UNIVERSITY OF COPENHAGEN
DEPARTMENT OF GEOSCIENCES AND
NATURAL RESEARCH MANAGEMENT

From tree torso to tree ruin

Developing guidelines for management of urban hazard trees in relation to optimizing biodiversity

Christoffer Echtvad Bergstedt
Master thesis 2019

Supervisor: Iben Margrete Thomsen

Submitted on: 2nd September 2019

Name of department: Department of Geosciences and Natural Resource Management

MSc Program: Nature Management

Author: Christoffer Echtvad Bergstedt

KU-ID: Pkv916

Title and subtitle: From tree torso to tree ruin – Developing guidelines for management of urban hazard trees in relation to optimizing biodiversity

Topic description: This thesis deals with a relatively new tool in management of hazard trees termed tree torso. Here it is investigated what benefits tree torsos can have for biodiversity and their relevance in relation to management of urban hazard trees.

Supervisor: Iben Margrete Thomsen

ECTS-point: 30

Submitted on: 02 September 2019

Abstract

Management of hazard trees is becoming more relevant in relation to biodiversity as more woody material is left behind after felling a tree. A new tree structure type termed tree torso that is a standing, heavily pollarded structure, is left behind more frequently in many urban parks in the Copenhagen area. The benefits these have for biodiversity in relation to other tree remnants are unknown as it is a relatively new concept. The aim was to explore the benefits tree torsos have for biodiversity by investigating the presence of microhabitats for different tree remnants. These remnants are tall tree torsos (>3m), tree torsos (<4m), lying stems and tree stumps. Furthermore, the difference in microhabitats recorded with different tree species of these remnants was explored. The data was collected by visiting urban areas and observing microhabitats on the different tree remnants which were recorded through a simple present/absent registration. Additionally, a questionnaire was sent to park managers from the different selected research areas to gain insight into their knowledge and experiences with tree torsos. The results were used to produce guidelines for how to manage future hazard trees with focus on biodiversity. The main conclusions of the study were that tall beech torsos have more microhabitats than beech torsos (<4m) while this was not the case for willow and poplar that had more microhabitats with <4m tree torsos. There was little difference between the different tree structure types in relation to the number of microhabitats apart from a few exceptions e.g. tall tree torsos having more small cavities while lying stems and tree stumps were more beneficial for epiphytes. Furthermore, not every tree remnant provides a wide variety of microhabitats at first, and time is needed to develop certain kinds of microhabitats. This is problematic as not all tree remnants may be allowed to stand for a longer period of time. The selection of hazard trees for tree torsos should depend on variation in tree species, the different microhabitats they already have and their potential to develop more microhabitats over time. This study has shown, that in many cases a large stump and a lying stem can provide most of the microhabitats registered, except for nesting cavities for birds and bats. Lying stems and tree stumps might be the best long-term solution in relation to improving biodiversity in areas where safety concerns have high priority.

Resume

Forvaltning af risikotræer er blevet mere relevant i forhold til biodiversitet, efterhånden som mere af træet efterlades efter fældning. En ny træstrukturtype kaldet en trætorso, der er en stående, stærkt stynede struktur, efterlades oftere i mange urbane parker i København og omegn. Trætorsoer er et relativt nyt koncept, og det er derfor uvist, hvilke fordele de har i forhold til biodiversitet sammenlignet med andre efterladte træstrukturer. Målet var at undersøge fordelene, som trætorsoer har for biodiversiteten, ved at undersøge tilstedeværelsen af mikrohabitater for forskellige efterladte træstrukturer. De undersøgte træstrukturer er høje trætorsoer (>3m), trætorsoer (<4m), liggende stammer og stød. Derudover blev forskellen undersøgt for forskellige træarter i forhold til de registreret mikrohabitater på de forskellige træstrukturer. Data blev indsamlet fra byområder og mikrohabitater blev observeret på de forskellige træstrukturer, som blev registreret gennem en simpel tilstede / ikke tilstede registrering. Derudover blev der sendt et spørgeskema ud til parkforvaltere fra de forskellige udvalgte byområder for at få indsigt i deres viden og oplevelser med trætorsoer. Resultaterne blev brugt til at udforme nogle retningslinjer for, hvordan man håndterer fremtidige risikotræer med fokus på biodiversitet. Undersøgelsens hovedkonklusioner var, at høje bøge torsoer har flere mikrohabitater end bøge torsoer på under 4 meter, mens dette ikke var tilfældet for pil og poppel, der havde flere mikrohabitater i trætorsoer under 4 meter. Der var stort set ingen forskel mellem de forskellige træstrukturtyper i forhold til antallet af mikrohabitater bortset fra nogle få undtagelser, f.eks. har høje trætorsoer flere små huller, mens liggende stammer og stød kan have flere epifytter. Desuden understøtter ikke alle træstrukturer en stor mængde mikrohabitater til at begynde med, og der er brug for tid til at udvikle visse former for mikrohabitater. Dette er problematisk, da ikke alle træstrukturer kan have lov til at stå i en længere periode. Udvælgelsen af risikotræer, der skal blive til trætorsoer, bør være på baggrund af variation i træarter, de forskellige mikrohabitater de allerede har, og deres potentiale til at udvikle flere mikrohabitater over tid. Denne undersøgelse har vist, at et stort stød og en liggende stamme i mange tilfælde kan give de fleste af de registrerede mikrohabitater bortset fra redehuller til fugle og flagermus. Liggende stammer og stød er muligvis den bedste langsigtede løsning i forhold til forbedring af biodiversiteten i områder, hvor sikkerhedsproblemer har høj prioritet.

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Tree Microhabitats

Introduction

The basic understanding of a habitat is an area or location where an organism or a community lives, and it is characterized by its biotic and physical properties (Rasmussen & Sloth, 2005). Habitats are further made up of abiotic and biotic factors that diversify and separate different habitat types. The abiotic factors include temperature, light, soil, humidity and wind, while the biotic factors can be related to presence or lack of predators and food availability (Chapin *et al*., 2012). A microhabitat is a smaller component of a bigger habitat, which constitute specific conditions required by an organism related to variation in abiotic factors. Trees can harbour many different microhabitats for a variety of species, and the more diversified the tree structure is, the more microhabitats can be present. Furthermore, different tree species may provide different microhabitats and develop microhabitats at different time rates.

A human torso is defined as the trunk of human statue apart from limbs and head (Sykes *et al*., 1982). The same definition can be used for a tree torso as it is mainly the trunk that is left where the "head" and "limbs" have been cut off. In this project, tree torsos with limbs are still included, but the tree will always be heavily pollarded. Furthermore, we define tree torsos as being around two meter in height or more, anything under would be classified as a stump or a tall stump. Tree torsos are often dying or dead wood but can in some cases be living with some branches still sprouting leaves or with epicormic shoots.

Dead wood is a highly variable resource depending on a wide variety of extrinsic and intrinsic factors, supporting many insects, fungi and other organisms. Dead wood differs depending on the tree species it originated from with importance to physical and chemical differences. Standing dead trees are often drier and decompose at a slower rate than lying dead wood. The heartwood of old trees, that are still alive, may also be considered dead wood especially as the wood starts to decompose due to decay fungi. This often forms hollows that is a valuable habitat for many organisms when exposed to the outside. Wood experiences different chemical and physical changes as it decomposes. When a tree dies it is quickly colonized by a variety of wood-digesting bacteria, fungi and other microbes which account for a large proportion of rotting wood biomass (Ulyshen & Sobotnik, 2018).

Saproxylic insects are a group of insects depending on dead or dying wood either directly or indirectly. This group mainly consist of Coleoptera (beetles), Hymenoptera (wasps, bees, ants and sawflies) and Diptera (true flies) but includes other insect groups as well. Those that consume woody parts such as wood, bark, phloem for food are the directly dependent species while the indirectly dependent species are those that feed on other dependent species or require dead wood for nesting etc. Besides the saproxylic species, many other invertebrates benefit from the presence of dead wood without requiring it which is e.g. seen with hibernating insects that gain a shelter for overwintering. Saproxylic insects have different functional groups where the main groups are wood feeders, phloem feeders, predators and fungus feeders, but other groups can also be considered saproxylic such as sap feeders, cavity-nesting bees and wasps, and aquatic insects confined to dendrotelms (water-filled holes in trees). The secondary phloem layer just beneath the bark is a desirable resource due to it being sugary and protein rich while the wood is hard to chew and difficult to digest. Wood is also characterized by very low concentrations of nutrients, but the substrate is very rich in relation to energy content. Utilization of wood as a diet is mainly made possible by interactions with prokaryotes, fungi and other microbes. Wood is not as nutritious as fungal biomass which can provide a food source for many insects while also enriching the food source and provide enzymes that helps with the digestion of wood. An example is with various termites that prefer to feed on wood decayed by fungi. The fungal food source can be hyphae under bark or in the case for many beetles and flies, fungal fruiting bodies. Some specialized groups of fungus feeders feed on symbiotic fungi that they cultivate within their nests or galleries. Furthermore, fungi can modify and improve habitat conditions by softening the wood, killing trees and make it more accessible for saproxylic insects. Predators make up another large group of insects associated with dead or dying wood, where the more specialized are parasitoids (kills the host in the end) on saproxylic species (Ulyshen & sobotnik, 2018).

Three decaying phases related to succession of insects are the phloem, subcortical-space and the rot phase. The phloem phase is the first, but also the shortest of the phases and last until the nutritious phloem layer underneath the bark has been entirely degraded by fungi and insects. The subcortical-space phase begins when the phloem layer is partly degraded and last until the bark has completely fallen off. The rot phase is the longest phase and last until the wood is completely incorporated and humified into the soil. As a tree falls to the ground, breakage and fragmentation often occur which produce damaged areas that decay more rapidly. Moisture levels are also important in relation to decay as tree parts in contact with the soil decay more rapidly than those elevated. Furthermore, heartwood often decays at a slower rate than sapwood in dead trees; whereas in living trees the sapwood and the phloem will be the last parts to die and decay. A variety of rot occur when different wood-decaying fungi colonize parts of a tree (Ulyshen & Sobotnik, 2018).

Fungi are the most conspicuous and important organisms in relation to their capability of digesting lignocellulose. Especially filamentous fungi are effective at decomposing wood as they quickly extend deep within the wood where they can translocate nutrients and water between locations by use of their mycelia. There are three main wood-rotting fungal types; white rot fungi, brown rot fungi and soft rot fungi. White rot fungi are common in hardwoods where they degrade all basic units of wood such as cellulose, lignin and hemicellulose, although many white rot fungi are selective delignifiers especially in conifers. Brown rot fungi are primarily associated with conifers and are incapable of degrading lignin, but some brown rot fungi are specialized in degrading tannin-rich heartwood, such as sulphur polypore (*Laetiporus sulphurous)* on oak. Soft rot fungi are capable of degrading hemicellulose and cellulose, but the degradation is less extensive than brown rot. Soft rot fungi are inhibited by white and brown rot fungi and thrives more in wood saturated with water. Fungal fruiting bodies are known to create shelter for a variety of arthropods and insects (Ulyshen & Sobotnik, 2018).

Bacteria are also important organisms for the degradation of wood, but due to their limited mobility and small size, are often more active where mycelial fungi are less abundant. Such situations would be in tree wounds, aquatic environments, sap flows and highly decomposed wood. There are three forms of bacterial decay; Tunnelling, erosion and cavitation. In tunnelling, bacteria penetrate cell walls and seems to be able to degrade lignin besides hemicellulose and cellulose. In erosion, bacteria present in wood cells creates flows through the cell walls. Cavitation is more restricted to certain situations and involves forming cavities within the cell walls (Ulyshen & sobotnik, 2018).

Tree hollows are mainly formed by biotic factors, but also to a lesser degree abiotic factors, which make each hollow unique and they can host a wide variety of saproxylic insects. Tree hollows are considered patchy habitats, but they provide long-lasting resources and a stable abiotic environment. Cavities can be wet, moist or dry depending on the exposure and size of the opening which will determine the composition of insects and fungi (Micó, 2018). Kraus et al. (2016) have included five categories of cavities in their catalogue of tree microhabitats, which are trunk cavities, insect galleries and bore holes, woodpecker cavities, dendrotelms and branch holes. Watson & Green (2011), describes hollowing as a natural occurrence and a co-evolutionary relationship between fungi, tree, bacteria and other organisms.

Primary cavity nesters such as woodpeckers are part of developing small holes (<10cm) in trees, which is used for nesting, but even bigger holes are developed as part of the feeding behaviour of these species that can leave excavated parts on the tree trunk. The creation of nesting holes often takes place in partly dead or weakened wood. These holes can then be used by secondary cavity nesters, who do not excavate their own holes, which includes birds as well as bats (Zawadzka & Zawadzki, 2017: Lowe et al., 2011). These holes can further serve as an entry point to the tree for other organisms, such as fungi and insects. The size, position and shape of these cavities depend on the species of woodpecker, and these cavities also have high nitrogen inputs from dead nestlings, food remains and faeces. This make the habitat more suitable for invertebrate colonization (Micó, 2018). Furthermore, woodpeckers can be used as an indicator for other species that depend on these cavities for roosting, nesting and feeding (Morrison & Chapman, 2005).

A wide variety of pockets of decay and rot holes is a common appearance when trees die (Micó, 2018). Rot-holes, alternatively termed branch holes, can be created by breakage at the trunk or through human management, such as removing branches hanging over roads and railways. These cavities mainly occur in slow growing trees when the fungal decay of wood is faster than the closing of the wound and the fungus *Psathyrella cernua* is suggested to be a key part of creating this microhabitat (Fritz & Heilmann-Clausen, 2010). Some species of wood decaying fungi specialize on heartwood which is part of the creation of tree cavities. The decayed heartwood is colonized by microorganisms and invertebrates that will modify the cavity. The cavity is further expanded by beetle larvae that feed on the wood. Material will eventually accumulate at the bottom of the cavity such as carcasses, excrements, twigs, leaves and seeds (Micó, 2018). Watson & Green (2011), further describes how decay is not a disease, but rather a normal consequence of injury and/or aging in trees. They also explain how the decaying process provides habitats for other organisms and releases nutrients that have been locked up in the wood.

Insect galleries and bore holes provide an entry point for organisms such as fungi and other insects that do not excavate their own holes. Bore holes can provide nesting habitat for wood-nesting solitary bees and wasps while also providing hibernation sites for other insects. Furthermore, galleries are an important hunting place for predators feeding on saproxylic species (Micó, 2018).

Dendrotelms are semi-permanent water-filled holes in trees which provide an important aquatic habitat for insects in the temperate region. The water is mixed with woody debris, leaf litter and tree exudates, such as resin or gum, which create a special habitat for saproxylic aquatic or semiaquatic insects. The microhabitat highly favours larvae of flies in the order Diptera which feeds on different bacteria, protozoan and fungi. Furthermore, these water-filled holes facilitate rot and hollowing of the tree structure which is closely linked to abiotic and biotic factors and contribute to the creation of unique cavities (Micó, 2018).

Aim:

The overall goal with the project is to gain insight into the kinds of tree microhabitats a tall tree torso (>3m) can provide for biodiversity compared to a tree torso (<3m) while also exploring the management aspect of leaving behind these tree remnants. The paper will be divided into two parts, one dealing with the tree microhabitats and one dealing with the management of hazard trees in urban environments. Furthermore, the thesis will provide some recommendations and guidelines for promotion of biodiversity by management of future urban hazard trees.

Scientific questions:

- Which kinds of tree microhabitats are more present in tree torsos than other forms of tree remnants, and is there a difference between tall (>3m) and low (<3m) tree torsos?
- Are there tree species that can provide more tree microhabitats than others, or some tree microhabitats that only some species can provide?
- What do managers of the selected urban areas think of the practise of leaving behind a tall or low tree torso compared to leaving behind a stump or log?
- What is the main reason that managers adopt the practise of leaving behind a tree torso?

Method

Using a field spreadsheet of different tree microhabitats, produced from described microhabitats in Kraus et al. (2016), data is collected from selected urban green spaces (table 1). These green spaces are chosen based on familiarity with the area and on the quantity of tree torsos present at the location. The data collection occurred from 19/03/2019 to 05/04/2019, where no leaves had appeared on the tree structures which was an advantage in relation to spotting microhabitats that would be hidden by leaves in the summer period. The positions and the species of the tree torsos are registered, although the latter can be impossible for old and barkless specimens or for trees that share similar bark structure. This was especially true with the identification of the species of tree stumps that mainly were barkless. Later, Google street view and information received from the managers of the areas helped identifying some of the unknown tree remnants. In addition, revisiting some of the areas helped with the identification as some tree torsos had produced leaves. Tree torsos are further split into tall tree torsos (>3m) and tree torsos (<3m) where microhabitats for the former is registered for the lower (<3m) and the upper (>3m) part. This was decided based on the management practise of the Municipality of Copenhagen, since they in general leave tree torsos at a height of about 3m. It was later noted that many tree torsos were left at 4 meters height, especially in Utterslev Mose. These shared more similarities with the tree torsos (<3m) and thus were added to these. These 4m tree torsos were noted as tall tree torsos at first, but later the high and low part were merged in such a way that a microhabitat only counted once. The height was estimated by using my own height and an arm's reach up in the air, which is approximately 3m, furthermore <4m tree torsos height was noted, as a side note at first, by visual evaluation. For each tree torso all the different tree microhabitats are registered based on whether they are present or absent except for fungi where the number of species is noted as well. This was also done for selected lying stems and tree stumps. The microhabitats were grouped under different categories; cavities, injuries and wounds, bark structures, growth forms, epiphytes. Some microhabitats were merged to make it easier to register such as cavities which were divided into small cavities (<10cm) and large cavities (>10cm). The registration of annual polypores and pulpy agaric was made difficult due to data collection being in the wrong season for many of the species in these categories. Some samples were still observed as they still had either decayed fruiting bodies or fresh fruiting bodies. It was necessary to acquire earlier registrations provided by e.g. the Municipality of Copenhagen and Iben Thomsen. Furthermore, blue marks were noticed, especially in Fælledparken, as meaning the tree would have been infected with *Meripilus giganteus* if it had multiple blue marks while a single blue mark could be *Polyporus squamosus*. For each registration a series of photographs were taken to use as documentation while also providing prime examples of the different tree microhabitats.

Additionally, an extra fieldtrip was taken to a somewhat untouched forest to get examples of older tree torsos to be used as reference of what the younger urban tree torsos can become. Also, other examples were gathered around this area, but this was mainly to gain more observations of different main tree species. Main tree species refers to already collected data as the extra fieldtrip was done some time after the original data collection. The main tree species and genera are beech and willow (with most registrations) followed by birch, oak and poplar. All the main tree species had over 10 registrations. Other tree species were grouped together with unknown species and included e.g. maple, robinia, linden, ash, alder, elm and different conifers.

