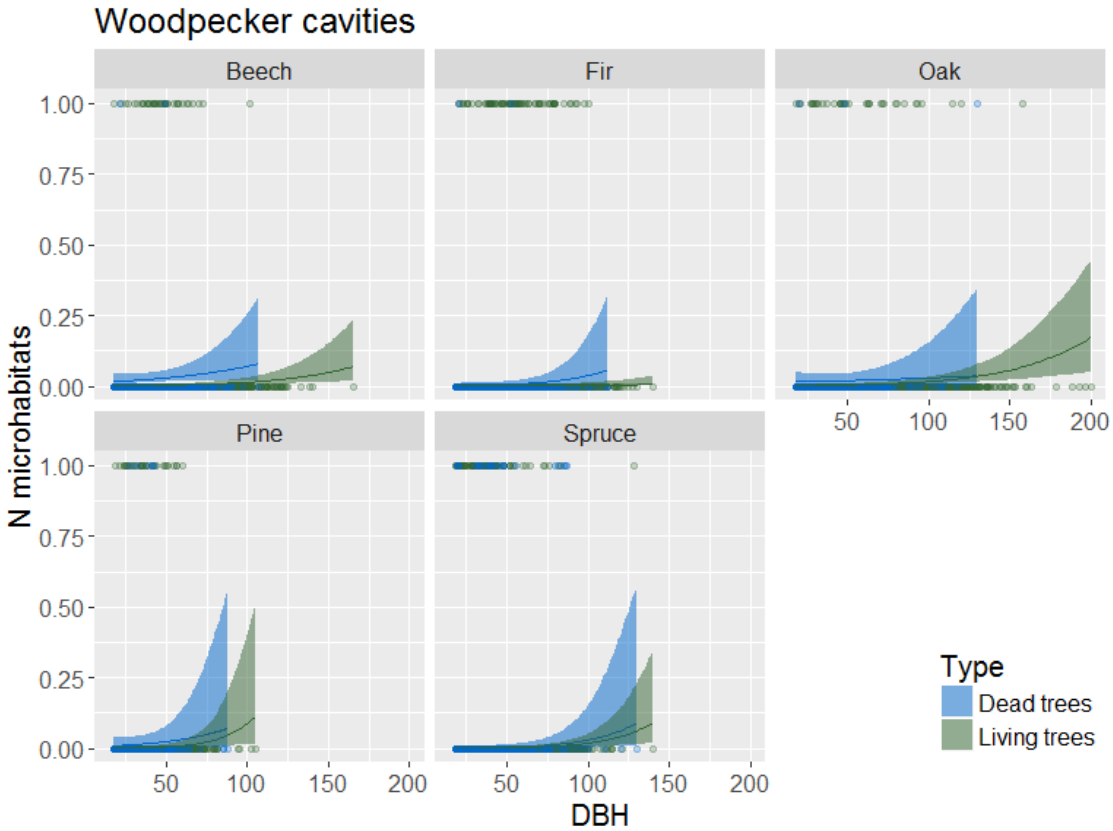



Trunk cavities
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

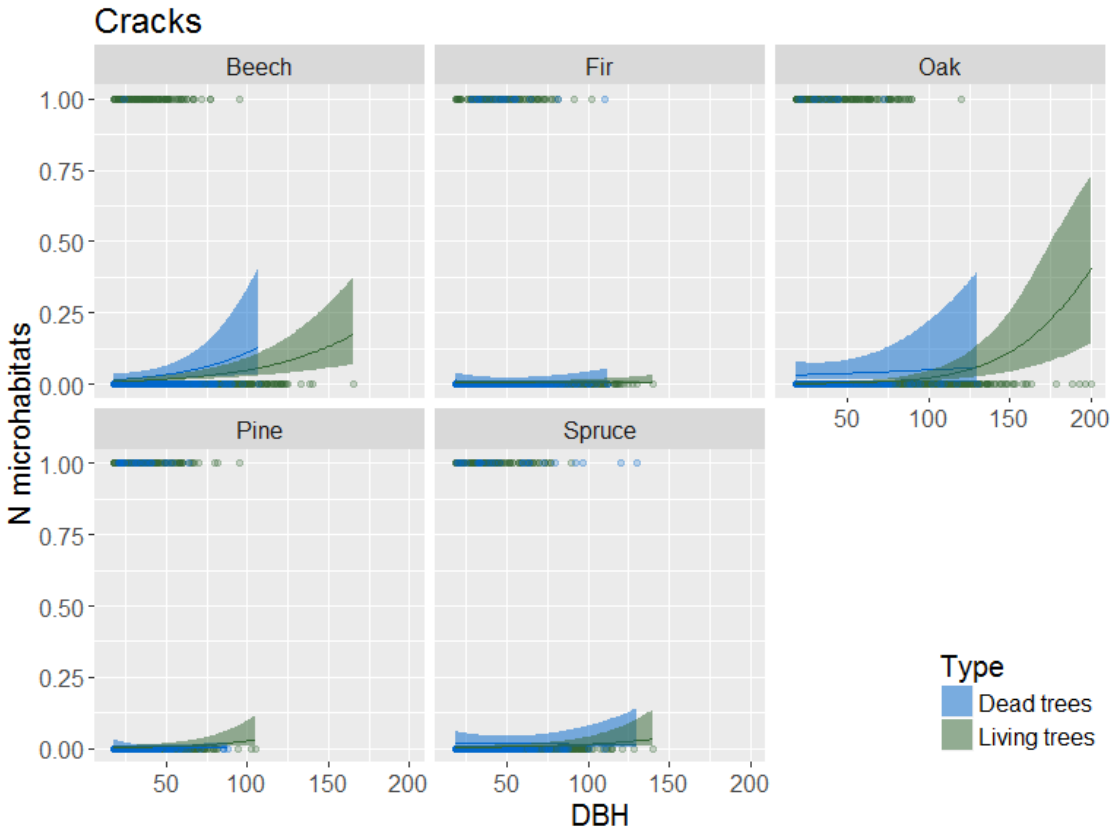
558


Canopy cavities
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

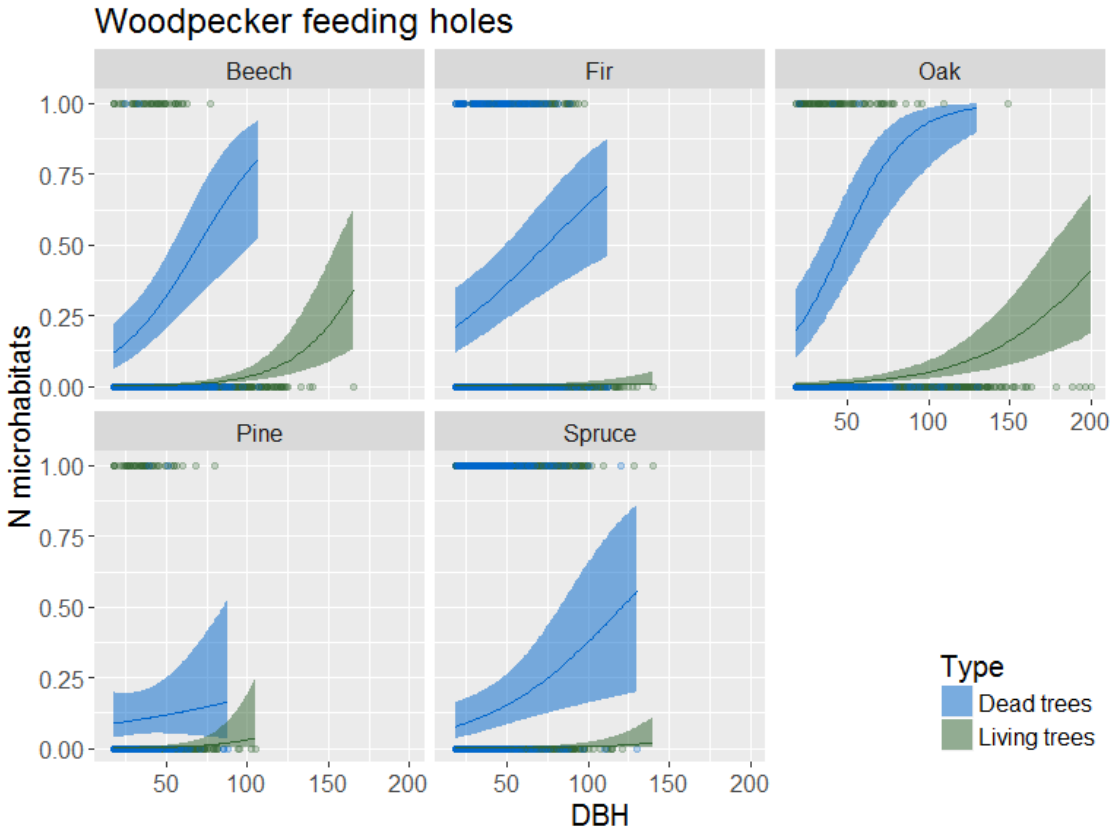