Table 1: *Background table. Overview of the different selected research areas. Registration area was measured using a polygon tool provided by Arealinfo.dk. Water bodies and islands in the area was subtracted from the estimated registration area as tree torsos were only registered in the terrestrial environment and in areas reachable by foot. Furthermore, Utterslev Mose was divided in to two areas when looking at the registration area where west includes Vestmosen and Kirkemosen and east include Midtmosen and Østmosen.*

Name	Type	Purpose	Owner	Main tree species	Location	Registration area	Registration dates
Frederiksberg Campus (Landbohøjskolens Have)	Public park/garden	University park, educational, biodiversity and recreation	University of Copenhagen	Broadleaves, conifers, exotic species	Copenhagen, Frederiksberg	3.32ha	March 2019
Ryvangen Naturpark	Public nature park	Recreation, biodiversity and some historical aspects	Municipality of Copenhagen	Mixed broadleaves	North from Ryparken station, Northern part of Østerbro, Southern part of Hellerup	7.19ha	March 2019
Bellahøjparken	Public park	Recreation and biodiversity	Municipality of Copenhagen	Mixed broadleaves	Copenhagen, Bellahøj	5.32ha	March 2019
Degnemosen	Public bog/lake	Recreation and biodiversity	Municipality of Copenhagen	Mixed broadleaves	Copenhagen, Bellahøj	2.53ha	March 2019
Bispebjerg	Public	Recreation,	Municipality	Broadleaves,	Copenhagen NV	38.06ha	March 2019

Kirkegård	Cemetery	biodiversity and to bury the dead	of Copenhagen	conifers, exotic species	(North west), Bispebjerg		
Fælledparken	Public park	Recreation and biodiversity	Municipality of Copenhagen	Beech, broadleaves, few conifers	Østerbro, Copenhagen	39.78ha	March 2019
Søndermarken	Public park	Recreation and biodiversity	the Agency for Culture and Palaces	Mixed broadleaves, conifers	Copenhagen, Frederiksberg	28.14ha	April 2019
Frederiksborg Slotspark	Public castle park	Recreation, cultural/historical and biodiversity	the Agency for Culture and Palaces	Mixed broadleaves	Hillerød, Northern Zealand	48.17ha	April 2019
Utterslev Mose (Østmosen, Midtmosen, Vestmosen and Kirkemosen)	Public bog/lake	Recreation and biodiversity	Municipality of Copenhagen	Willow, Poplar, broadleaves	Brønshøj, Utterslev, Emdrup, Copenhagen NV (North west)	West – 32.67ha East – 37.19ha	April 2019

Results

In this section, data collected in the field will be presented with tables and graphs. First the amount of different tree structures will be presented overall (table 2). Second the mean value of microhabitats for different tree structure types will be presented by graphic representation to give an idea of how many microhabitats there are on average in the tree structure. Then a less detailed graph that shows all the different microhabitats and their mean value for the different tree structures to get an idea of how the distribution of these are across the different tree structures. Lastly there will be some graphs that showcase the microhabitats for the different main tree species. To view the total amount of registered microhabitats for each tree structure, see graph in appendix 1.

Table 2: *Table containing the amount of different tree structure types registered for each area. For convenience some areas have been grouped and furthermore Utterslev Mose has been split into west and east. Note that lying stems and tree stumps were chosen as samples within the observation area and many were excluded. These were collected as examples, which is why we see less of these. Both kinds of tree torsos were collected with only a few excluded from Utterslev Mose. Furthermore, some might have been overlooked when collecting data. Note that Frederiksborg Slotspark has a higher number of tall tree torsos, this might be because it is a more forest like environment. Also note that there is a higher number of tree torsos (<4m) in Fælledparken and both Utterslev Mose locations, this is due to a new initiative in Fælledparken (recently) and an old initiative in Utterslev Mose (10 years ago). In total 73 tall tree torsos, 79 tree torsos, 29 lying stems and 46 tree stumps were registered.*

Area	**Tall tree torso (>3m)**	**Tree torso (<3m) + (<4m)**	**Lying stem**	**Tree stump**
Frederiksberg Campus (Landbohøjskolens Have)	4	4	1	1
Ryvangen Naturpark	6	5	2	7
Degnemosen and Bellahøjparken	4	1	2	3
Bispebjerg Kirkegård	6	4	11	1
Fælledparken	10	20	3	3

Søndermarken	8	4	3	11
Frederiksborg Slotspark	17	7	2	9
Utterslev Mose West (Vestmosen, Kirkemosen)	6	17	1	4
Utterslev Mose East (Midtmosen, Østmosen)	12	17	4	7

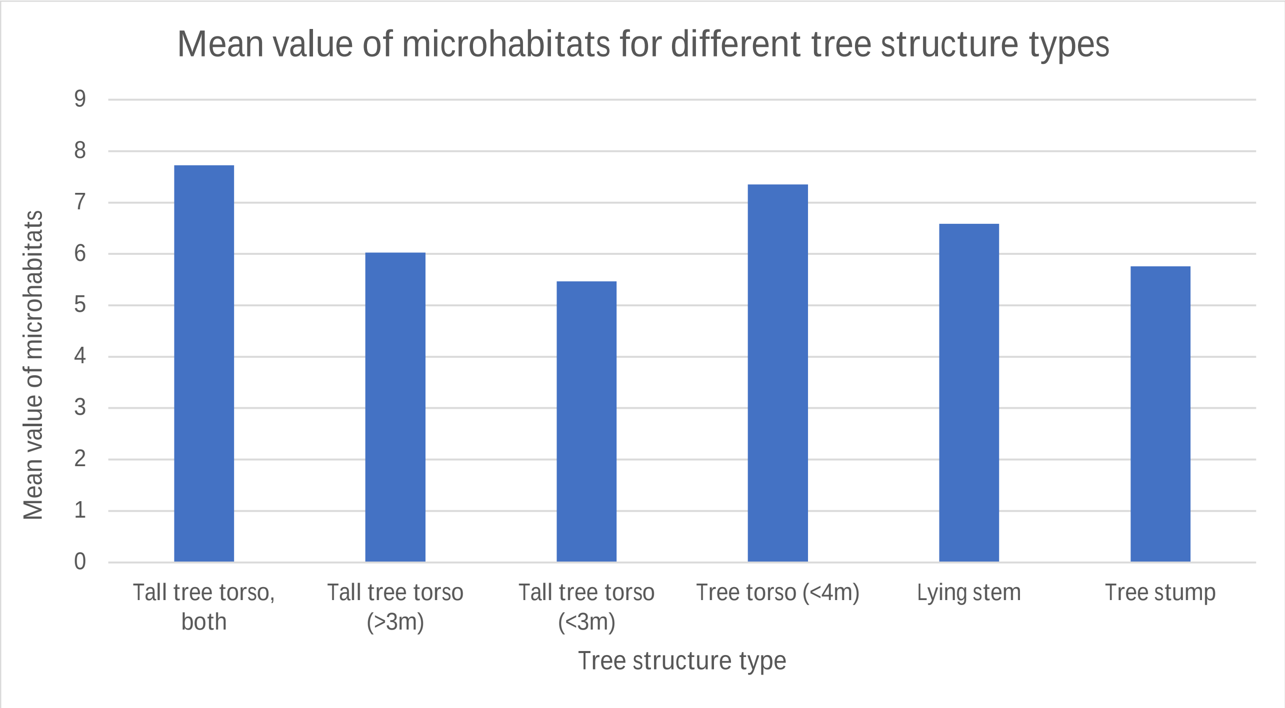


Figure 1: *Shows the overall mean value of microhabitats across all observations for all the different types of registered tree structures. Tall tree torsos are represented as three columns, two where the upper (>3m) and lower (<3m) half are represented and one where they both are included. Tall tree torsos are taller than 4m. Notice that there is no real difference between a tall tree torso in full length compared to a tree torso (<4m). Also, that there is no real difference between the upper and lower part of a tall tree torso. It is important to know that lying stems and tree stumps were selected as scattered samples to represent good examples and thus are subjected to bias. Overall there is not much difference between the different tree structure types when disregarding tree species.*

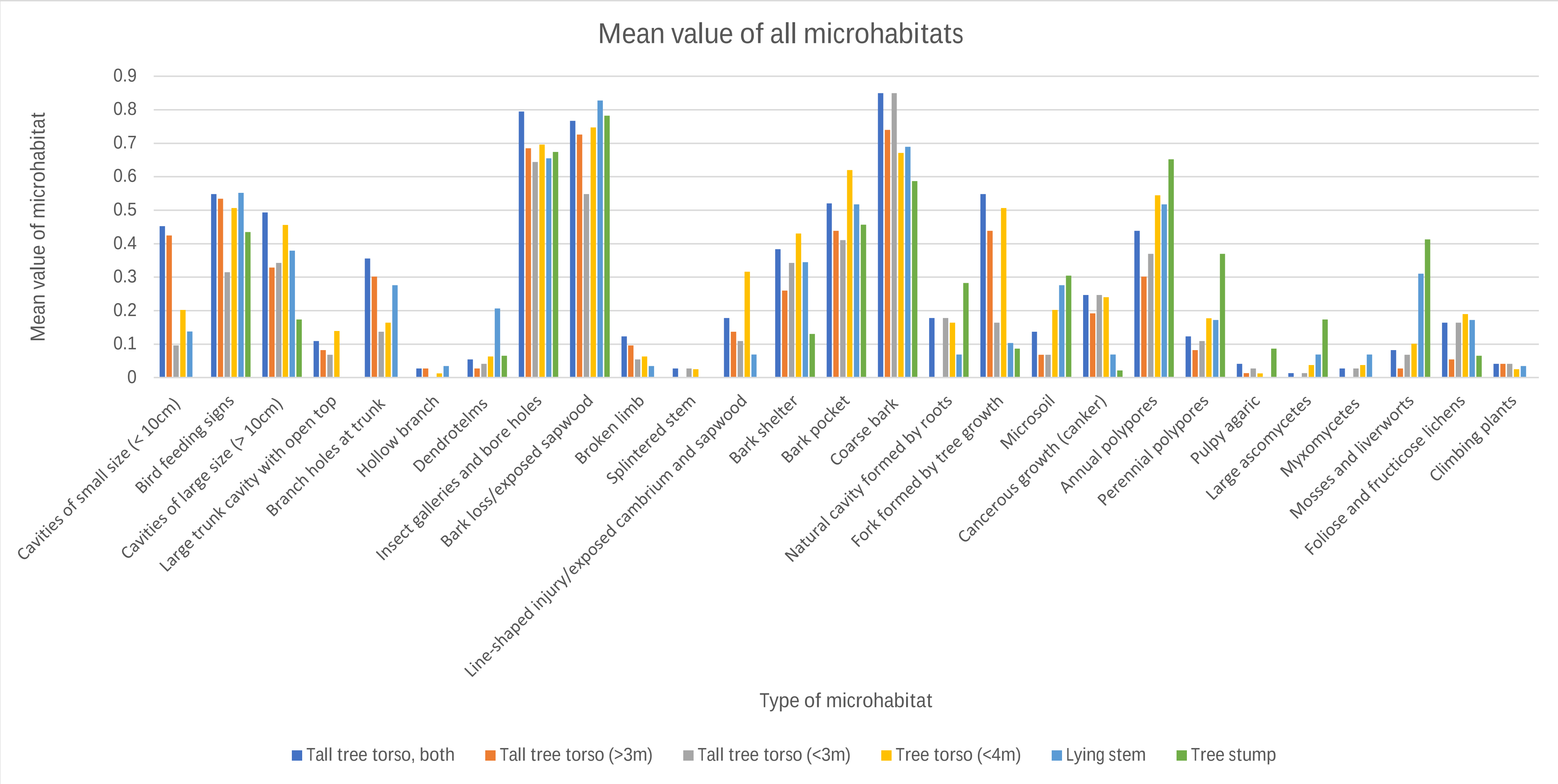


Figure 2: *Shows the mean value of all microhabitats for all tree structure types. The general trend is that there is not much of a difference between the different tree structure types. The most notable difference is seen with small cavities in tall torsos upper part compared to the other tree structure types. Also note that there are more dendrotelms in lying stems and tree stumps have more of the different fungal types. Furthermore, the most common microhabitats include bore holes, bark loss and coarse bark. For a more detailed view of the different microhabitat categories see appendix 2.*

Relating to table 2 it is seen that there are far more tall tree torsos in Frederiksborg Slotspark, which is likely related to the area being with more forest-like parts and thus can allow for taller torsos to be standing. It is also seen that there are many tree torsos (<4m) in both Fælledparken and Utterslev Mose which in case of Utterslev Mose relates to the big pollarding project in 2009/2010 (Thorsen, 2010). Overall, there is not much difference in relation to the mean value of microhabitats the different tree structure types can provide, when disregarding tree species but note that the tall tree torso in full length produce a similar mean value as a tree torso (<4m), see figure 1.

In relation to figure 2, it is seen that small cavities mainly appear in the upper parts of tall tree torsos. These are mostly woodpecker entry holes. There are no observed small cavities in tree stumps as these mainly are created from branch holes or woodpeckers. When looking at bird feeding signs there is not much of a difference, but there are less on the lower part of tall tree torsos. In relation to large cavities fewer are observed on tree stumps. When looking at large trunk cavities with open top, the lying stems are excluded as these are exclusive for standing tree structures. Furthermore, tree stumps are excluded as it is hard to define a large trunk cavity when there is not much trunk left. No branch holes are observed on tree stumps, which is to be expected, and further adds to the reason why no small cavities are registered on tree stumps. More branch holes are seen in lying stems and the upper part of a tall tree torso. This of course depends on the size of the lying stem. In relation to hollow branches, these are kind of rare as they are hard to spot, and most tree torsos are without branches. The same goes for dendrotelms as these can be hard to spot as well, especially in the upper part of tall tree torsos. Insect galleries and bore holes are very common microhabitats as these occur on most of the tree structure types. It is important to note that these are mainly bore holes with fewer cases of actual insect galleries. Overall, there is not much difference between the different tree structure types in relation to this microhabitat. Another common occurrence is bark loss/exposed sapwood as this is also seen frequently with all the different tree structures, but a little less on the lower part of tall tree torsos. Another rare microhabitat is broken limbs which is due to tree torsos not having many branches left or the removal of these by the managers while the tree was alive. The same goes for a splintered stem which can be hard to define and the reason behind its rare occurrence is that trees are being cut down instead of being allowed to break naturally. Line-shaped injury/exposed cambium and sapwood is another microhabitat that have been hard to define, but still some examples have been seen and apparently, they are mostly seen with tree torsos (<4m).

In relation to different bark structures, when looking at bark pockets and shelters there is not much difference, but notable is that there are less bark shelters in tree stumps. Furthermore, coarse bark is often species specific, but there are examples of e.g. older beech with coarse bark structure. Overall there is not much difference between tree structures as coarse bark is a species-specific trait or is developed with old age and thus not something that is developed when the tree starts to decompose. Another rare microhabitat is seen with natural cavities formed by roots and is mainly seen with tree stumps, but the tree structure type does not define whether a tree have a natural cavity formed by roots. Forks formed by tree growth is mainly seen with standing structures as a lying stem with what would have counted as a fork if it was standing is excluded, but still some forks were registered on lying stems mainly if there was microsoil in them or water. Even though there are less forks in lying stems and tree stumps there appear to be more microsoil in these. Cancerous growth is common across the standing structures with less appearances with lying stems and tree stumps. For annual polypores, tree stumps seem to be the better structure type with the upper part of tall tree torsos scoring the lowest mean value. Tree stumps also scored highest for perennial polypores, pulpy agarics and large ascomycetes. In relation to mosses, this microhabitat is most often seen on lying stems and tree stumps. Lichens are evenly distributed with less on the upper half of a tall tree torso and less on tree stumps as well. Climbing plants were not observed much and in the few cases with climbing plants it was difficult to register other microhabitats as the whole structure often was completely covered.

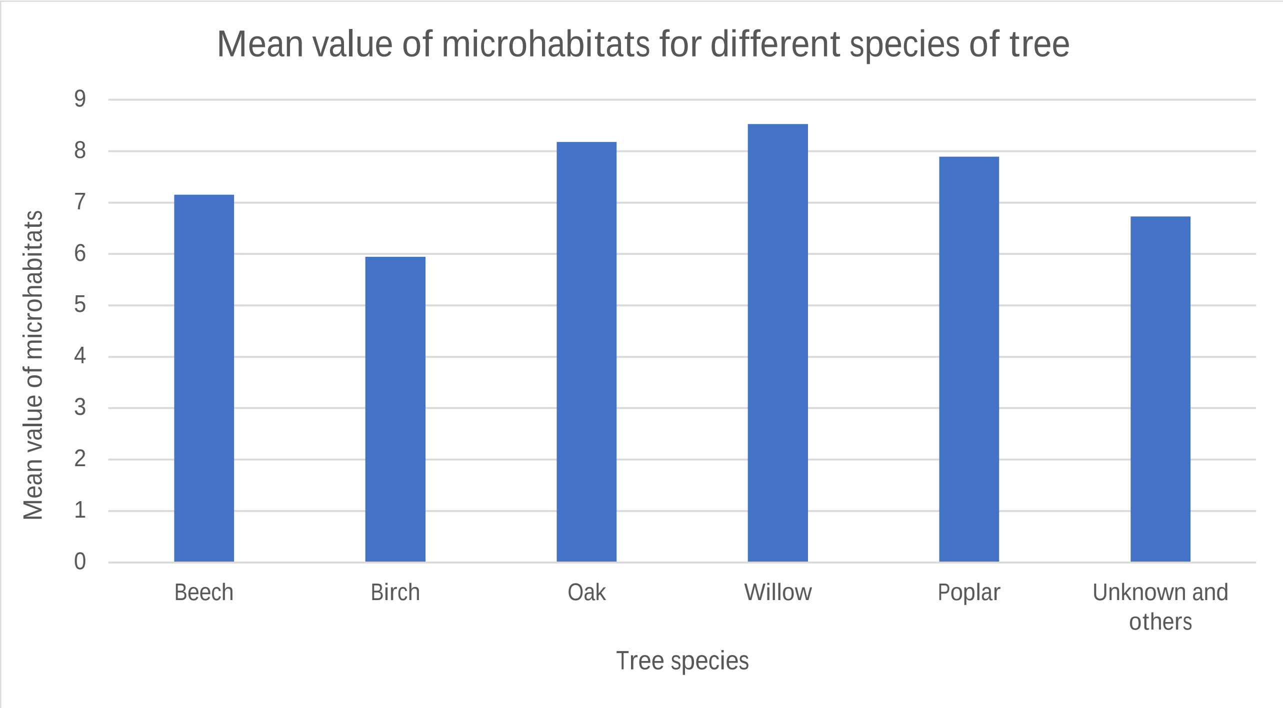


Figure 3: *Shows the overall mean value of microhabitats across all observations for different tree species. The different tree structure types were merged together under the different tree species. The tall tree torsos had their upper and lower part merged in such a way that the microhabitats only count for one except for fungi where each species of fungi is added to the pool. The unknown and others group are made up of observed identified species that did not have enough registrations to be included as a main species and species that could not be identified, particularly in the case of lying stems and tree stumps. Other species included maple, ash, linden, black alder, hornbeam, elm and different species of conifers. There is not much of a difference between the different tree species, but most microhabitats are recorded with oak, willow and poplar, whereas birch had the lowest score. The number of samples of the different tree species were beech 60, birch 18, oak 17, willow 34, poplar 28, and unknown and others 96.*

Overall there is not much difference in relation to the mean value of microhabitats the different tree species can provide. The most microhabitats have been registered with oak, willow and poplar while the least was seen with birch, see figure 3.

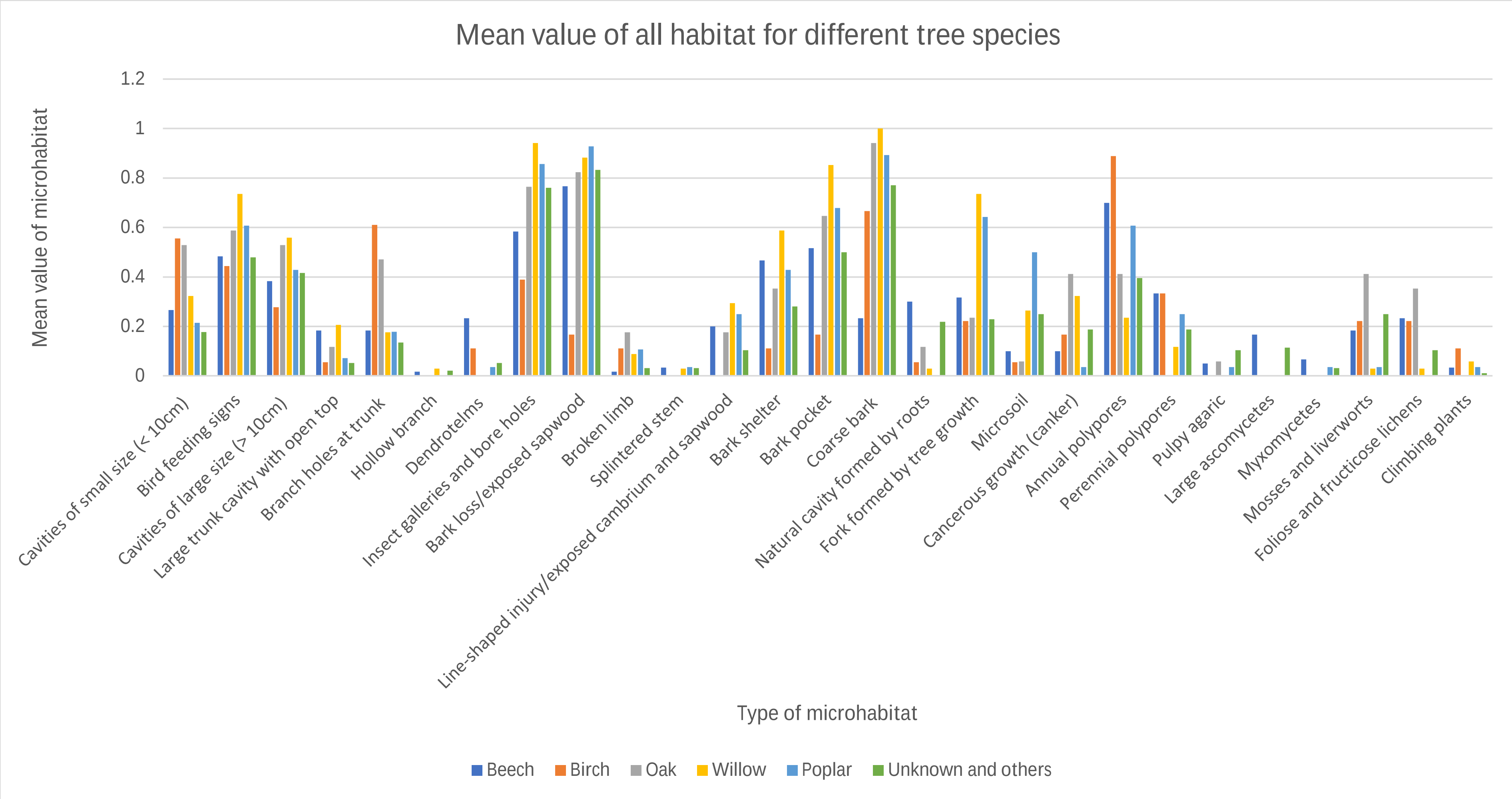


Figure 4: *Shows the mean value of all microhabitats for all tree species. Generally, there isn't much difference between the tree species. Note that birch and oak both have more branch holes and small cavities. Birch have less bore holes, bark loss, bark shelter and bark pockets. Furthermore, it is seen that beech have fewer occurrences with coarse bark. It is also seen that forks are more related to willows and poplars. Additionally, annual polypores*

appear on almost 90% of the observed birch followed by beech and poplar. Furthermore, mosses and lichens seem to be most common on oak. For a more detailed view of the different microhabitat categories for different tree species, see appendix 3.

In relation to figure 4 it is seen that oak and birch have more small cavities and branch holes. Insect galleries and bore holes are still a common appearance among the different tree species with the least amount registered with birch and most with willow, which also have the most bird feeding signs. Willow and oak also have more large cavities and most cancerous growths. Large trunk cavity with open top is mostly seen with willow and beech, but overall it isn’t registered much. Hollow branches are hard to spot as explained earlier which is also the case for dendrotelms, but still there is observed more dendrotelms with beech and birch. Bark loss is also a common appearance with all the tree species except for birch. As mentioned earlier both broken limbs and splintered stems are a rare occurrence, but still it seems that there are a little more broken limbs recorded with oak. Line-shaped injuries are seen with all the species except for birch. As with bark loss, birch doesn’t seem to have many bark shelters and bark pockets either. Furthermore, bark pockets appear generally more than bark shelters. With coarse bark it is seen that beech has the lowest value, while the rest have about the same value with birch falling a little behind. With natural cavities formed by roots it is most often seen with beech, and unknown / others. Forks formed by tree growth is mostly registered with willow and poplar while the other species are evenly low. Microsoil is mostly seen with poplar which is also connected to the number of forks as these allow for microsoil to accumulate. Furthermore, cancerous growth is mainly seen with oak and willow.

Still referring to figure 4, annual polypores are seen on almost 90% of the observed birch with beech and poplar following behind. In case of perennial polypores there is not much of a difference, but beech and birch have the most observations, while oak doesn’t have any registrations. Large ascomycetes are only registered on beech, and unknown / others. Mosses and lichens appear mostly on oak with fewest registration on willow and poplar.

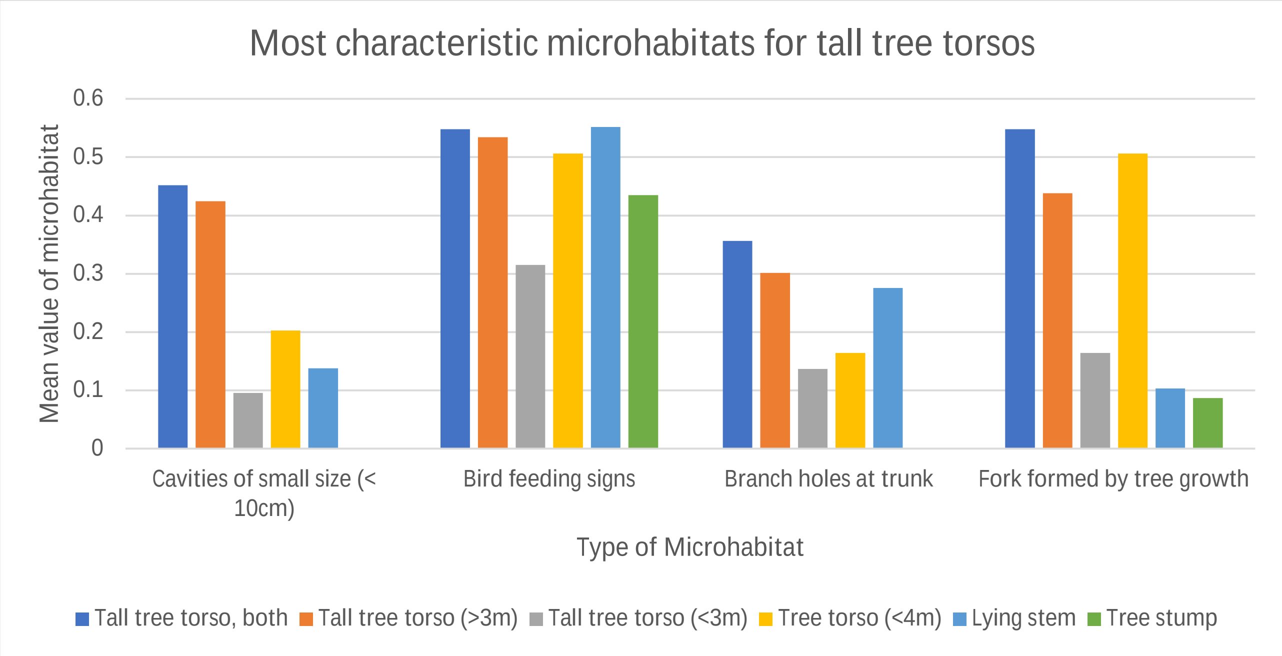


Figure 5: *An extraction of the most important microhabitats that characterise tall tree torsos. Small cavities are mainly found on the upper part of tall tree torsos. Tree torsos (<4m) show similar patterns for bird feeding signs and forks formed by tree growth, and with branch holes lying stems are just as good as a tall tree torso.*

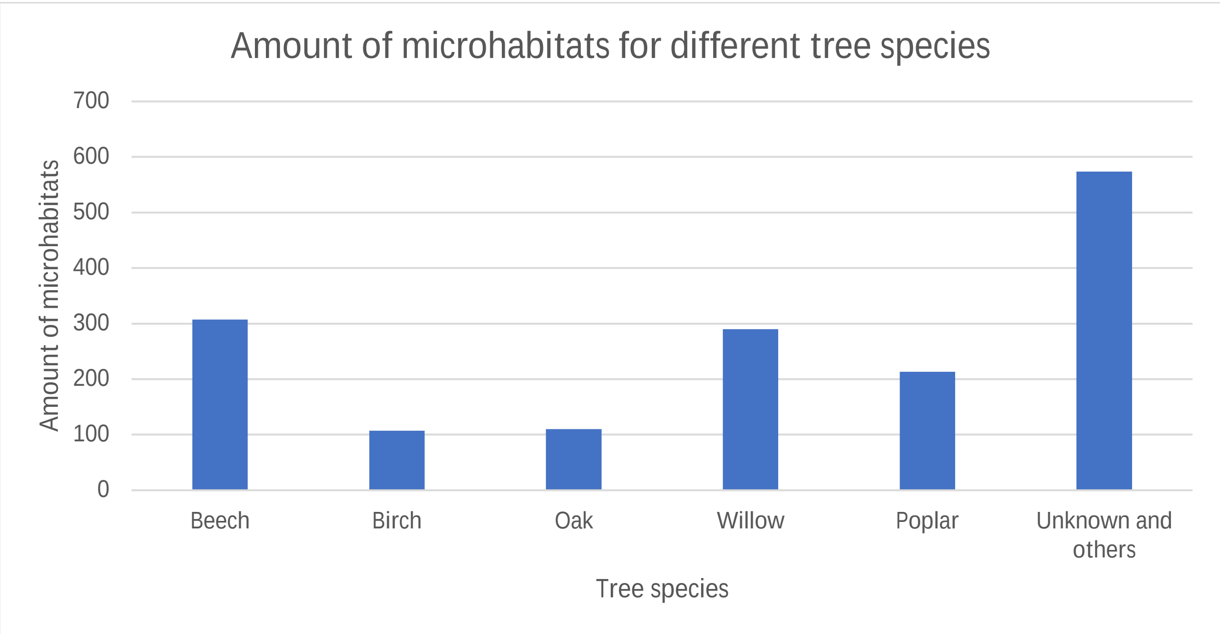


Figure 6: *Shows the number of microhabitats for each tree species. Only original research localities are included here. The number of samples for the different tree species was beech 46, birch 18, oak 14, willow 34, poplar 27, and unknown and others 88. None of the tree species included in the last group had more than 10 individuals, and the majority (51 out of 88) were tree stumps and lying stems.*

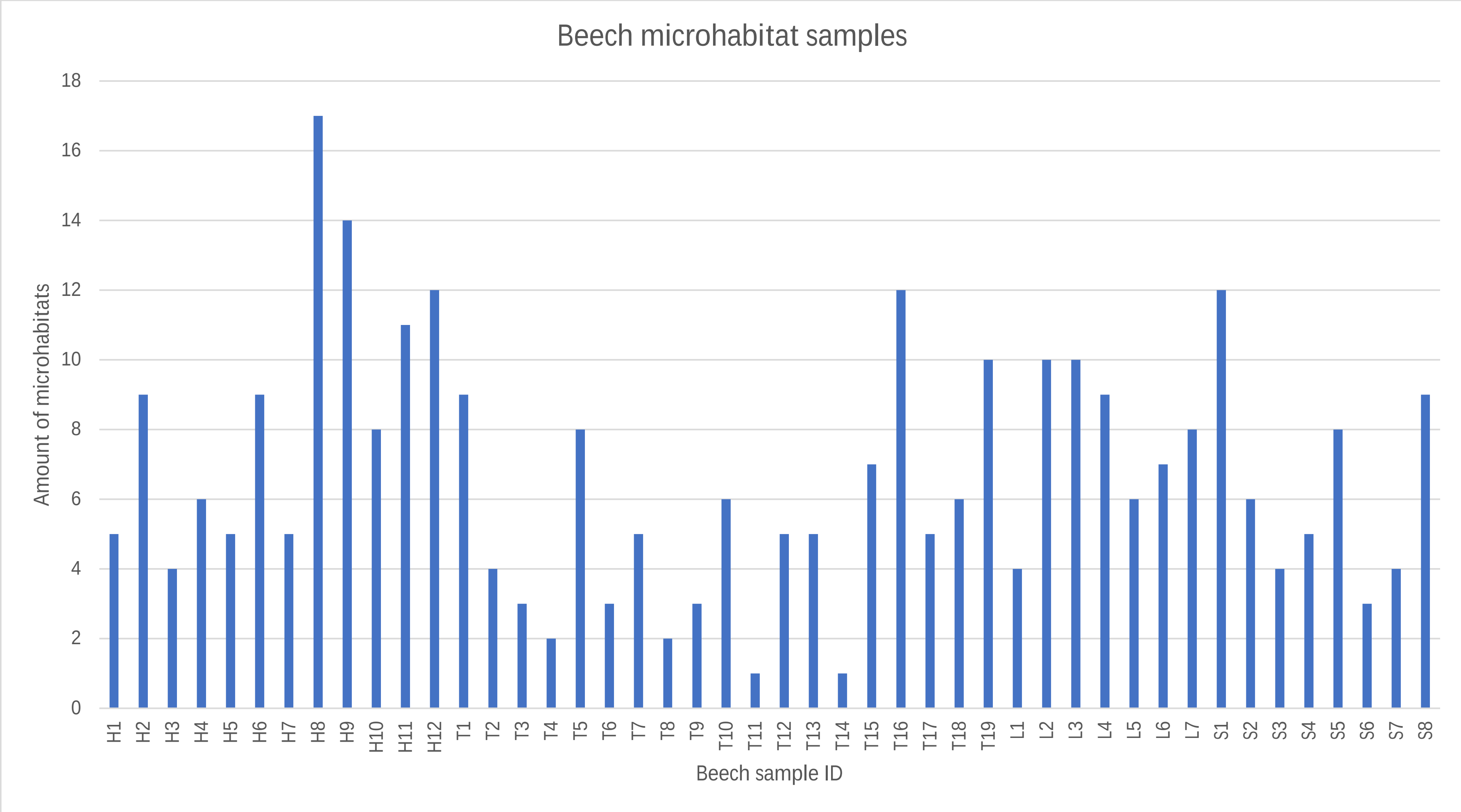


Figure 7: *Shows the number of microhabitats for each beech sample. H is for tall tree torsos (>3m), T is for tree torsos (<4m), L is for lying stems and S is for tree stumps. 18 out of 46 beech have over 7 microhabitats, 8 beech have less than 4 microhabitats i.e. 40% of beech has many microhabitats while around 17 % have very few.*

In relation to figure 7 it is seen that 7 (58%) of the tall beech tree torsos have more microhabitats than the average while only 4 (21%) of the beech tree torsos (<4m) have over the average. Furthermore, lying stems have 4 (57%) and tree stumps have 3 (38%) over the average, which shows as expected that they have been selected as ‘good’ examples.

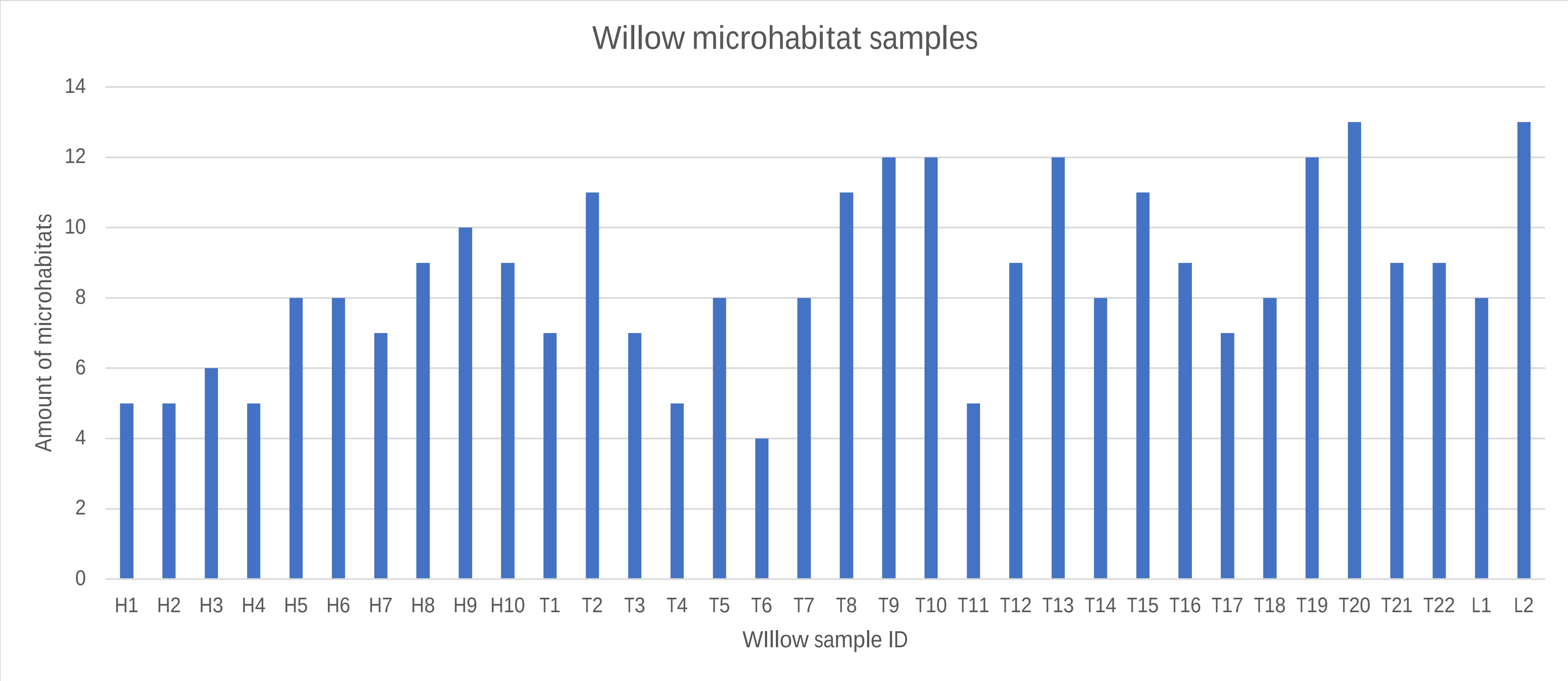


Figure 8: *Shows the number of microhabitats for each willow sample. 23 out of 34 willow have over 7 microhabitats while none have under 4, i.e. 67% of willow has many microhabitats.*

Relation to figure 8 it is seen that only 3 (30%) of the tall willow tree torsos have more microhabitats than the average while 12 (55%) of the willow tree torsos (<4m) are above the average. Additionally, lying stems have only 2 registrations and tree stumps have none with this species.