559


Woodpecker cavities
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

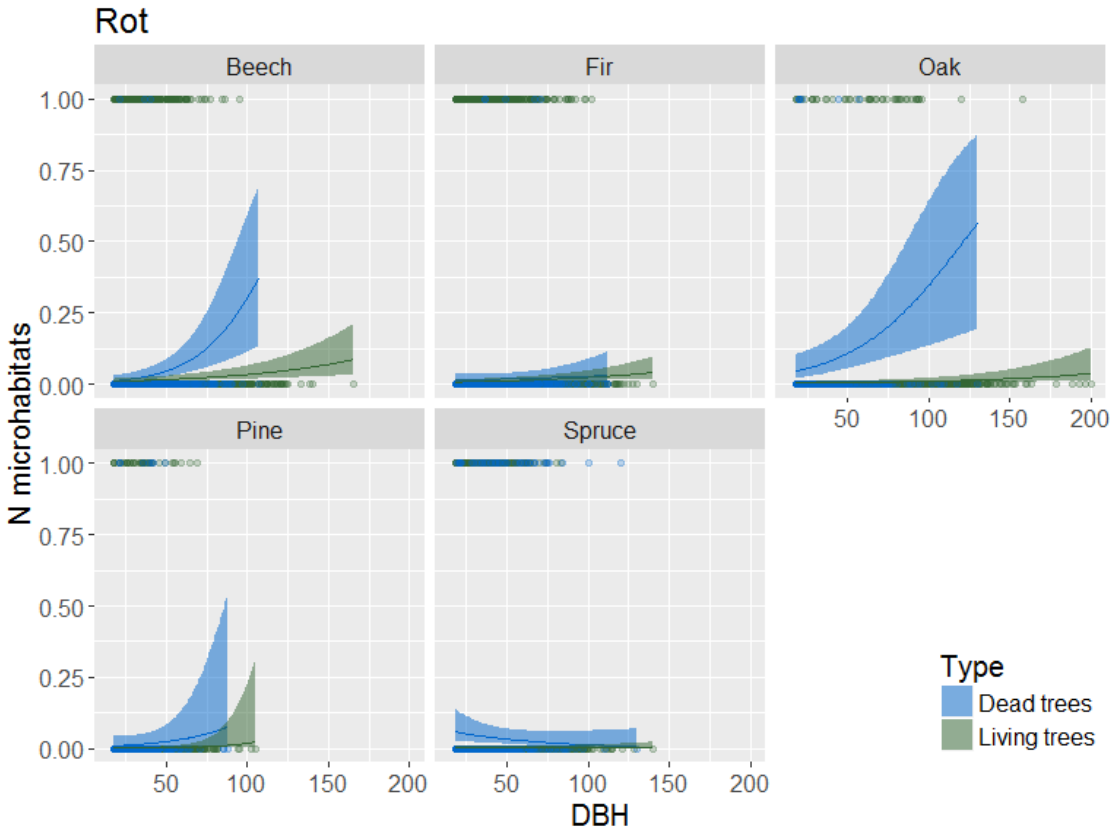
560


Cracks
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

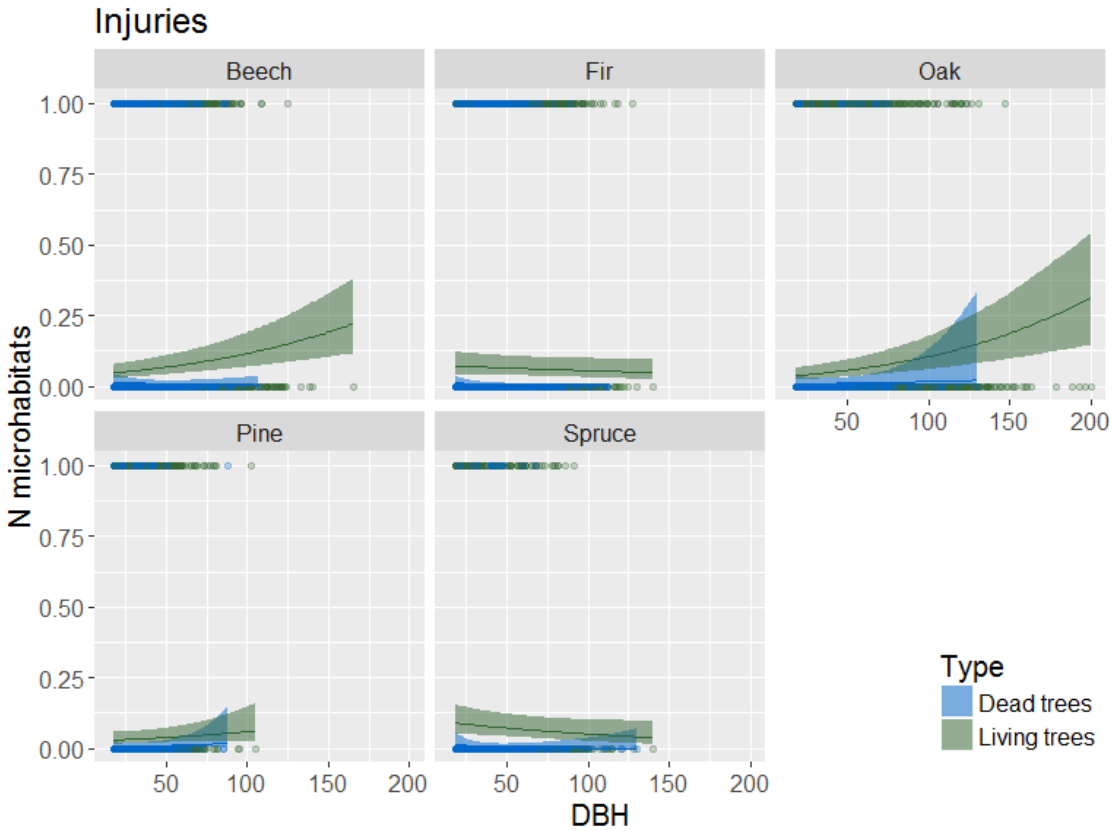
561


Woodpecker feeding holes