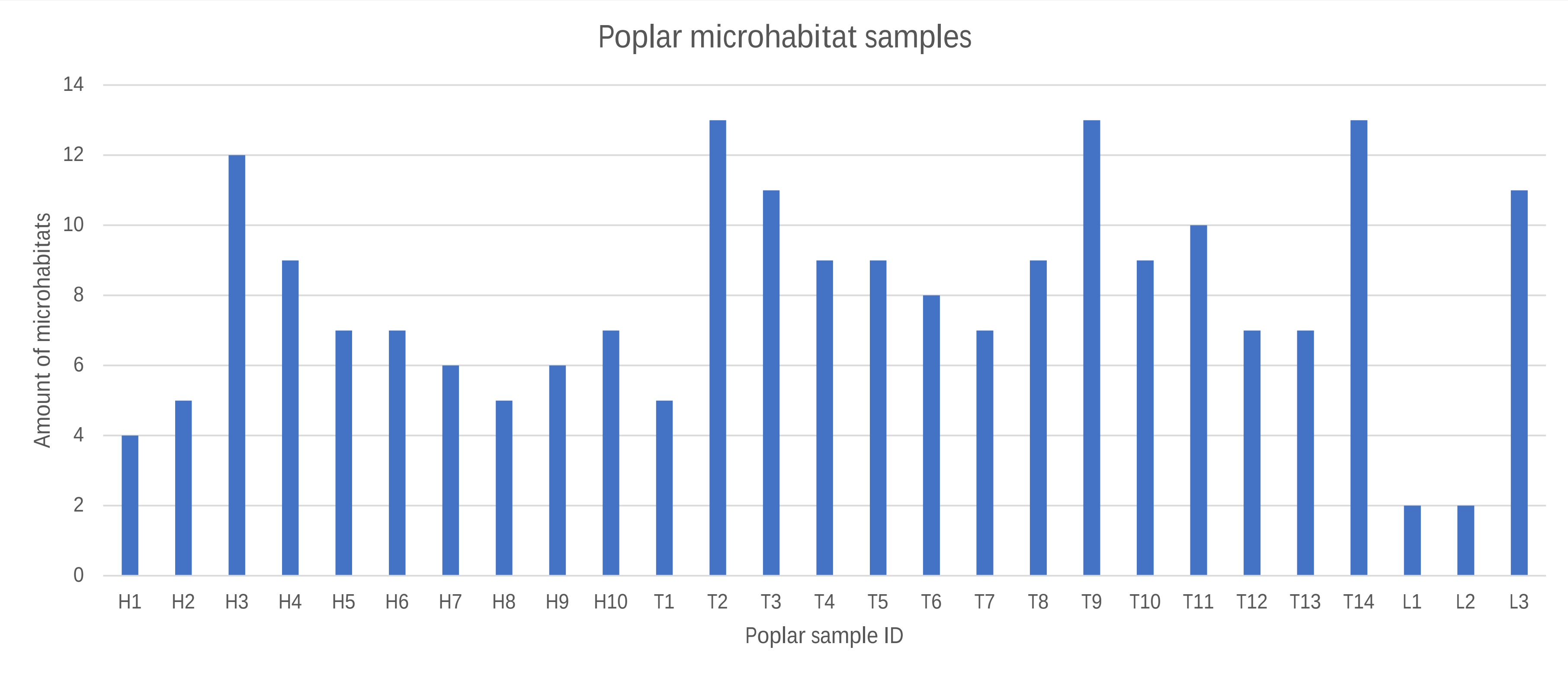


Figure 9: *Shows the number of microhabitats for each poplar sample. 13 out of 27 poplar have over 7 microhabitats, 2 poplar have under 4 microhabitats i.e. 48% of poplar has many microhabitats while around 7% have very few microhabitats.*

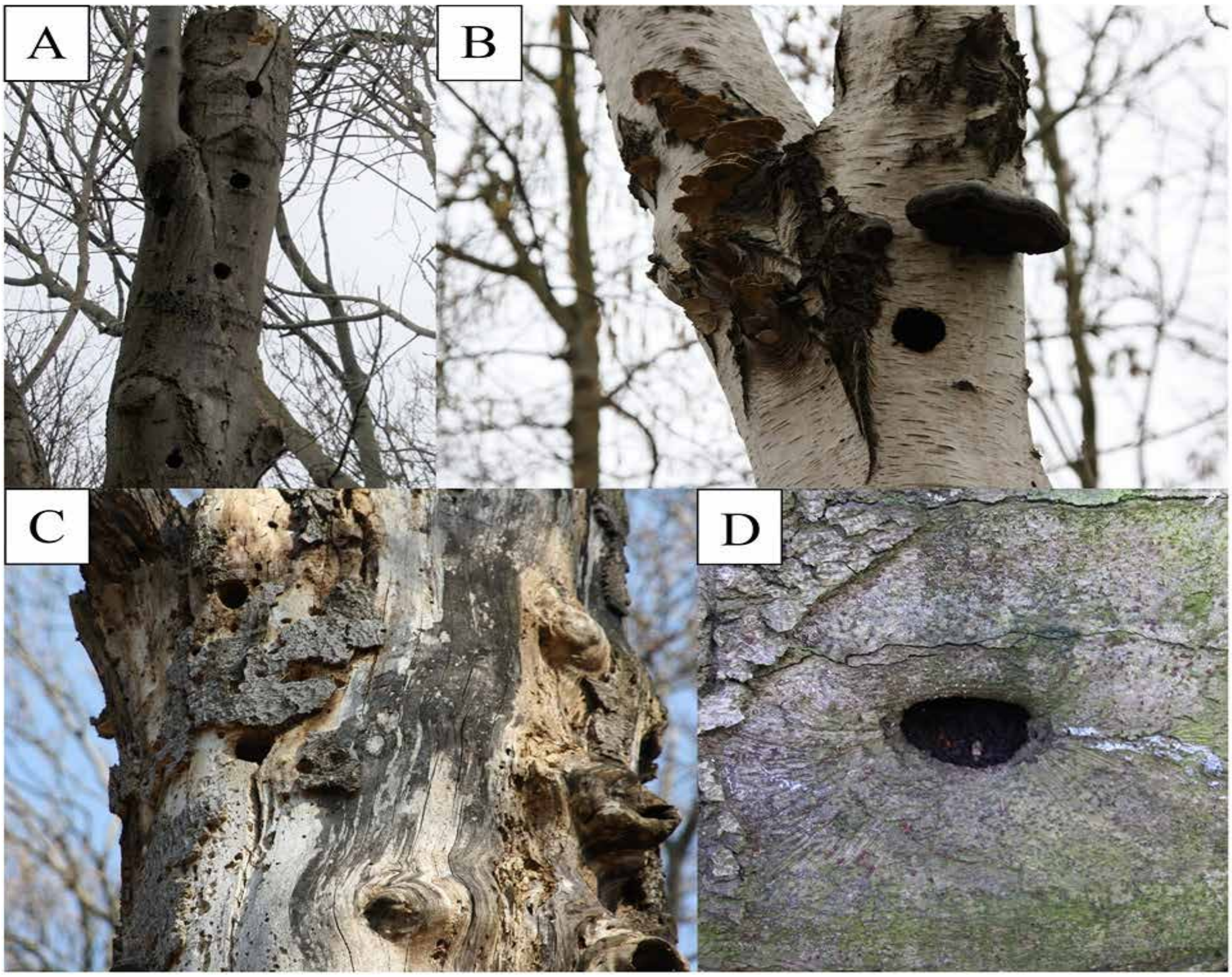
In figure 9 it is seen that only 2 (20%) of the tall poplar tree torsos have more microhabitats than the average while 10 (71%) of the poplar tree torsos (<4m) have over the average. Furthermore, lying stems have only 3 registrations and tree stumps have none with this species.

Microhabitat examples

In this section different microhabitats are illustrated by pictures taken during the data collection. Some microhabitats are grouped in the same picture as there was either lack of good examples or it didn't make sense to include more examples of that specific microhabitat.

Cavities of small size (<10cm)

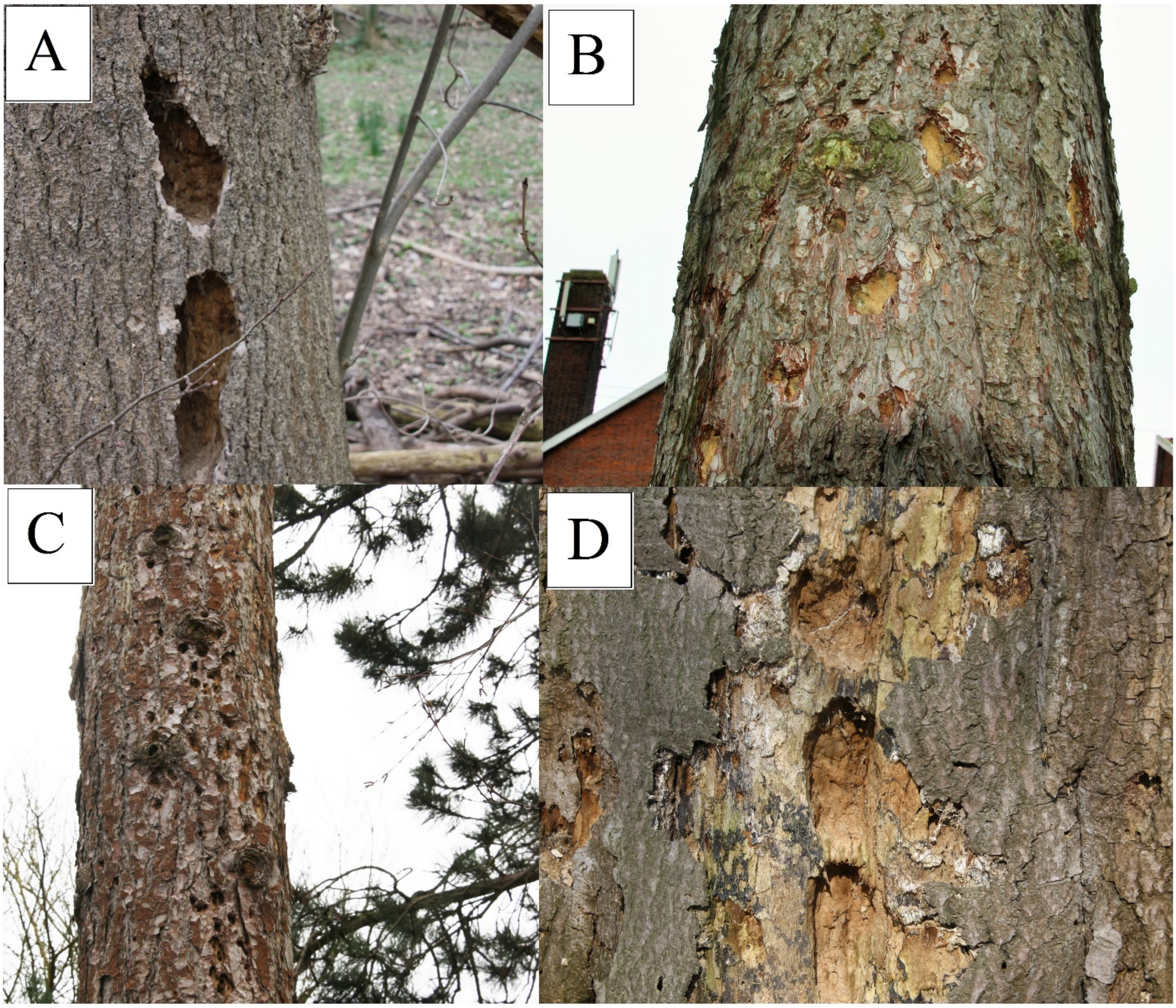
Relating to picture 1, picture A illustrates possible connected woodpecker breeding cavities called a woodpecker "flute" (Kraus et al., 2016). Picture B illustrates a small hole, likely a woodpecker nest and two annual fungi can also be seen where one of them is *Piptoporus betulinus*. Picture C is also likely to be a woodpecker nest and here we also see missing bark and some signs of bird feeding. Picture D illustrates a small cavity that is not a nesting hole but contains microsoil. This is likely due to it being on a lying stem. A high proportion of small holes registered are bird nesting cavities.



Picture 1: Different types of cavities of small size (<10cm).

Bird feeding signs

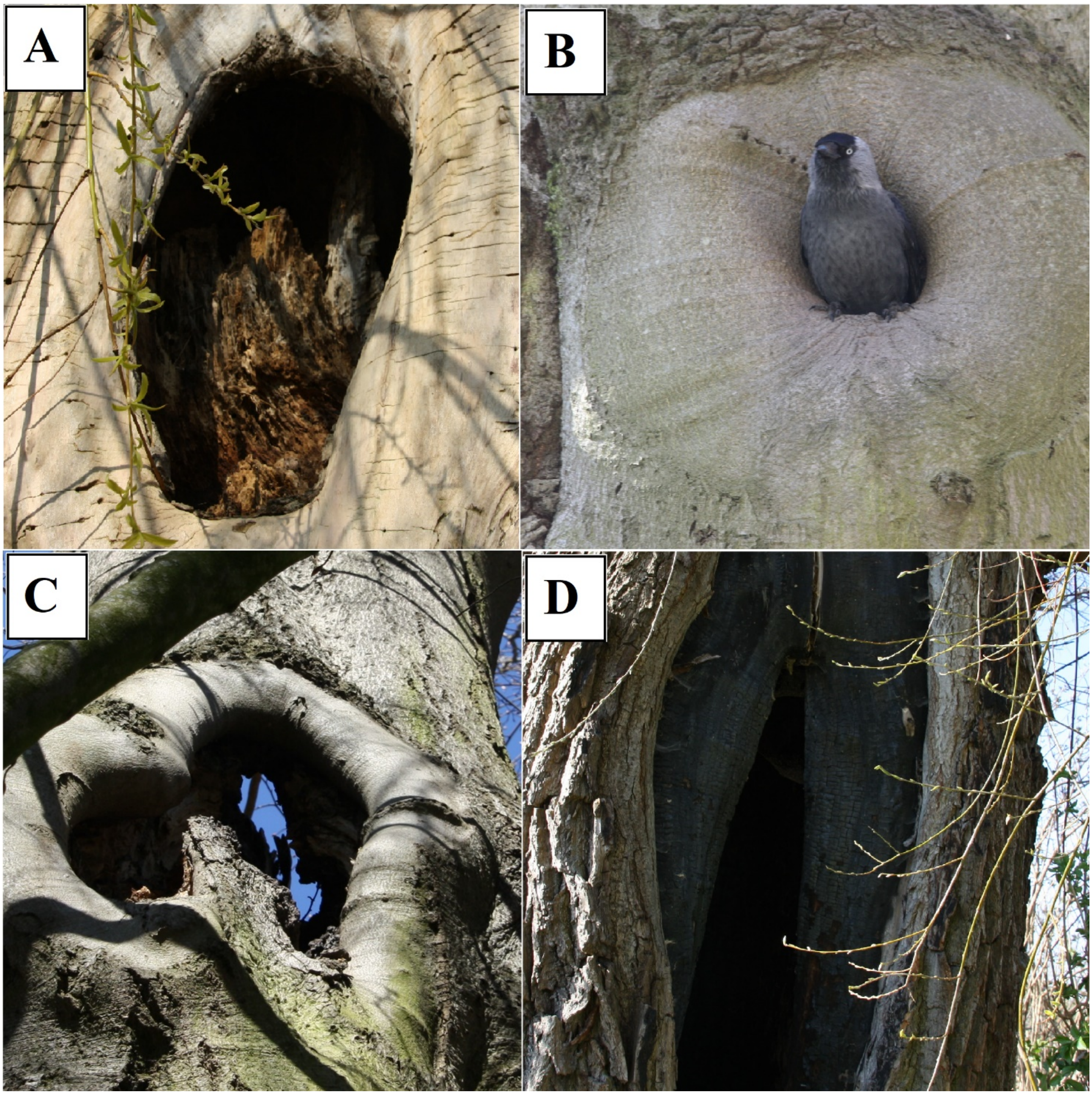
In relation to picture 2, picture A shows how woodpeckers can excavate and make big cavities (>10cm) in trees. Picture B and C shows smaller signs of bird feeding represented as small holes in the bark structure. Picture D also shows how woodpecker feeding holes can look, but here the surrounding bark structure is also damaged which is probably related to the tree being older than the one seen in picture D.



Picture 2: *Different types of signs of bird feeding.*

Cavities of large size (>10cm)

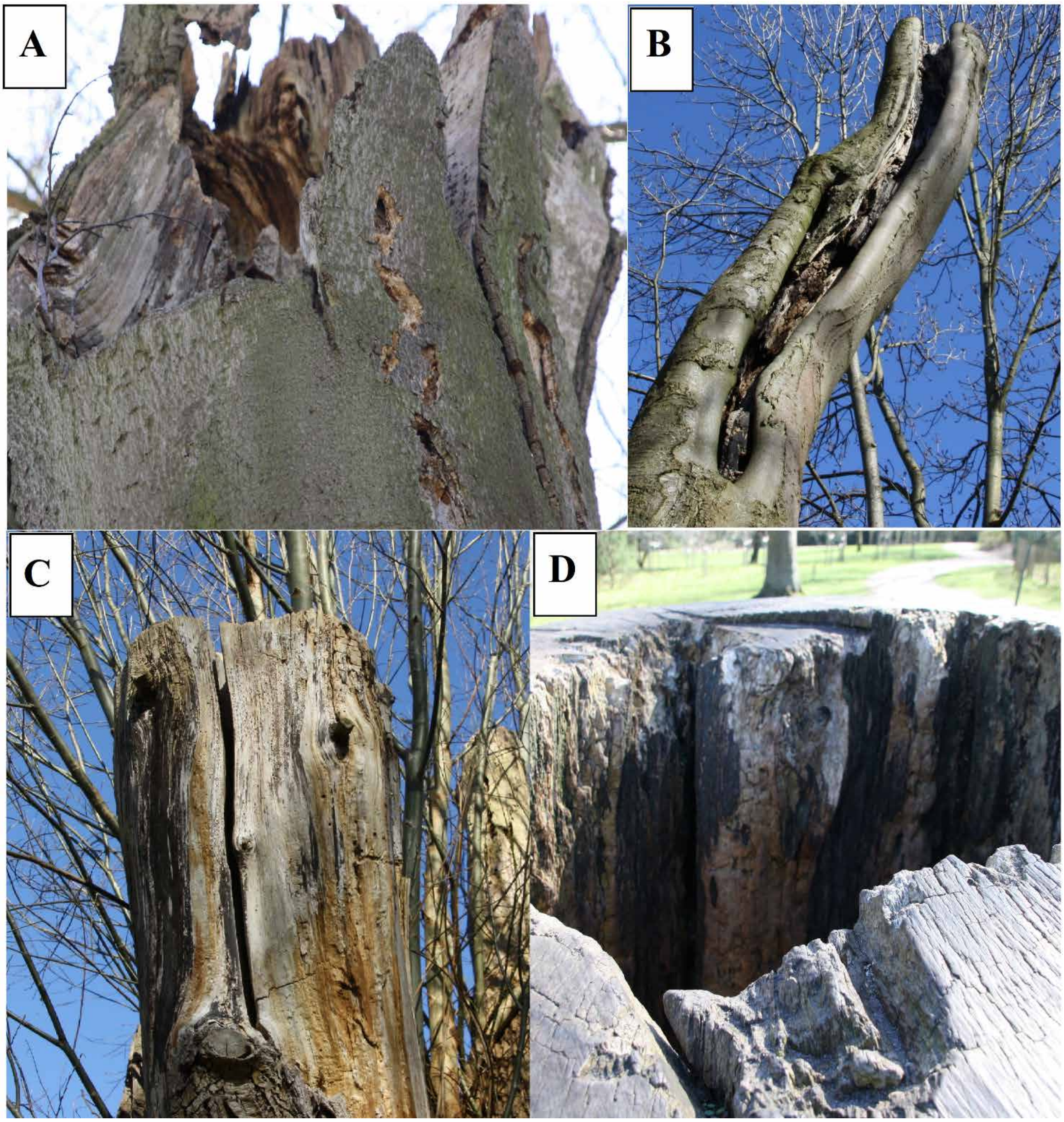
Relating to picture 3, picture A illustrates a large cavity with some decaying wood within and loss of bark all around. Picture B shows a large cavity with a Jackdaw coming out, which is a common bird in Denmark. Picture C shows a large cavity with a hole through to the other side of the tree. Picture D illustrates a large cavity with ground contact and inside hollowed structure while also having charred parts from a fire.



Picture 3: *Shows different types of large cavities (>10cm).*

Large trunk cavity with open top

Picture 4 shows different kinds of large trunk cavities with open top with picture B being the most prime example and the picture D being the largest cavity forming a hollowing structure.



Picture 4: *Different large trunk cavities with open top.*

Branch holes at trunk

Picture 5 shows different branch holes with picture A being the most unique as the two others appear to be more common branch holes in the urban environment.