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

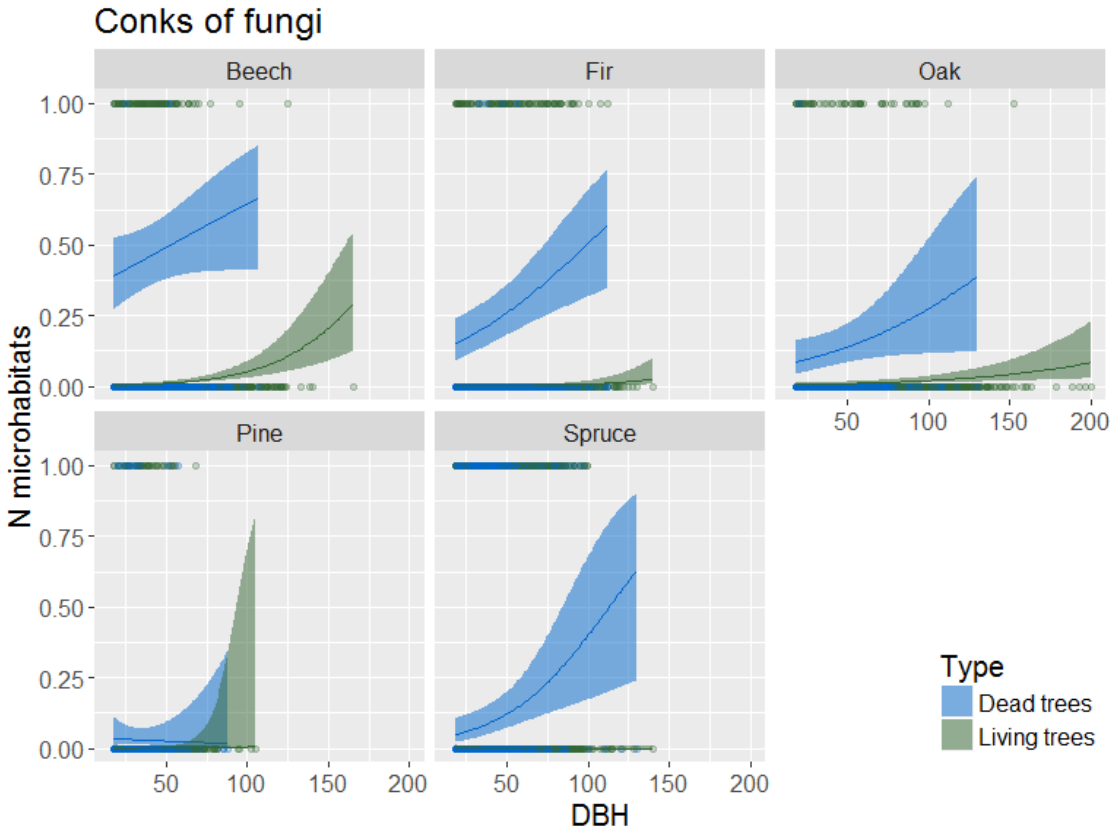
562


Rot
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

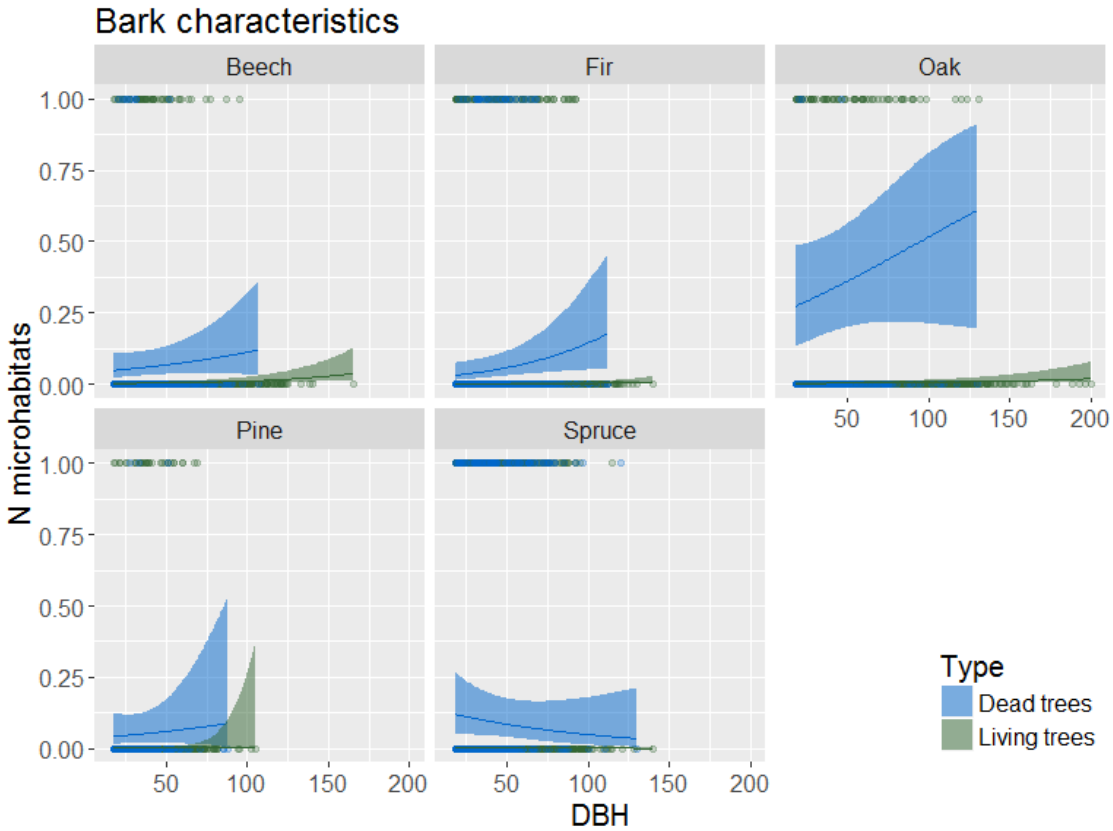
563


Injuries
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

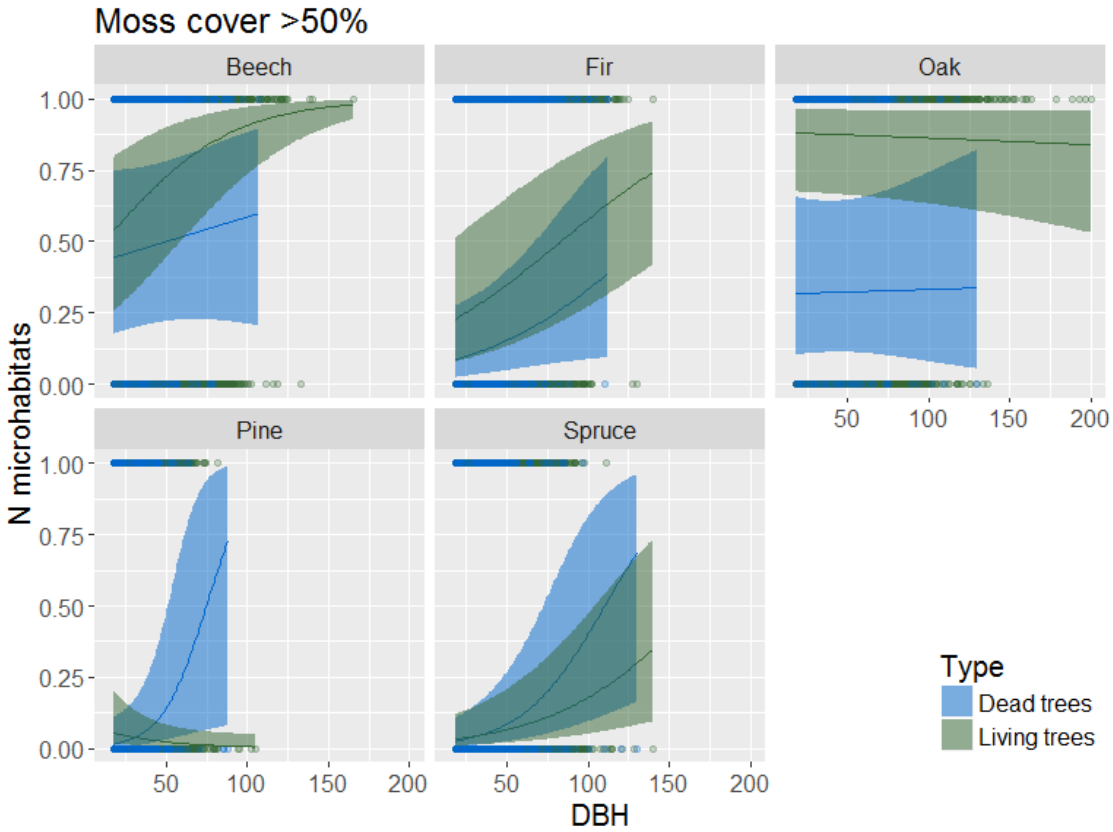
564


Conks of fungi
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

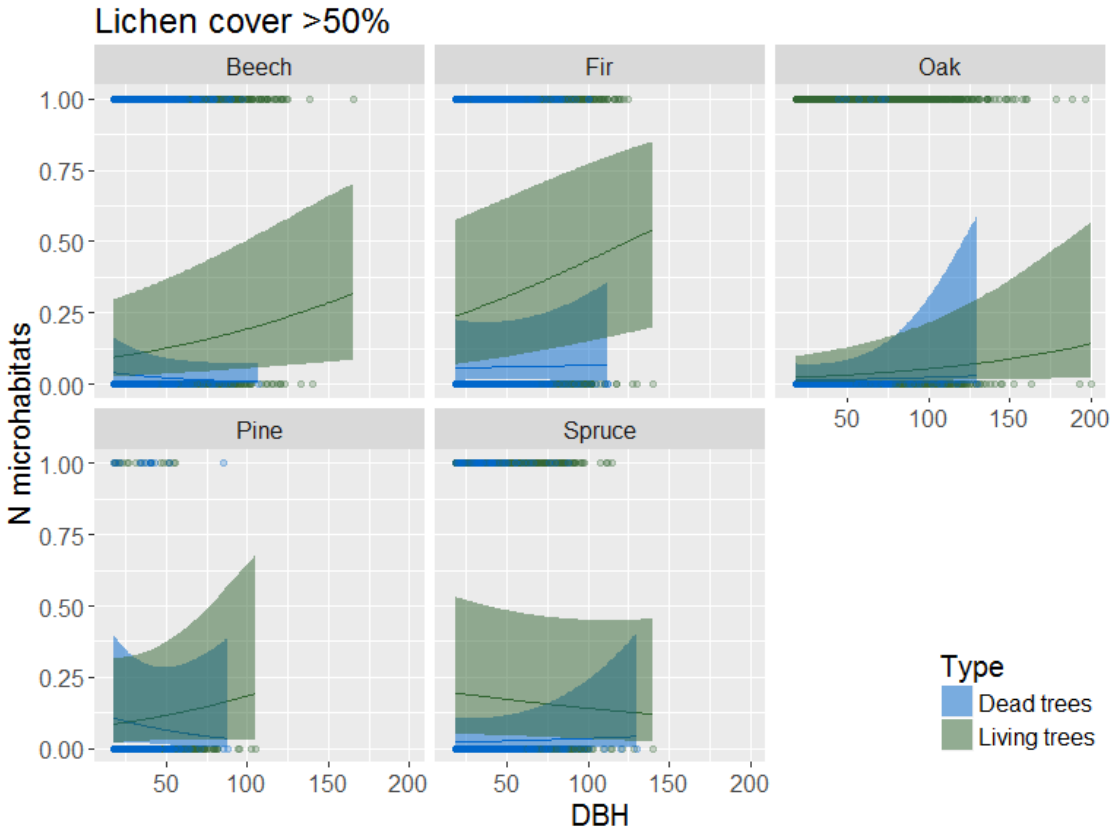
565


Bark characteristics
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

566


Moss cover >50%