Picture 5: *Shows different examples of branch holes at trunk.*

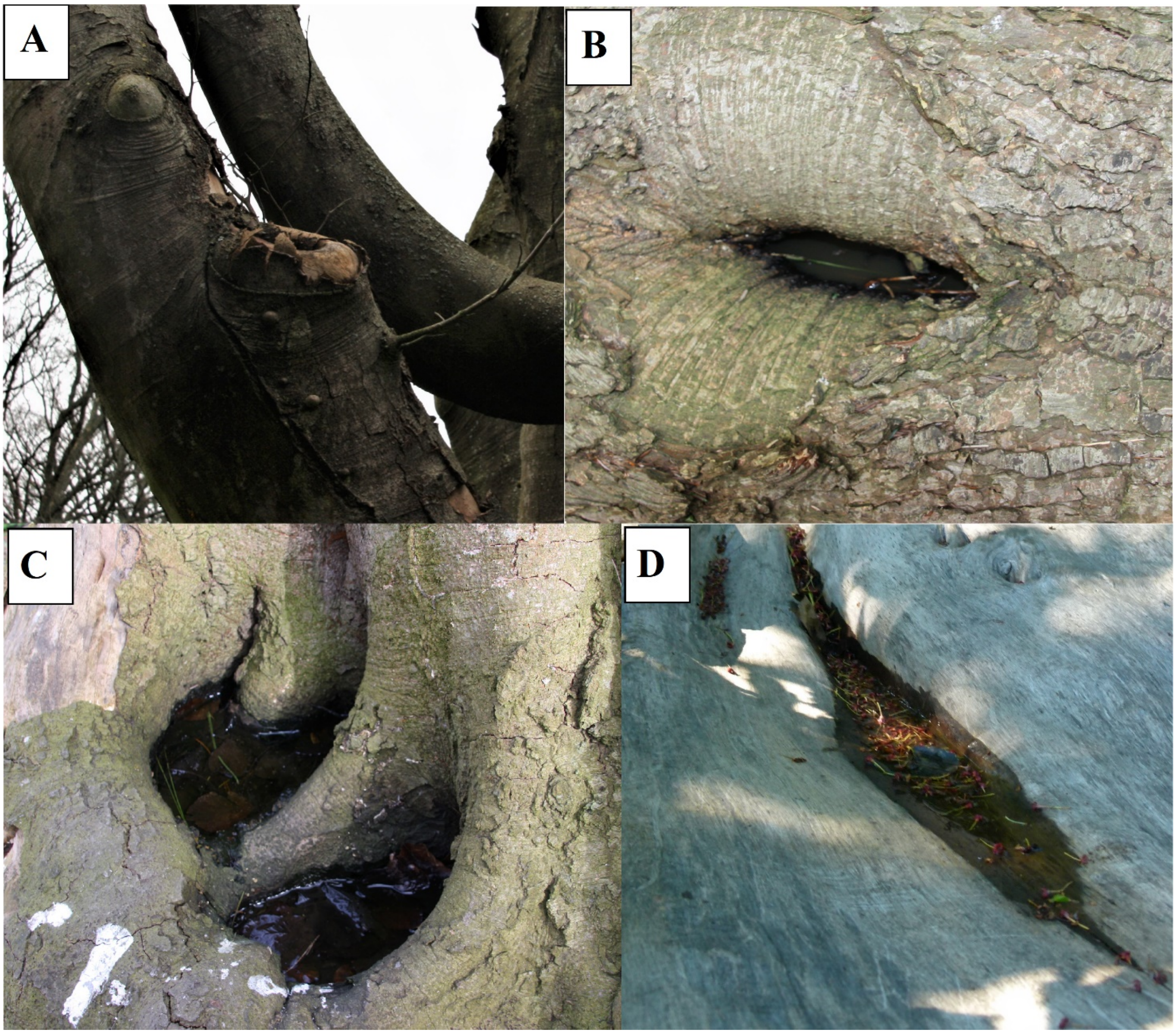
Hollow branch

Picture 6 shows the only good picture example of a hollow branch from the collected data. The reason being that it is part of a lying stem which makes it easier to spot while it is harder to detect in tree torsos, as they are standing stems. Furthermore, in the municipality's definition of a tree torso they also state that they are without any particular branches which might explain the low sample size of these hollow branches.

Picture 6: *Shows how a hollow branch can look.*

Dendrotelms

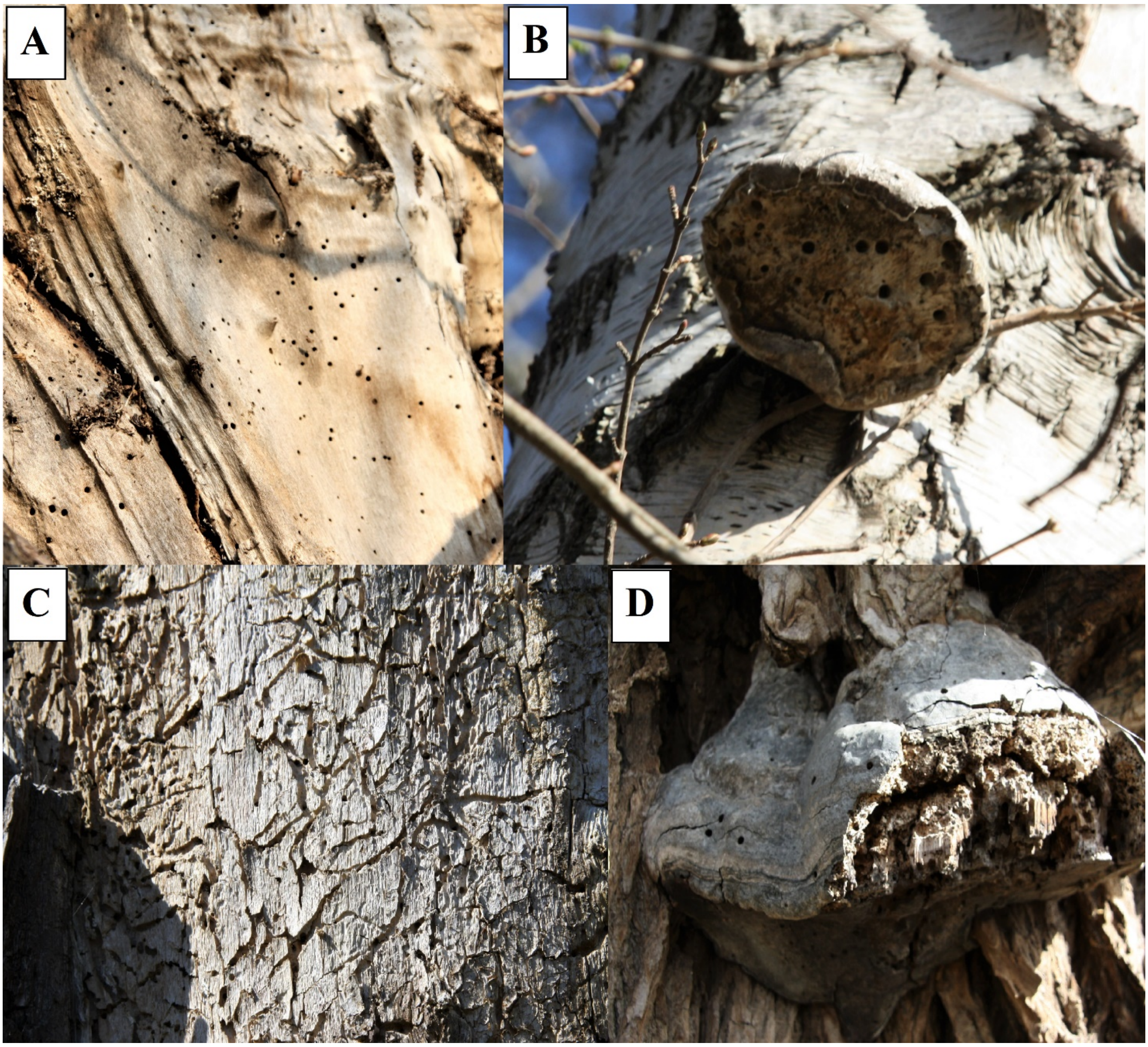
Relating to picture 7, picture A illustrates a branch hole dendrotelm. Picture B shows how proper placement of a lying tree can contribute to making more of these relatively rare microhabitats. Picture C shows that even tree stumps can contain dendrotelms as illustrated here by water-filled natural root cavities. Picture D shows a different kind of dendrotelm which is not really a hole, but rather a depression that can hold water as well.



Picture 7: *Shows different variants of dendrotelms.*

<u>Insect galleries and bore holes</u>

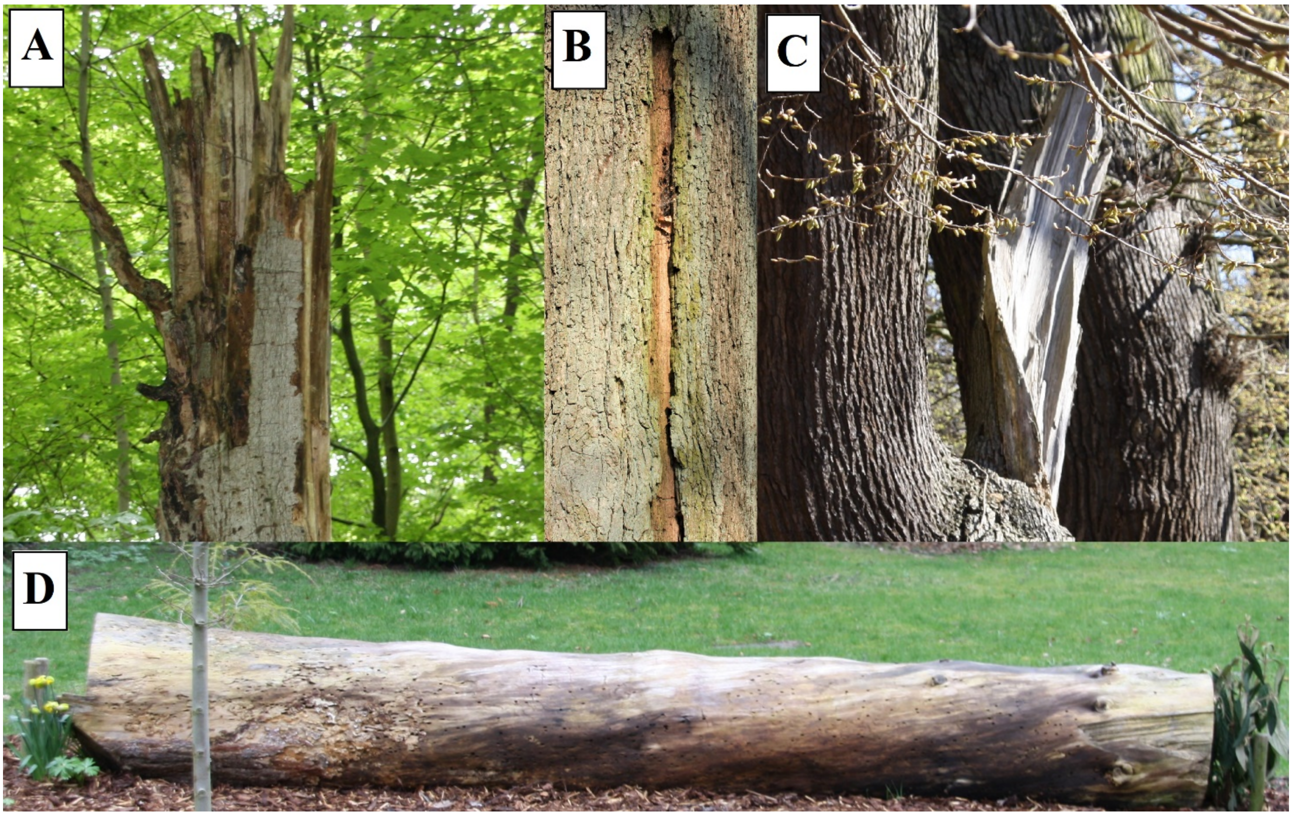
Relating to picture 8, picture A shows the most common observation of bore holes where the bark is also gone. Picture B illustrates bore holes in an annual polypore. Picture C represent how an insect gallery can look like with tunnels dug under the bark, the bark is gone here. Picture D shows how bore holes also can appear on a perennial polypore.



Picture 8: *Shows different bores holes and one insect gallery (C).*

Injuries and wounds

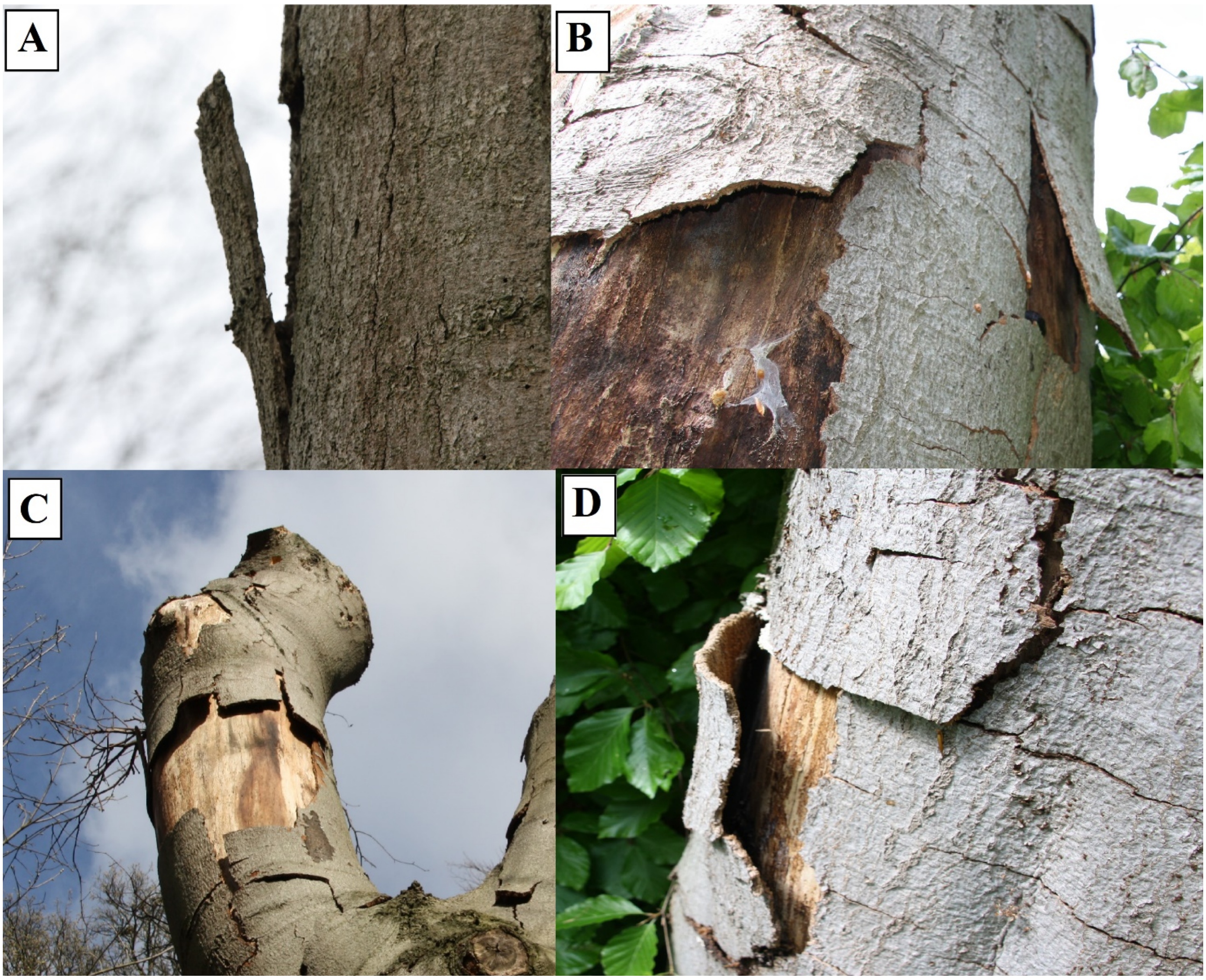
In relation to picture 9, picture A shows a splintered stem from the unmanaged forest at Kaffehøj. This was included as splintered stems were rare and other examples weren't as representative as this one. Picture B shows the most prime example of a line-shaped injury. Picture C represent a broken limb which is one of the rarer microhabitats as branches are often pruned before they break naturally. Picture D shows a completely barkless structure and illustrate the difficulty it can cause when trying to identify tree species. As three of these were rare, only the prime examples were included while for the barkless microhabitat there weren't much variation between examples other than some still having parts with bark still.



Picture 9: *shows different injuries and wounds. A represent a splintered stem. B represent a line-shaped injury/exposed cambium and sapwood. C represent a broken limb. D represent bark loss/exposed sapwood.*

Bark pockets and shelters

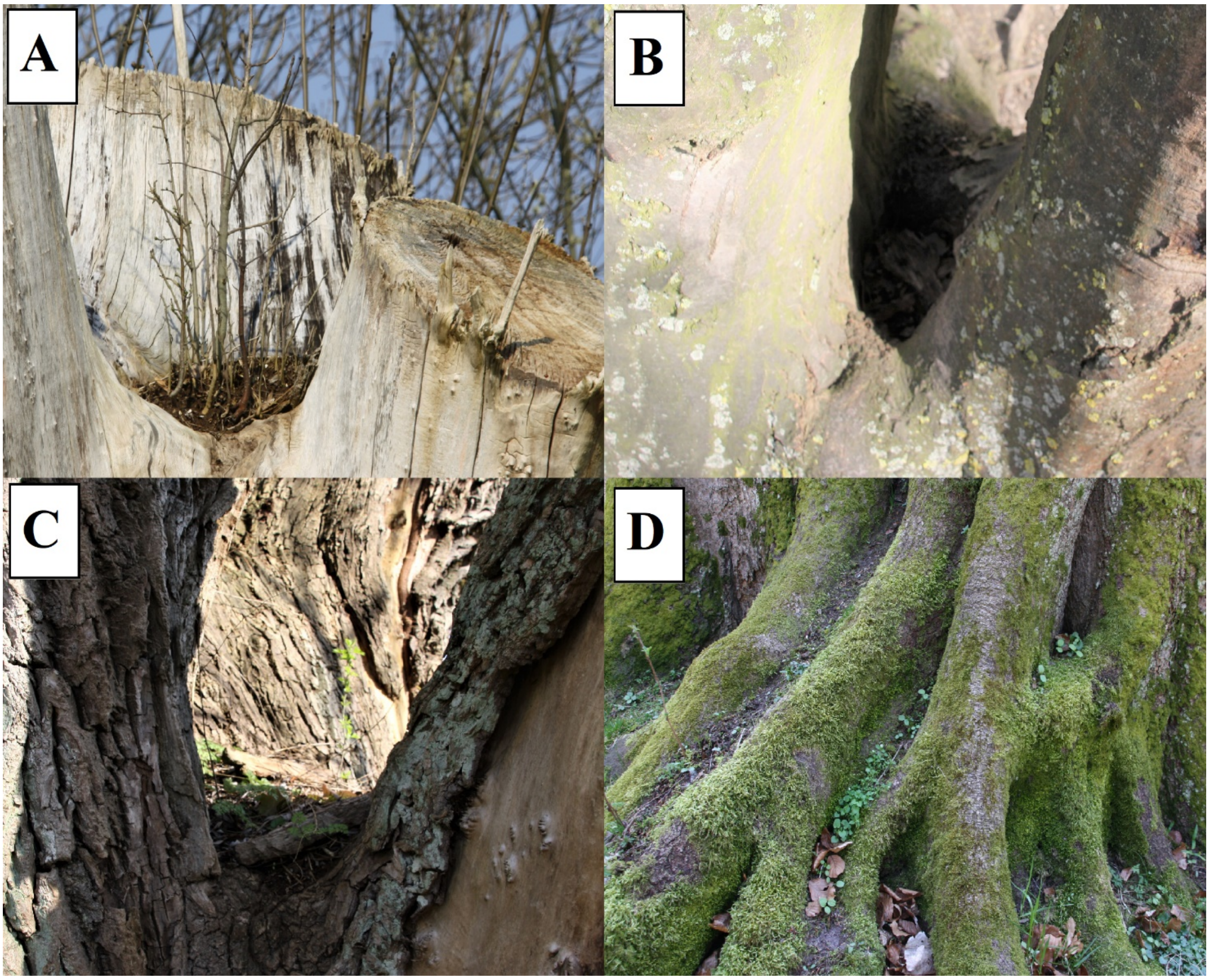
Relating to picture 10, picture A shows a prime example of a bark pocket while picture B shows two bark shelters. Picture C and D include both structures coming from the same point on the structure which is a common appearance. Coarse bark could be illustrated here as well but felt unnecessary as it is represented on other pictures.