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

567


Lichen cover >50%
Beech
Fir
Oak
Pine
Spruce
N microhabitats
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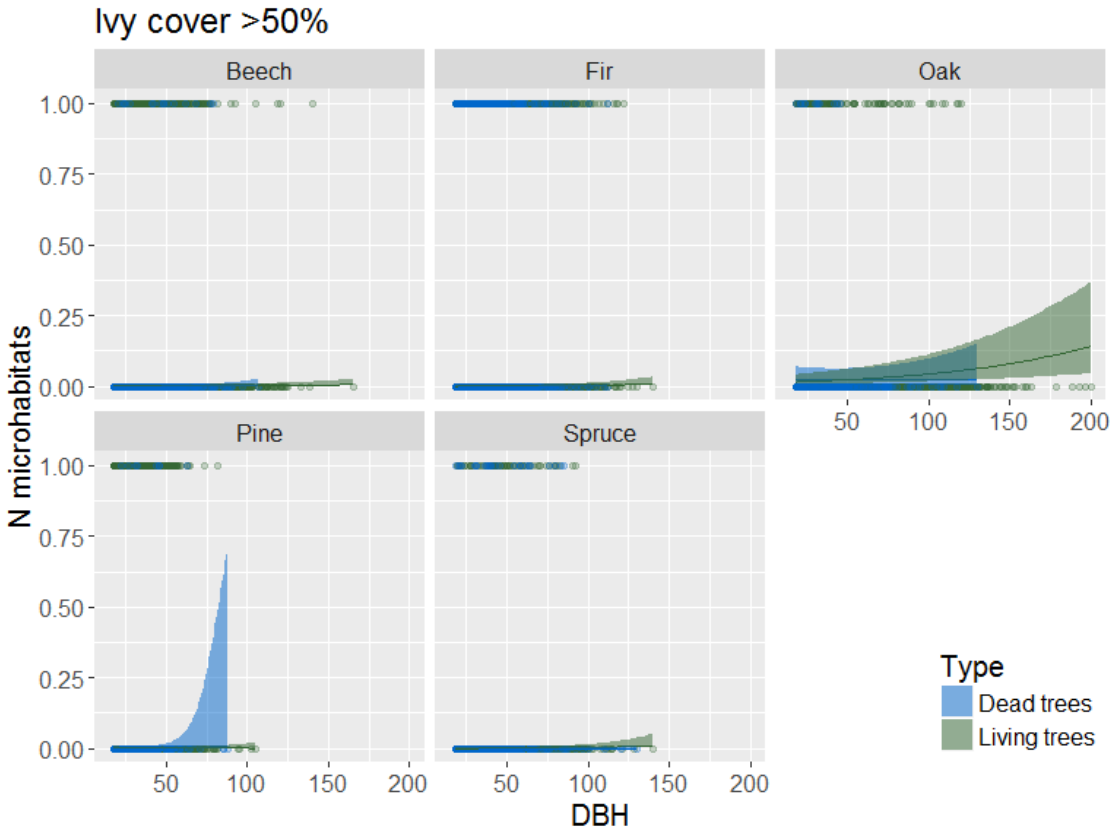
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees


Ivy cover >50%
Beech
Fir
Oak
Pine
Spruce
N microhabitats
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0.75
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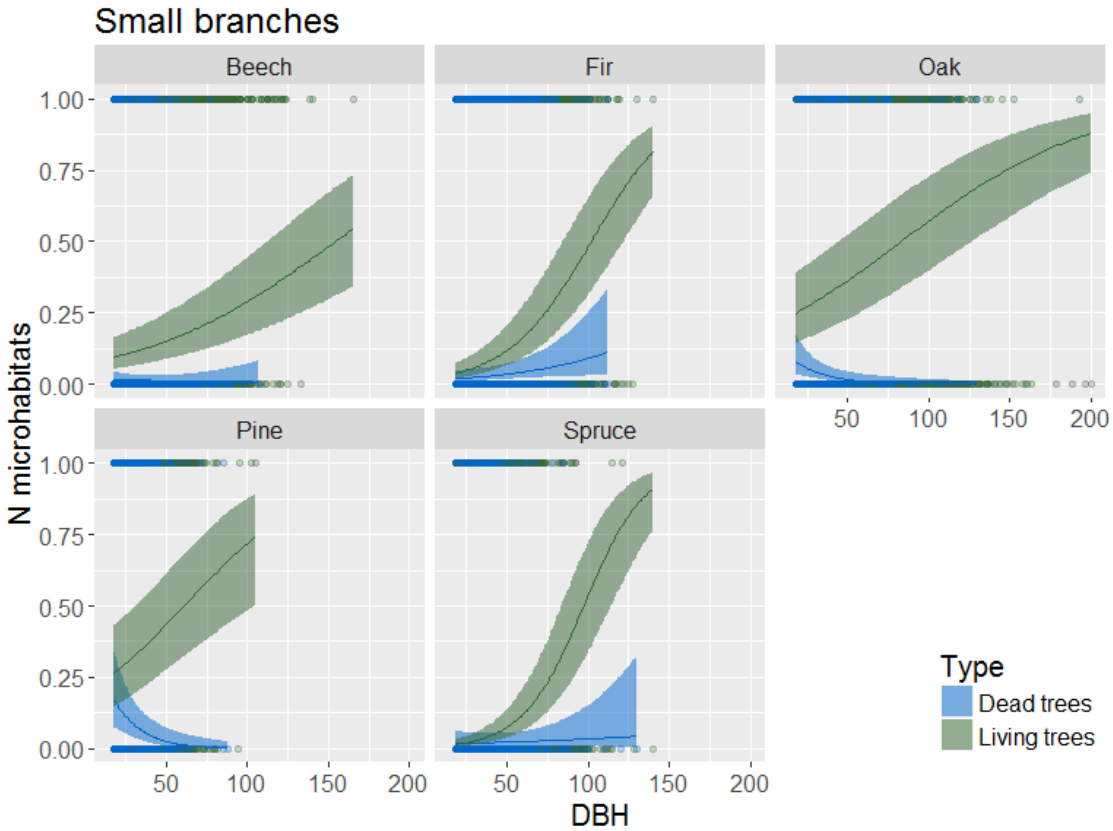
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees


Small branches
Beech
Fir
Oak
Pine
Spruce
N microhabitats
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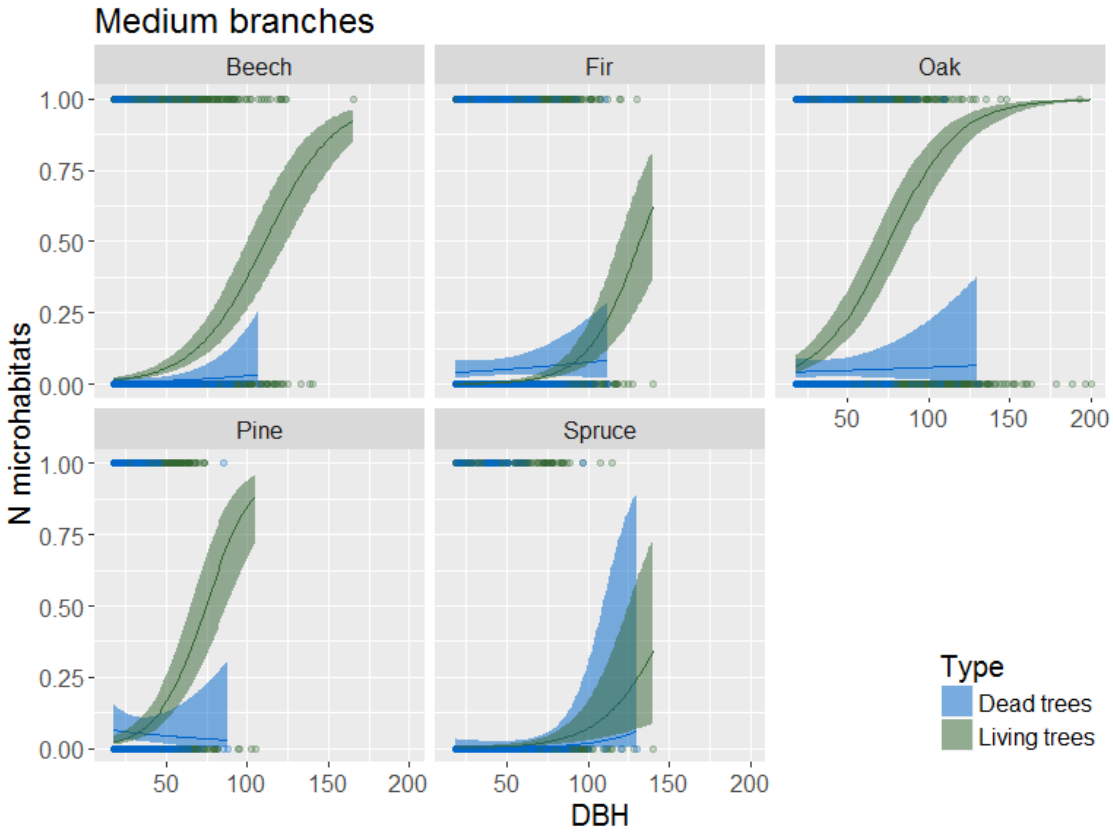
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