Picture 10: Shows different examples of bark shelters (B, C and D) and pockets (A, C and D).

Forks formed by tree growth and natural cavities formed by roots

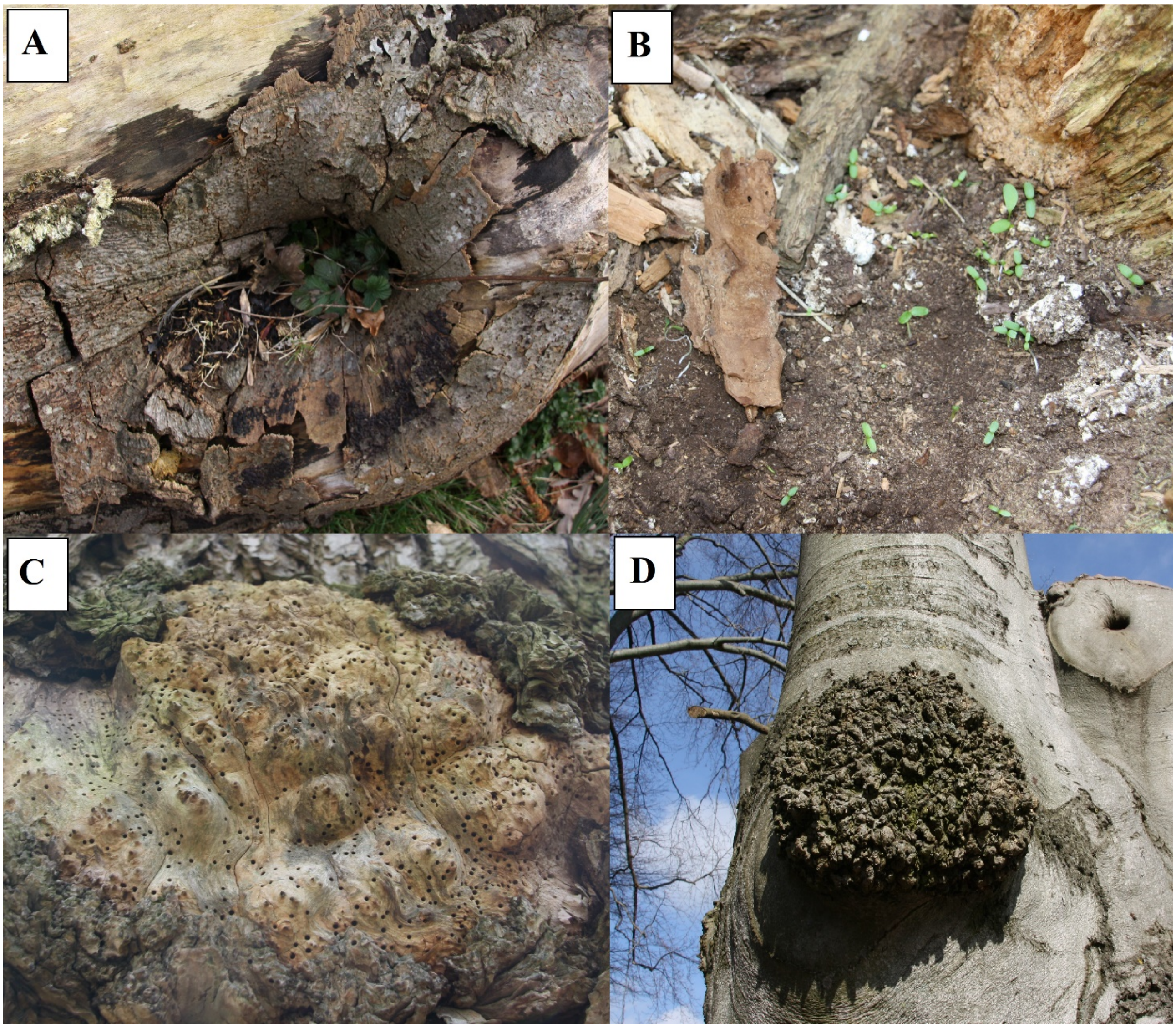
Relating to picture 11, picture A shows a fork between three stems where some plants are growing. Picture B illustrates a fork created from early division and therefore is located close to the ground. Picture C illustrates another way a fork can look and here there is also plants growing. Picture D is the best representative of natural cavities formed by roots and there are also plants growing in them.



Picture 11: *Shows three examples of forks (A, B and C) and one examples of natural cavities formed by roots (D).*

Microsoil and cancerous growth

In relation to picture 12, picture A shows microsoil in a cavity and there are also plants growing. Picture B illustrates microsoil collected in a fork with plants growing as well. Picture C shows a cancerous growth full of bore holes and without bark. Picture D shows a cancerous growth on beech which partly can provide some coarse bark to an otherwise smooth bark structure.



Picture 12: *Shows two examples of microsoil (A and B) and two examples of cancerous growth (C and D).*

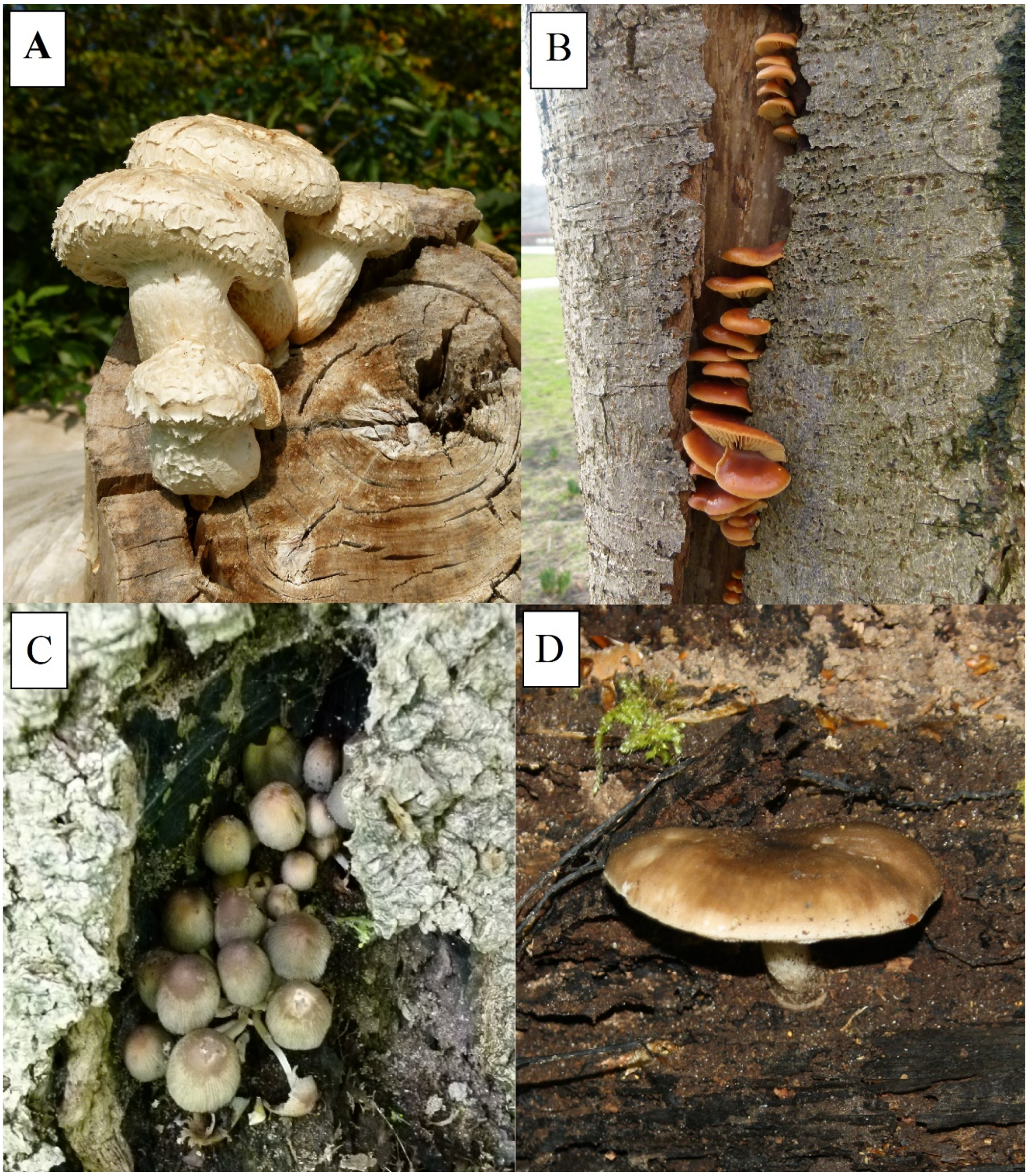
Annual polypores

In relation to picture 13, picture A shows Dryad's saddle (*Polyporus squamosus)* on a beech torso in Fælledparken. Picture B shows beefsteak fungus (*Fistulina hepatica)* which is usual seen on oak trees. Picture C shows *Laetiporus sulphureus*, on a tree at Frederiksberg campus that was later made a tree torso. picture D shows *Meripilus giganteus* with fresh fruiting bodies since the ones captured when collecting the data were in a very decayed stage. All these pictures were provided by Iben Thomsen as it wasn't possible to get good examples due to the period the data was collected.

Picture 13: *Shows species of annual polypores.*

Pulpy agaric

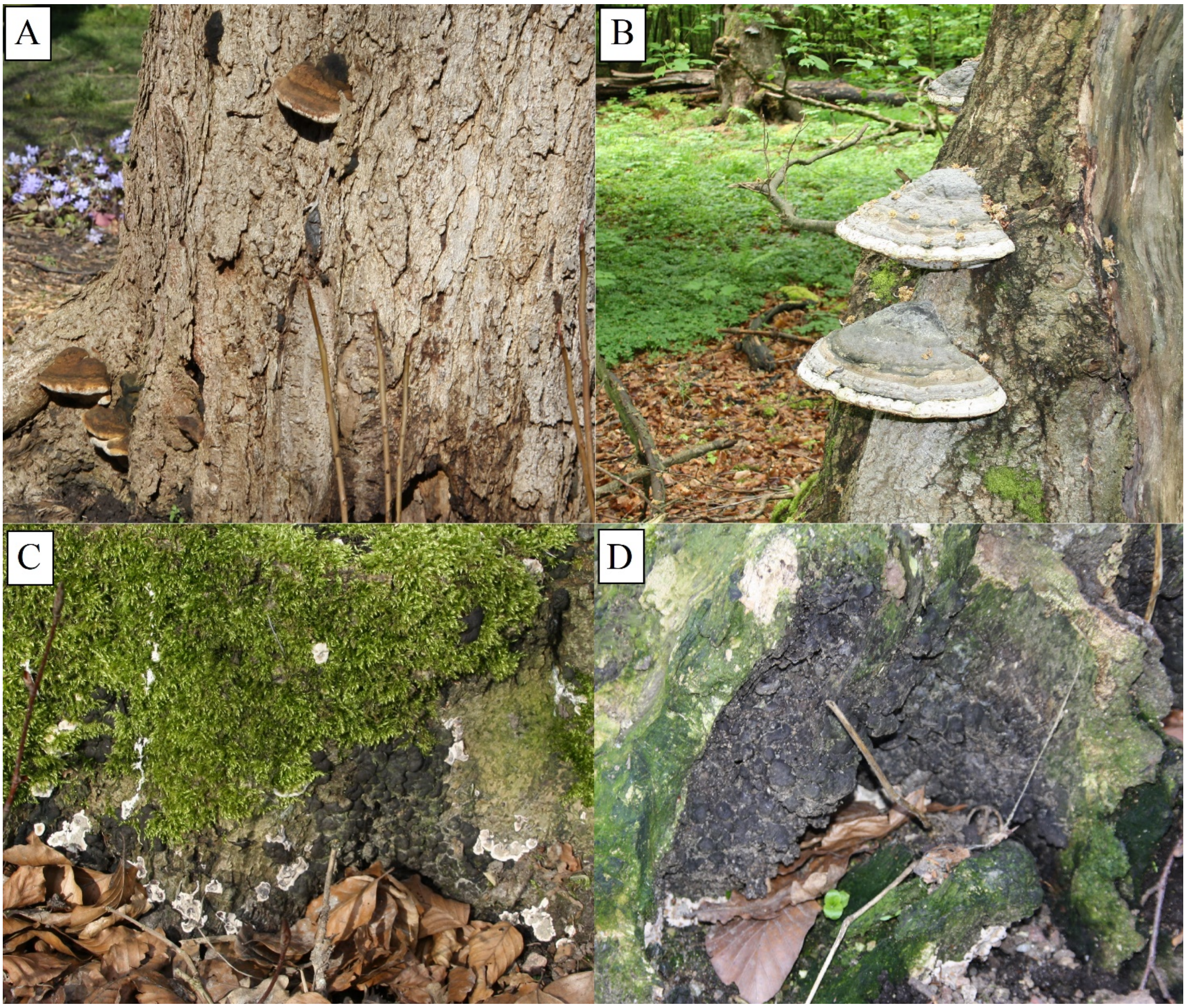
In relation to picture 14, picture A shows poplar pholiota (*Hemipholiota populnea*) on a lying stem in a park near Bispebjerg Hospital. Picture B shows velvet shank mushroom (*Flammulina velutipes*) which is common on horse chestnut and linden. Picture C shows what is likely to be glistening inkcap (*Coprinellus micaceus)* on an ash torso in Ryvangen Naturpark. Picture D shows an unknown species and is from a lying stem at Kaffehøj. Pictures A to C were provided by Iben Thomsen as there were few examples from the collected data.



Picture 14: *Shows different pulpy agarics.*

Perennial polypores and large ascomycetes

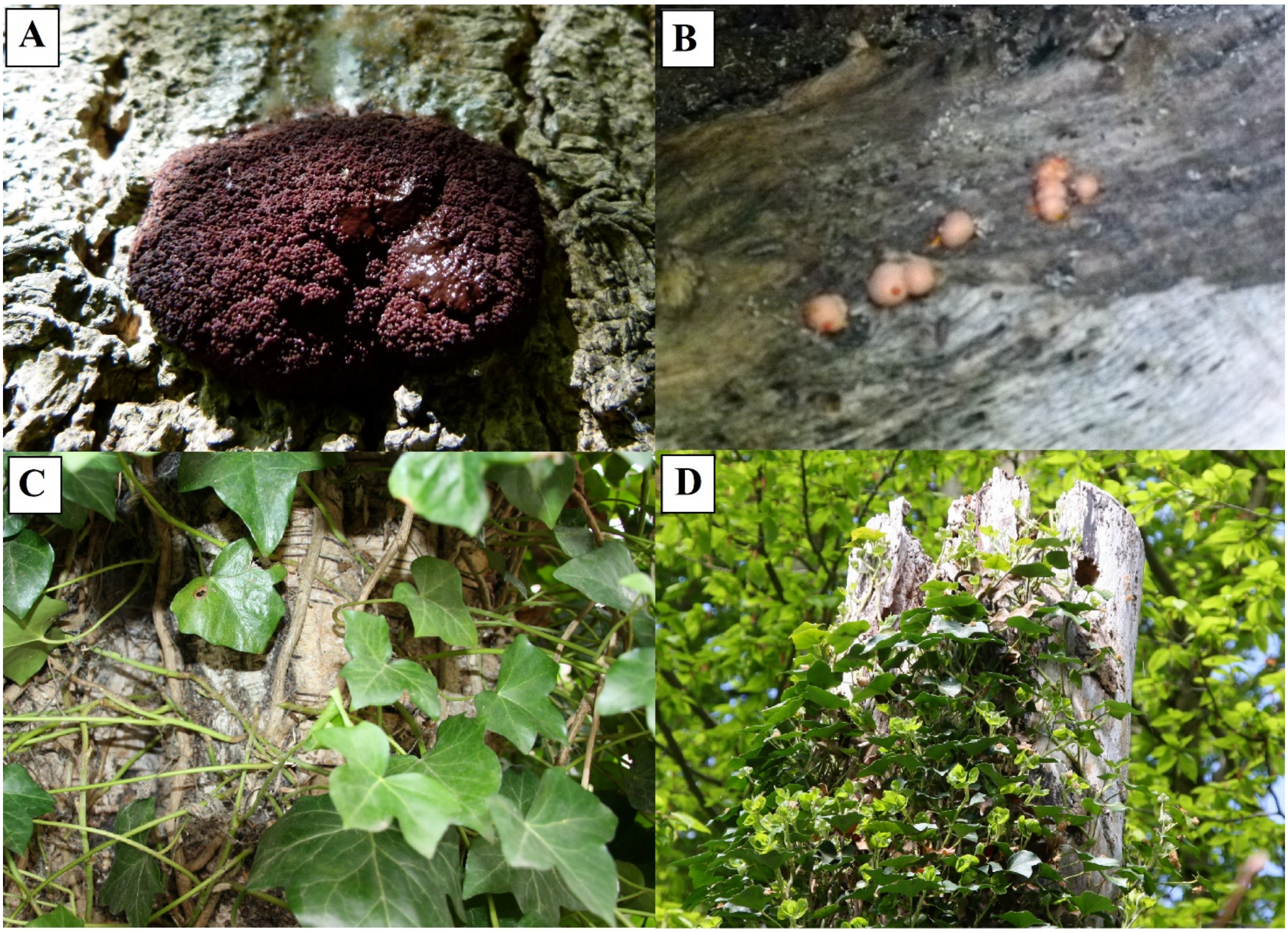
In relation to picture 15, picture A shows a perennial polypore of a species of *Ganoderma.* Picture B shows a more commonly registered perennial polypore, *Fomes fomentarius*. Picture C shows the large ascomycetes *Kretzschmaria deusta*, the light grey parts are the anamorph stage and the black parts are crusts where the perithecia are submerged (Thomsen & Skov, 2011). Picture D shows more of the black crusts.