570


Medium branches
Beech
Fir
Oak
Pine
Spruce
N microhabitats
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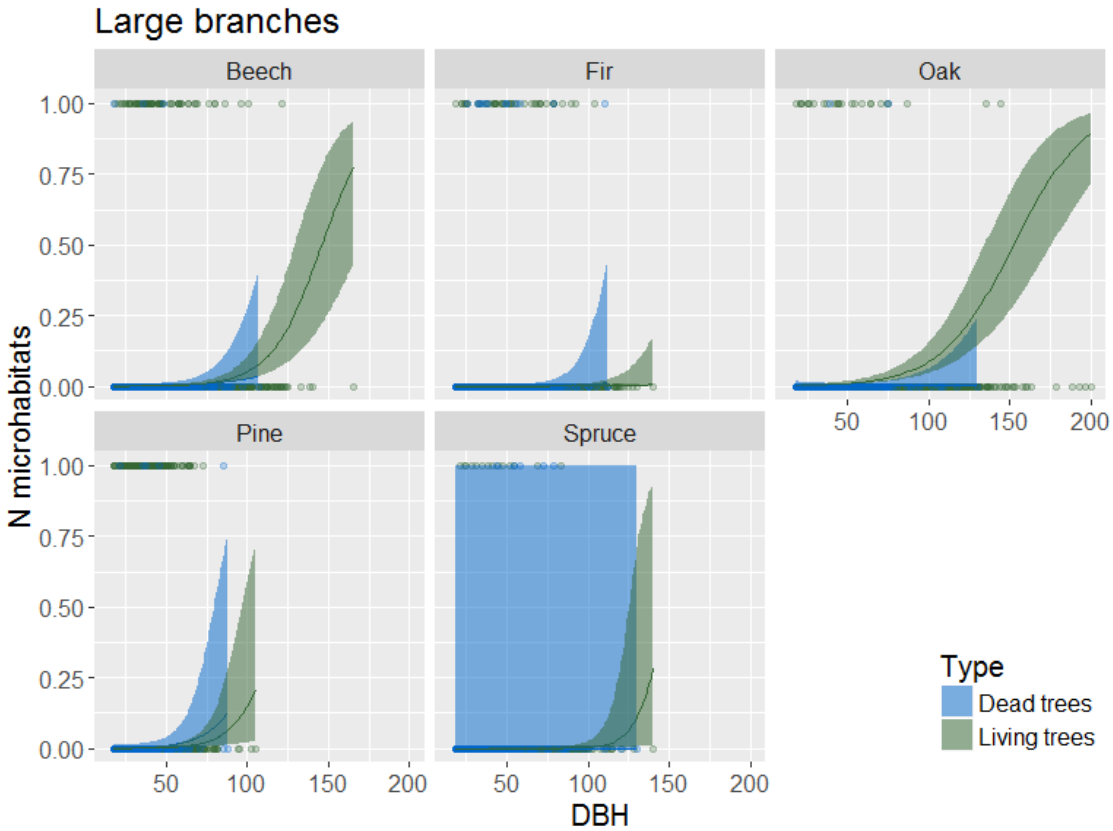
50
100
150
200
DBH
Type
Dead trees
Living trees

571


Large branches
Beech
Fir
Oak
Pine
Spruce
N microhabitats
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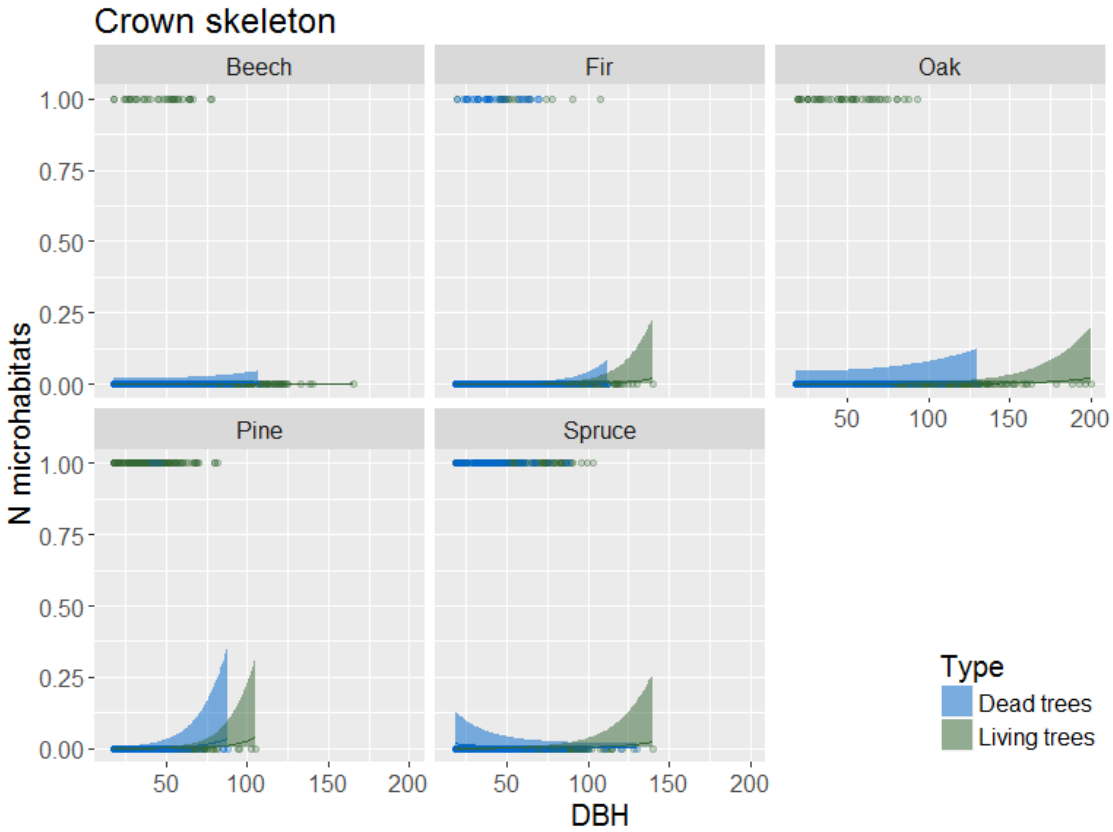
50
100
150
200
DBH
Type
Dead trees
Living trees