Picture 15: *Shows two pictures of perennial polypores (A and B) and two pictures of Large ascomycetes (C and D).*

Myxomycetes and climbing plants

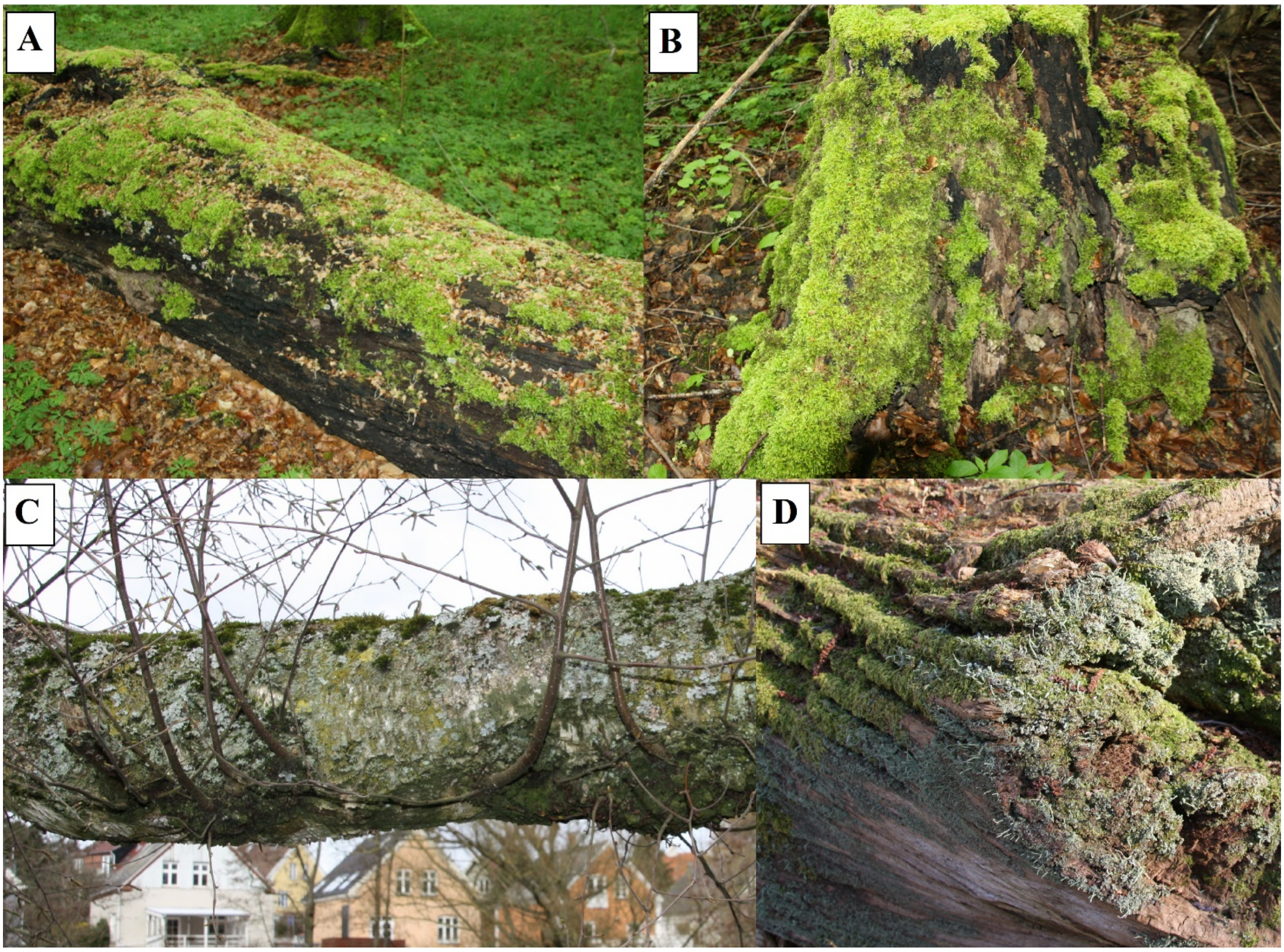
In relation to picture 16, Picture A shows the largest recorded myxomycetes in this dataset and was observed by Iben Margrete Thomsen. Picture B shows the most common observed species of myxomycetes *Lycogala epidendrum* commonly known as 'Wolf's milk'. Picture C illustrate how climbing plants which is mainly Common ivy (*Hedera helix)* in Denmark can make it difficult to observe other microhabitats. Picture D shows how some microhabitats still can be observed which in this case are a small cavity and a large trunk cavity with open top.



Picture 16: *Shows two examples of myxomycetes (A and B) and two examples of climbing plants (C and D).*

Mosses and lichens

In relation to picture 17, picture A and B shows a lying stem and a tree stump in a later stage of decay almost completely covered by mosses. Picture C shows a combination of mosses and lichens on a low hanging branch from a tall tree torso. Picture D is of a lying stem that was almost completely covered in the species of lichen seen on the picture.



Picture 17: *shows two examples of mosses (A and B) and two examples of lichens (C and D) which still include some mosses.*

Discussion

In this section the results from the fieldwork will be discussed with the focus on trying to explain some of the trends while also looking at the relevance of certain microhabitats. The rarity of certain microhabitats will also be considered.

Small cavities appear mainly on the upper parts of tall tree torsos as these are the reason behind leaving most of the tall tree torsos in a certain height taller than 4 meter as part of conserving habitats for mainly bats, but also woodpeckers. This is one of the few microhabitats that have helped managers with guidance of hazard tree management. A biologist explained that bats don't sleep in holes that are closer than 3 meters to the ground, therefore cutting tree torsos in 3 meters height removes a potential resting habitat for bats (Thorsen, 2010), thus the need for taller tree torsos. Oak and birch were the tree species with most small cavities and branch holes, which in case of oak probably is related to management practises with pruning of hazardous branches as it is known that older oaks tend to start dropping branches, thus allowing for development of these cavities. This is likely also the reason behind more large cavities in oak. In relation to large cavities, willow also had many, which might be due to old age where lots of willow trees were part of the pollarding in Utterslev Mose 2009/2010. Small cavities are relevant in the sense that they are habitats for protected species, but also can be used as a guidance tool. In relation to the rarity, they are common on upper parts of tall tree torsos as these have been left there for a reason, but they are rare on lower tree structures. Large cavities may also be important to consider as these aren't as restricted to the upper part of the tall tree torso.

Bird feeding signs were mostly favoured on the upper part of tall tree torsos and less on the lower parts which might relate to the preference of birds not wanting to take risks feeding on lower parts. The controversy in this is that feeding signs also were seen on lying stems and tree stumps, which in case of lying stems could be from before the tree was felled. The favouring of the upper part may be related to insects seeking shelter higher up when possible. Also, there were seen more bird feeding signs on willow which can relate to willow being one of the tree species that generally support a high diversity of insects (Southwood, 1961). This is likely also connected to the amount of insect galleries and bore holes which also were mostly seen with willow. Bird feeding signs and bore holes are not important microhabitats to consider as these will eventually appear as the tree decomposes which is also supported by the fact that bore holes were a common appearance on all the different tree structure types. On the other hand, insect galleries might be important to consider as these were rare and constitute an important hunting habitat for predators feeding on saproxylic species.

As explained earlier hollow branches and dendrotelms are microhabitats that can be hard to spot. Other reasons for the rarity of hollow branches is most likely due to removal of branches from most tree torsos, while the rarity of dendrotelms could be due to drought, also potential dendrotelms were not included as it would be unknown whether these could hold water. One structure where dendrotelms are easier to spot is in lying stems with cavities facing upwards. One action that could be taken, in relation to promoting more dendrotelms, would be to face lying stems, that contain cavities, upwards. At least two such examples can be seen at Bispebjerg Kirkegård. Dendrotelms are earlier described to be an important microhabitat in the temperate region for saproxylic aquatic or semiaquatic insects and thus a promotion of these could be beneficial for these types of insects, while also providing drinking water for other animals depending on the location of the dendrotelm.

In relation to different bark structures the reason behind less bark shelters are mainly due to bark pockets forming from the cutting surface point and thus are easier created. Also, there were observed less bark loss, bark shelters and pockets with birch which might be species related. Bark loss, bark pockets and shelters may be important microhabitats, but not something necessary to manage for since these will eventually appear with age of most tree remnants. Coarse bark is something that can't be managed for since it is often species or age related as seen with beech and birch where coarse bark can develop with age. One of the reasons behind oak and poplar not having a 100% appearance of coarse bark is simply due to a complete loss of bark on some samples.

A rare microhabitat is natural cavities formed by roots which were mainly seen with tree stumps, beech, and unknown / others. This could be a species-specific trait since beech tends to develop a flat root system with roots near the surface especially in areas with high ground water table. The tree structure type doesn't define whether a tree has this microhabitat, but the species might do. One thing that can be considered is to leave tree remnants that have this microhabitat. The importance of this microhabitat is unknown, but natural root cavities are easy to preserve since all that is needed is a large tree stump. Other rare occurrences are broken limbs and splintered stems, althrough broken limbs were seen a little more with oak which might be because again older oaks tend to drop large branches. These two microhabitats may not be as important with managed hazard trees, but there are ways to promote them as seen with veteranisation where the purpose is to promote the development of the same microhabitats that veteran trees provide (Bengtsson *et al.,* 2012). The importance of these two is unknown, but in relation to providing access for organisms to the tree, managed hazard trees generally have plenty openings already.

Even though there are less forks formed by tree growth in lying stems and tree stumps there appear to be more microsoil on these. This might be due to lying stems and tree stumps often having been around for longer and thus accumulated more microsoil. Forks are also mostly observed with willow and poplar which might be a species-specific trait such as early division into multiple stems. Microsoil is mainly observed with poplar whereas it is seen less with willow for unknown reasons. Forks are relevant in terms of accumulating material that decomposes over time and turn into microsoil. Microsoil can provide habitat for different smaller organisms and there are even examples of plants growing on top of tree torsos. Forks can be preserved when managing hazard trees as the placement of the fork can be a controlling factor for where to cut the tree, but this of course depend on the allowed height of the tree torso in relation to safety. Since forks are common in living trees it is less important to preserve them in tree torsos.

It is unknown why cancerous growth appeared less on lying stems, but in relation to fewer occurrences on tree stumps it is likely due to lack of volume and height. Cancerous growth was mainly seen with oak and willow and it’s possible that it’s common for these species to develop this microhabitat. In relation to relevance it is unknown what these provide other than a coarser bark structure in trees with smooth bark.

In relation to the different fungi, some were potentially left out, especially pulpy agarics, since it was the wrong season for many species. The upper part of tall tree torsos scored the lowest mean value and thus the height doesn’t seem important for the presence of fungi. This result is further validated by tree stumps scoring the highest mean value. Here it is important to consider the time perspective as tree stumps often can be allowed to decompose naturally while tree torsos are monitored and eventually cut down if causing a risk of breaking or falling. It is also very likely that tree stumps are remnants of trees infected with wood decaying fungi and thus already had fungi present. Many tree stumps are also from a time when that was all that was left behind for biodiversity. This might have allowed tree stumps more time to accumulate different species of fungi. Annual polypores were observed on almost 90% of the birch trees which is likely due to birch polypore (*Piptoporus betulinus)* that can have living or dead fruiting bodies the whole year (Thomsen & Skov, 2011), while other species of fungi in this category doesn’t leave decaying fruiting bodies for long. Another observed example is with giant polypore (*Meripilus giganteus)* that often have some decayed fruiting bodies still on the ground. When looking at perennial polypores there were not much of a difference in relation to tree species other than beech and birch had the most observations and oak didn't have any registrations. In this category the main observed fungal species were tinderbox fungus (*Fomes fomentarius)* and species of *Ganoderma*. *Fomes fomentarius* are mainly found on beech, birch and elm, while rare on other deciduous trees (Thomsen & Skov, 2011), which might explain why it hasn't been observed on oak. The genus of *Ganoderma* can be found on all deciduous trees (Thomsen & Skov, 2011) but hasn't been observed on oak in this study. In the case of large ascomycetes which in this case refers to brittle cinder (*Kretzchmaria deustra)*, the reason for it to be mainly found on tree stumps is likely due to managers being afraid of this species as it is one of the more dangerous ones when it comes to decomposition of trees. They do not want tree torsos that produce a significant risk of falling over. *Kretschmaria deustra* were also only registered on beech, and unknown / other species which is because of the species host trees which are beech, linden and other deciduous trees (Thomsen & Skov, 2011). The relevance of fungi is mainly linked to decomposition of wood, but they can also provide shelter and a food source for other organisms. In terms of rarity, fungi are often common and the cause of hazard trees, thus they are likely to appear on any tree remnants. Some species of fungi are more common than others and therefore it might be relevant to preserve rare species. This preservation can be managed for by ensuring that one of the tree structure types are left behind with the species on it.

Another microhabitat that might be affected by time, but also height, are mosses that appear mainly on the lower tree structures. Here it is important to note that it is easier to meet the 25% cover requirement with e.g. tree stumps. Lichens were somewhat evenly distributed, but the reason why there is less on tree stumps might be due to competition with mosses while with the upper part of the tall tree torsos might simply be due to height. It is not necessary to manage for mosses and lichen as these can grow on living trees as well. In relation to climbing plants it is worth discussing the worth of this microhabitat as it is not necessary to have these on the tree structure types as these can climb on living trees as well. Climbing plants are not actually important as it is unrelated to tree remnants and they could be planted if needed.

Relating to figure 5 where it is seen which microhabitats are characteristic for tall tree torsos, four types were selected. Small cavities were the only microhabitat that helped define tall tree torsos as the other microhabitats had similar patterns in other structure types. Tree torsos (<4m) and lying stems had similar numbers when looking at bird feeding signs. Branch holes were somewhat similar with lying stems. Forks could also be reached with tree torsos (<4m), but this is likely due to what discussed earlier as these were mainly found on poplar and willows which had many samples of tree torsos (<4m). Relating to figure 7 it was seen that tall tree torsos had more microhabitats in beech compared to other structures while in figure 8 and 9 it was tree torsos (<4m) that had the most microhabitats for willow and poplar. No comparison could be made for oak and birch due to the low number of samples. This gives a clue that it is important to preserve tall beech tree torsos while tall tree torsos are less important for willow and poplar. It is likely that this is due to pollarding which isn't really done with beech. Furthermore, most tree stumps and lying stems were registered as unknown / others and beech. There did not seem to be a major difference between tall and low tree torsos in unknown / other in relation to number of microhabitats, though tall tree torsos had a higher average, see appendix 4 for a graphic representation of unknown / others.

The time aspect has been mentioned a couple of times, but in relation to the tree structure type it could be worth considering as some tree structure types can be allowed to be left for longer than others. This is especially true for tree torsos over and under 4m as tree torsos over 4m are considered a larger risk and therefore are more likely to be cut down sooner. This is relevant for some microhabitats that are created or accumulated over time as these may not appear before the tall tree torsos are cut down. The main benefit of tall tree torsos is the conservation of habitats for bats, woodpeckers and other birds, but in relation to most other microhabitats the other tree structure types might be better as these can be allowed to be around for longer. Furthermore, tree stumps and lying stems of different species should have a high priority as some species of different organisms are host specific.

Measuring errors

There will always be some measuring errors when the data collection is done based on a single person’s subjective assessment. Another person may not make the same assessments. Here are listed the most relevant of such potential errors.

- Assessing whether a microhabitat is above or below 3m when inspecting tall torsos.
- Assessing whether a microhabitat meets the above 25% coverage requirement to be included.
- Assessing whether a microhabitat is extensive enough to be registered. An example of this is where a tree would have minimal bark loss potentially from vandalism or a smaller accident which would not be assessed to be extensive enough to be included.
- Assessing whether a tree torso is approximately <4m.
- Potential errors when handling the dataset e.g. typing errors or missing data.
- Leaving out some samples in Utterslevs Mose based on there being too many of the same species, which might have resulted in some important microhabitats being missed.
- Potential missed samples in bigger areas such as Frederiksborg Slotspark.
- Selecting lying stems and tree stumps by choosing `good`examples may have biased the sample towards higher values of microhabitats.
- Wrongly identifying some fungi as perennials when they were annuals which was later corrected. This was the case with *Piptoporus betulinus* where the annual fruiting bodies persist long after they have been active.

Management of urban hazard trees

Introduction

There are no specific laws regarding management of urban hazard trees, but precautions are still taken if trees are a risk for people and property. The principles of common torts are applied for damages caused by trees. The Nature Protection Act states that visits to nature happen at your own risk Cf. Nature Protection Act § 23 paragraph 1. Furthermore, EU's Habitat Directive involves a ban against harming bats and their habitats and since bats use old trees with cavities, the law influences the management of hazard trees. If a tree contains bats, it cannot be cut down without a waiver from The Nature Agency (Thomsen & Skov, 2011). In the UK, the owner or manager of a site is responsible for taking actions to minimise or prevent the risk of damage to property or personal injury that can come from the presence of any tree on the site, or from its uprooting or breakage. This is defined in law by the Occupiers' Liability Act (Lonsdale, 1999).

There are different signs to look for when assessing a tree for hazards to the surroundings. These are bad structure, crown symptoms, wood decaying fungi, and loss of roots or limitations for roots to grow. Signs of such problems can help the manager decide on what actions to take in relation to management of the tree, whether it should be cut down, pruned or in other ways be made safe for its surroundings. Furthermore, the warning signs can help decide which trees should be under stricter monitoring. A tree can be monitored for different reasons e.g. if the tree has a certain value and the manager tries to conserve it for as long as possible, or if the tree starts to show signs of weakness that can have negative consequences. Trees under monitoring can have the signs mentioned earlier, but also many wounds, other bark damages or slime flux (Thomsen & Skov, 2011). Matheny & Clark (1994) also describe the signs to look for and further adds the importance of age and size. Trees don't have an infinite lifespan, and arborists must be aware of patterns of tree growth which change with age. Assessment of old age in tree can be done based on size. The importance of size and age is simply related to the fact that older trees fail more frequently compared to young trees. Furthermore, trees in urban areas rarely reach their maximum lifespans.

One of the main causes for hazard trees are wood decaying fungi that live off lignin and cellulose/ hemicellulose which are the main components of wood. It is only a small group of wood decaying fungi that can kill living tree cells. These are called necrotrophs and parasites. Most of these start with digesting the dead parts of the tree, which are the heartwood in the branches, roots and stem or areas that are damaged. Afterwards the fungi will attack the living cells in the sapwood and bark of the tree. The tree is rarely at risk of falling or breaking if the decomposing fungi are confined to the heartwood, which are known from old hollow trees. The problem occurs when the fungi penetrate the sapwood to create fruiting bodies (Thomsen & Skov, 2011). Watson & Green (2011) further explain that a fungus and the host tree can often co-exist for decades and sometimes even longer, but also elaborate that some wood decaying fungi are problematic as they can extend into the sapwood. Furthermore, the decaying processes are more rapid in old, declining trees than in young trees (Matheny & Clark, 1994).

For most tree managers in Northwest Europa it is only necessary to know the most common problematic fungi in relation to hazard trees, i.e. fast decomposers of wood frequently occurring on common host trees. The most important in Denmark are *Kretzschmaria deusta*, species of *Ganoderma, Meripilus giganteus* and *Polyporus squamosus*. These species attack the most common deciduous trees. Furthermore, *Laetiporus sulphureus* attacks deciduous trees with coloured heartwood such as oak and willow (Thomsen & Skov 2011). *Fomes fomentarius* is one of the more dangerous fungi together with *Kretzschmaria deusta* and *Meripilus giganteus (*Thomsen & Skov, 2014). As a manager it is important to know when the fruiting bodies of these species appear, where they are located on the tree, and how they look. The time of tree inspection is dependent on what species of fungi you are looking for because different species produce fruiting bodies at different seasons. It will typically be in late summer or in fall after a period of rain. With suspicion of *Kretzschmaria deusta* or *Fomes fomentarius,* the tree needs to be inspected in May when new fruiting bodies appear. To inspect fungi on roots cessation of grass mowing in the root zone of the tree is advisable, due to mowing destroying the fruiting bodies of e.g. *Meripilus giganteus* (Thomsen & Skov, 2011).

The structure of a tree is essential for the strength of both the crown and stem. The bad structure relates to the way the tree grows, e.g. where two or more stems can grow from the same point, leading to instability compared to trees with a single stem. The reason for the instability is due to the weight of the crown pulling the stems apart or due to bad adhesion between the stem parts, which is further weakened when ingrown bark is in the branch angle. A bad growth structure can already be seen when the tree is young but is often first a problem when the tree gets large. Apart from multiple stems, the slope of the tree, one-sided crowns, bad branch structure (sharp angles) and long and heavy branches can contribute to a weak tree structure. Epicormic shoots appearing after pruning or pollarding contribute a particular risk as they break off easily due to their weak attachment to the stem. (Thomsen & Skov, 2011, Matheny & Clark, 1994). The most common cause of weakness above ground is the formation of a fork or weak branch junction where the wood of the two members is incompletely united because of the presence of a bark to bark contact zone. These unions are more easily split apart than connections with a complete woody connection (Lonsdale, 1999). There are differences in relation to stability when looking at forks where pointy forks are more instable than curved forks, which still are weaker than a tree with a single stem (Thomsen & Skov, 2011).