572


Crown skeleton
Beech
Fir
Oak
Pine
Spruce
N microhabitats
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0.50
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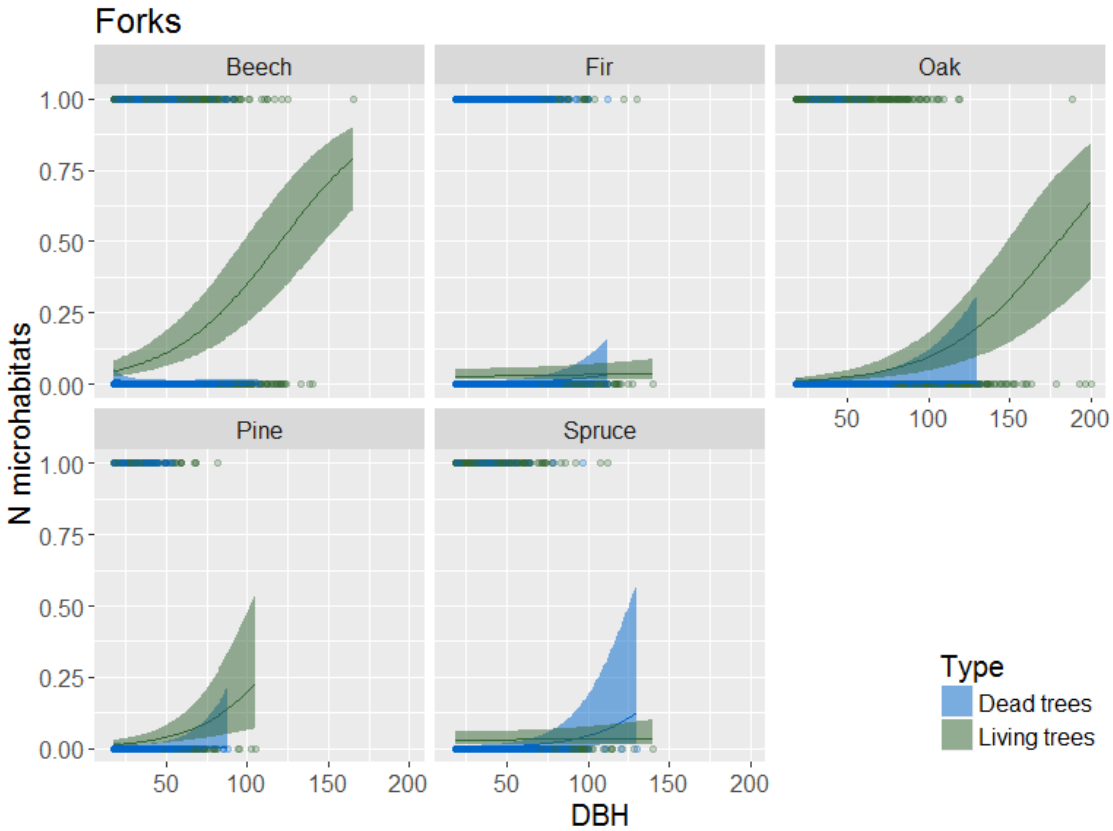
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

573


Forks
Beech
Fir
Oak
Pine
Spruce
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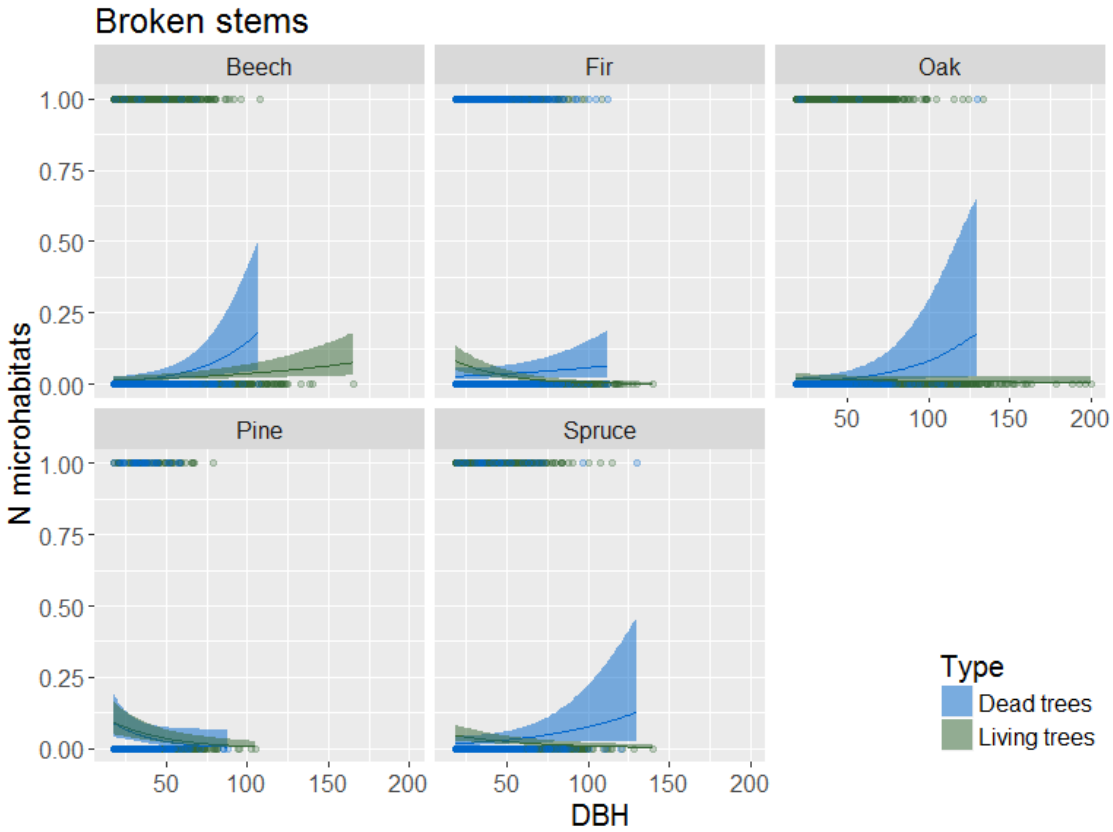
100
150
200
DBH
Type
Dead trees
Living trees

574


Broken stems
Beech
Fir
Oak
Pine
Spruce
N microhabitats
1.00
0.75
0.50
0.25
0.00
50
100
150
200
DBH
Type
Dead trees
Living trees

575