The condition of the tree crown can indicate the vitality of the tree while also giving a hint about the state of the roots. Leafless twigs, dead branches and small or few leaves contribute to a low crown density. Thin or discoloured foliage is often a sign of poor water and nutrient supply from the roots. The extent of the crown symptoms is important, related to whether they are one sided or extensive and for how long they have been present. The cause of the symptoms is also important as thin foliage can be a reaction to a passing drought, damages from road salt, or changes in the groundwater level. It is especially important to notice whether fungal fruiting bodies are appearing at the base of the tree. The more traffic there is in an area, the less crown symptoms can be allowed. Crown symptoms are not by themselves a reason for felling a tree but indicate a need for yearly monitoring in periods where wood decay fungi produce fruiting bodies. The monitoring last until it is certain there are no wood decay fungi in the roots or until the crown symptoms are gone (Thomsen & Skov, 2011, Matheny & Clark, 1994).

It is rare that damage to the bark itself makes the tree unstable. Instead the problem is the consequences of wounds that facilitate fungal attack and establishment while also decreasing vitality. These damages can occur from pruning, car collision, grass mowing and vandalism. One of the more important symptoms are areas with dead/sunken bark, as these may occur when decay fungi have killed the bark, but not yet produced fruitbodies. Something to pay attention to is whether fungal fruiting bodies appear in old open pruning wounds or at the base of the stem and around the roots after a collision injury. There are different warning signals to look for which includes abnormal or dead bark, large or many wounds and slime flux. It is relevant to look at the placement and extent of these. Slime flux often indicates that there is a problem in the bark, which may not be related to instability, but rather that the tree is stressed or due to the presence of *Phytophthora* (Thomsen & Skov, 2011, Matheny & Clark, 1994).

Damages to the root system can cause several consequences such as decreased stability, low vitality and increased chance of fungal attacks. Root damage is mainly seen with city and road trees and is most often caused by humans, e.g. when we build infrastructure, plant trees in small confined spaces, and when we mow grass too close to the stem and thus remove bark from the upper roots and potentially the trunk. Root damages in relation to construction of infrastructure are due to various activities such as digging, soil filling, paving and compression. Recommended actions include taking notes of all observations of construction work in the root zone. If large parts of the anchoring roots are destroyed, the tree should either be felled or have the crown reduced (Thomsen & Skov, 2011, Matheny & Clark, 1994). Lonsdale (1999) further describes how the inability of the root system to develop resistance to strong winds often is due to restricted rooting conditions such as waterlogging or compaction leading to structural failure.

There are alternative actions that can be taken besides felling a tree which can have different consequences relating to finances and time. The action needs to be adjusted depending on the level of symptoms and the placement of the fruiting bodies if any. These actions include pruning, securing the crown, management of the access for visitors by making it more difficult to get close or limiting longer stays under the crown, increased inspection and monitoring, fencing/signage, and in special cases pollarding. Pruning can be beneficial when a tree has a bad structure and help ease some of the pressure on the weak areas, but also when there is a need for removal of dry branches. Furthermore, it is important to crop epicormic shoots before they get too large and become a risk due to branch attachment failure (Thomsen & Skov, 2011).

It is important to consider these alternative actions because trees can have different values such as scenic, aesthetical, historical, economic and emotional. Of special importance is the value the tree has for biodiversity as trees are habitats for many different organisms. When a tree must eventually be cut down it is routinely recommended to leave behind a large stump or a lying stem for the benefit of biodiversity (Thomsen & Skov, 2011). Recently, higher stumps termed tree torsos are also suggested to be left behind to promote biodiversity. It is important to consider having different tree remnants due to biodiversity benefitting from variation. However, most urban tree managers and private tree owners are often reluctant to leave material for biodiversity due to the ‘messy’ look (Ravn *et al.*, 2016). This trend is further validated by Lars Birck (2019), who has had to convince his fellow gardeners to allow tree remnants to be left behind. In relation to tree torsos, the permitted height of the torso is often limited, due to fears they may fall and hurt people.

Method

To gather knowledge and insight from the managers of the selected areas a questionnaire was send by email. These questions were related to their work and management of tree torsos and what they allow regarding the height of tree torsos and their placement in the environment. Other considerations were to conduct interviews with the managers, but it was considered too time consuming as the recorded interviews would have had to be transcribed and meetings set up. The strength with the interview approach is that you can get a more honest answer and it is often used when interviewing e.g. farmers, but since we were dealing with managers that already work to improve biodiversity in their areas, the answers were expected to be honest. Another approach would be to do a tour of the area with the manager, this was done with the manager of Bispebjerg Kirkegård in relation to a tour with the Danish Society for Plant Diseases and Pests (Dansk Selskab for Plantesygdomme og Skadedyr).

List of questions:

1. Do you have any written policy or opinion about leaving large stumps, logs or tree torsos after felling of old trees? If yes, is it possible to acquire them for use in my master thesis?
2. What is the general policy for your green areas in relation to the height and placement of tree torsos?
3. Do you have a basis for selection of trees that are left as tree torsos, or is it random? This could be in relation to specific microhabitats on the tree or the age of the tree.
4. How long do you leave a tree torso standing? Is it a question about placement and height, or is it more about the state of decay of the tree torso?
5. Which other challenges have you encountered regarding tree torsos?
6. How old is your oldest tree torso?
7. What is your motivation for leaving behind tree torsos? Is it for biodiversity, for economic reasons or something else?
8. If there are areas, where you do not wish to leave tree torsos in, what would be the reason?
9. Have you received any reactions from the public regarding tree torsos?

The managers contacted:

Lars Birck from the University of Copenhagen at Frederiksberg Campus.

John Nørgaard Nielsen and Kristin Seybold from the Agency for Culture and Palaces. They work with the areas Søndermarken and Frederiksborg Slotspark.

Anja Hartvig Spork, Henriette Lunn Vonsbæk, Nina Lønholt Martin, Gunner Thalberg and Lars

Christensen from the Municipality of Copenhagen. They work with the areas Bellahøjparken, Bispebjerg Kirkegård, Degnemosen, Fælledparken, Ryvangen Naturpark and Utterslev Mose.

Results

This section concerns the response from the managers to the questionnaire. The questions and answers were in Danish but have been translated. The original text can be found in Appendix 5. The Municipality of Copenhagen has sent their administrative basis for torsos which answers most questions. Besides the few comments from the Municipality the administrative basis will be handled separately from the questions.

1. Do you have any written policy or opinion about leaving large stumps, logs or tree torsos after felling of old trees? If yes, is it possible to acquire them for use in my master thesis?

Lars Birck: "No we have nothing written down."

John Nørgaard Nielsen and Kristin Seybold: "No but it could be a new chapter in our hazard tree strategy when we revise it. We would like a suggestion for such a revision from you."

The Municipality of Copenhagen: They have sent their administrative basis for torsos.

2. What is the general policy for your green areas in relation to the height and placement of tree torsos?

Lars Birck: "Height: We are in general attentive to the degradation of the cambium, sapwood and heartwood in tree torsos which is much faster at ground surface due to the availability of both water and oxygen."

"The taller a tree torso, the larger the physical pressure can be at ground surface where the decay starts, especially if the tree torso is not standing straight."

"Therefore we do not wish for tall tree torsos in relation to the diameter. We do not have exact numbers on it. It always depends on an estimate where we also take the curve of the stem and the trees durability into consideration."

"Placement: We place them according to an aesthetic estimate, where we think they should be. But because it is also an educational garden, we keep some tree torsos with different fungi. If there is a new species for the fungus collection, it gives argument to preserve a tree torso."

John Nørgaard Nielsen and Kristin Seybold: “In forest like areas, tree torsos can be allowed to stand provided they are at least 20m from any path. The height between 4m and 10m. At fences / single trees closer to paths it is determined by each individual case.”

3. Do you have a basis for selection of trees that are left as tree torsos, or is it random? This could be in relation to specific microhabitats on the tree or the age of the tree.

Lars Birck: “The size of the stem, special fungal species on the tree and especially beautiful bark or the shape of the trunk is arguments for conservation.”

John Nørgaard Nielsen and Kristin Seybold: “Trees with woodpeckers can be allowed to stand with a little more height above the woodpecker cavity. Otherwise the selection mainly depends on placement and then the reason behind the felling. If the tree crown is damaged the tree torso can be in a completely different height than it would if there was a problem with the roots.”

4. How long do you leave a tree torso standing? Is it a question about placement and height, or is it more about the state of decay of the tree torso?

Lars Birck: “As long as possible. We will cut it down if the stem is at risk of falling, because we have a lot of guests and there must be no risk to their safety. But we will leave the stem as a log unless it means a significant increase in the work of cleaning this area (e.g. weeding), or trouble for the pedestrian traffic in the area.”

John Nørgaard Nielsen and Kristin Seybold: “Both and single evaluations. It is primarily a question about placement and safety. If the tree torsos are deep in the forest areas in areas with minimal traffic, they can be left to decay naturally.”

5. Which other challenges have you encountered regarding tree torsos?

Lars Birck: “We have had some operational challenges: The oldest generation of gardeners likes a more classical park where you clean it up when you e.g. cut down a tree. The traces have to be completely deleted and they have had difficulty in taking ownership of the idea of preserving tree torsos.”

John Nørgaard Nielsen and Kristin Seybold: “Single cases with fallen tree torsos, which were standing less than 20m from a path.”

6. How old is your oldest tree torso?

Lars Birck: “The oldest is from winter 2007. A beech tree that is part of the garden wall facing Thorvaldsensvej. We had to cut it down due to a widespread attack by the fungi *Meripilus giganteus*. The stem is far in its decay state and is full of life.”

John Nørgaard Nielsen and Kristin Seybold: “I would think they are about 10 years old. Some were up to 25 years old, but they disappeared.”

The Municipality of Copenhagen – Anja Hartvig Spork: “The oldest tree torso is from 2013. There may be some tree torsos in Utterslev Mose that are remnants of trees that were pollarded in 2009/2010.”

7. What is your motivation for leaving behind tree torsos? Is it for biodiversity, for economic reasons or something else?

Lars Birck: “It is for biodiversity and for use in the teaching at the University of Copenhagen”

John Nørgaard Nielsen and Kristin Seybold: “Biodiversity and practical considerations for example, if you cannot get access to wet areas, because it does not freeze enough winters in a row.”

The Municipality of Copenhagen – Lars Christensen: “I got the trees pollarded to 3-4 meters for them to be felled without the use of a lift.” “Since then we made especially in Damshusengen pollards of 7-8 meters as we wanted to make places for bats and had been told that bats live higher than 3-4 meters.”

8. If there are areas, where you do not wish to leave tree torsos in, what would be the reason?

Lars Birck: “Aesthetic reasons. E.g. we remove stumps in the poplar meadow (“poppelplænen”) at Thorvaldsensvej for this reason.”

John Nørgaard Nielsen and Kristin Seybold: “Aesthetic as well as safety considerations.”

9. Have you received any reactions from the public regarding tree torsos?

Lars Birck: “No”

John Nørgaard Nielsen and Kristin Seybold: “Positive comments on tours with the Danish Nature Conservation Association, Local department Fredensborg.”

The Municipality of Copenhagen – Anja Hartvig Spork: “There have been no reactions from the citizens that I know of. Many trees in Utterslev Mose was pollarded due to safety reasons and here

there were reactions from the citizens because it was so extensive."
The Municipality of Copenhagen – Henriette Lunn Vonsbæk: "I can add that I have had several citizen inquiries about tree torsos. The good thing is that it is from private individuals, nature guides or biologists who request more tree torsos or ask where they are or other things."

10. Further comments on the subject

Lars Birck: "I am not so excited about the term tree torso. All I meet think this is a somewhat scary word." "In the older forest literature, the word tree ruin is used. Certainly, derogatory then, but could you not reintroduce it? Ruins are exciting, and testify both to something that once were, but also to what might happen in it now and in the future." "Just a thought."
"I missed a question about the care/operation of the new shoots of the tree torso. They often sprout again, and you have to make sure that they do not break and hit someone if they become large. And the aesthetics of having epicormic shoots on the big stem."

The Municipality of Copenhagen – Lars Christensen: "And I would like to add that I cycle through Utterslev Mose and Damhussøen and the tree torsos from 2009/2010 besides being filled with outside rot and other good things also are beautiful, I think."

The administrative basis for tree torsos in the Municipality of Copenhagen

It is made based on securing deadwood for as long as possible in natural areas and parks, while also keeping safety high for its users. Furthermore, the objective with the guidelines is to diminish resource usage for pruning and inspection of tree torsos. They define tree torsos as standing stems with a circumference at breast height of minimum 1.5m and without any particular branches. Furthermore, tree torsos with a smaller circumference can be conserved if they have specific biological values. They leave tree torsos in 3 meters height in bushes and recreational areas ("Opholdsarealer"), e.g. with benches or other reasons for prolonged stay by visitors and they can then be deleted from the hazard tree monitoring system. Tree torsos can be left taller than 3 meters if they are habitat for bats but are then kept within the hazard tree system and if possible, the tree torso is cut in a height lower than the distance to nearest recreational area or path. Generally, tree torsos are not accepted on playgrounds. Inside thickets in natural areas the tree torso is cut in a height lower than the distance to nearest path or recreational area, and if they are not taller than the distance to this area, they are deleted from the hazard tree system. Again, if they are habitats for bats, they can be kept taller than the distance, but are kept in the hazard tree system. Tree torsos not part of the hazard tree system can be allowed to decay naturally for the benefit of biodiversity. Tree torsos still in the system can be felled or cropped if deemed necessary. Furthermore, tree torsos with wood decaying fungi still in the system will be felled or cropped after 10 years while tree torsos without can be conserved for 20 years. Monitoring frequency of the tree torsos is adjusted dependent on the type of wood decaying fungi and when monitoring occurs the distribution and amount of the fungi's fruiting bodies are registered. Additionally, visible rot development and sunken bark are registered. *Kretzschmaria deusta, Fomes fomentarius, Meripilus giganteus* are species of fungi that need to be monitored every third year and if the fruiting bodies are all around the tree torso, it needs to be felled or cropped. *Ganoderma, Laetiporus sulphureus, Armillaria, Pholiota squarrosa, Polyporus squamosus* are required to be monitored every fifth year and if there are many fruiting bodies around the tree torso, it needs to be felled or cropped. If none of the mentioned fungi are present, the monitoring still needs to occur every fifth year and here pronounced rot development in the lower parts can be reason to fell or crop the tree torso (*Municipality of Copenhagen, 2017*).

Discussion

Back in 2010, the Municipality of Copenhagen initiated a large tree felling and pollarding project due to their green spaces having lots of old willows and poplars. These trees had become unstable due to old age. One of these areas included Utterslev Mose. The municipality had a dilemma because if they chose not to do something about the old and sick trees and a citizen was injured from tree collapse, they would end up in court. On the other hand, pollarding and felling lots of trees and ruining something aesthetical would be met with complains from the citizens. The chosen trees were cut down to about 3-4 meter in height (what we call a tree torso in this project). If they had chosen to do crown reductions instead, they would have to return every 3-5 years to inspect them again and then they would probably have had to pollard the trees after 5 years anyway. Letting the trees stand would have been costly. The management method is also different because the areas are parks and not forests. The municipality is not taking the same risks as e.g. The Forest and Nature Agency (Thorsen, 2010). A year after the felling and pollarding of the 800 trees and the massive criticism the project got from the public and from the Society for Nature Conservation, new trees have been planted to meet the wishes of the citizens. One of the managers involved in the project agreed that the decision taken by the municipality was the right one, but that they failed to inform the citizens about the project. The citizens did not feel heard in the process which created strong reactions. They now involve the public in the process of replanting and make tours of the areas where they tell about the future for the areas and the background for felling in the first place (Thorsen, 2011).

The relevance of the feedback from the managers in relation to the project is both to get an insight into the problems they have encountered and the reasons behind their adaptation of the tree torsos concept. Furthermore, it is relevant as these are the people that try to implement the tree torso concept and have frequently interactions with gardeners that have other ideas. The Municipality of Copenhagen was the only one who had a tree torso policy, their administrative basis. Still there are dead wood and tree torsos in the other research areas meaning they must have been advised or gotten inspiration from someone or somewhere. They seemed to follow the same guidelines as the Municipality of Copenhagen as most of their tree torsos were about 3-4 meters tall and most of the tall tree torsos were either with a small cavity or far enough away from paths and roads to not be a risk. In relation to the collected microhabitat data it was mainly seen that tall tree torsos had woodpecker holes which further is validated here as that is one of the guidelines that the administrative basis suggests. The relevance of the administrative basis in relation to the project is that it can be revised with some improvement such as the selection of tree that should be left as tree torsos. Furthermore, the project can provide other managers with some guidelines and help them develop their own administrative basis.

Height and placement of tree torsos depend on different elements such as the curve of the stem, the trees durability and the diameter of the stem. Preserving different fungi is an argument for leaving behind tree torsos. In relation to the municipality's administrative basis, tree torsos can be taller if it contains a habitat for bats. Tree torsos can also be allowed to stand in forest like areas, provided they are at least 20m from any path, which is also observed in e.g. Frederiksborg Slotspark. Furthermore, trees with woodpeckers can be allowed to stand with a little more height above the woodpecker cavity, which has been observed several times across all the research areas.

They state that their selection of trees left as tree torsos depends on the size of the stem, special fungal species on the tree and especially beautiful bark or the shape of the trunk. In relation to the shape of the trunk there is a perfect example from Bispebjerg Kirkegård where a tree torso (<4m) has a special tree structure with many branches coming from a low point. The selection is also mainly depending on the location where it can be hard to preserve tall tree torsos if they are close to path or roads with a lot of traffic. This makes good sense since the tree torso could fall over if there is a problem with the roots and thereby produce a safety risk. The managers do not mention much about microhabitats other than woodpecker holes and species of fungi. It might be possible to take more microhabitats into consideration when selecting tree torsos as many tree torsos lack special microhabitats e.g. seen with the new beech torsos in Fælledparken. But it is also important to remember that some microhabitats develop over time as the wood starts to decompose.

In relation to how long a tree torso can be left standing, they would like for them to stand for as long as possible, but they will cut it down if the stem is at risk of falling. They will leave the stem as a lying stem unless it means a significant increase in the work of cleaning this area (e.g. weeding) or if it creates trouble for the pedestrian traffic in the area. Here it could be possible to implement the lying stems in a way that it can be used recreational, such as a bench which they have done in Bispebjerg Kirkegård. If the tree torsos are deep in the forest areas in areas with minimal traffic, they can be left to decay naturally. As it is previously described walking in forest areas is at own risk and therefore it makes sense to leave it to naturally decay, unless there is a lot of traffic in the area. An example of taking precautions for the pedestrian traffic is seen at Kaffehøj in Northern Zealand where they pollarded a tree at the edge of the stand trees and left it as a tall tree torso, despite the stand being designated as unmanaged. The reason was probably the presence of a 'forest kindergarden' ("Skovbørnehave") in the vicinity and other visitors frequently using the nearby path.

The different challenges the managers encountered were e.g. operational challenges where the oldest generation of gardeners likes a more classical park where you clean it up when you e.g. cut down a tree. These old traditions are potentially one of the reasons why there is a lack of old tree torsos, but many older tree stumps as this was what could be allowed to be left for biodiversity in the past. As we get more aware of the importance that biodiversity has, we will need to change and adapt new methods into the management of urban green spaces. The newer generation of gardeners would likely have been taught this while the older generation will have to adapt to new practises. Furthermore, the administrative basis from the Municipality of Copenhagen is relatively new as it was created in 2017 and thus it can be expected that more tree torsos will appear in the future. This also contribute to the idea that leaving behind tree torsos is a new concept and that it will take time for the old gardeners to adapt to this new practise. There are some examples of old tree torsos e.g. an old beech torso from the winter 2007 which is part of the garden wall facing Thorvaldsensvej. It is the same tree torso as shown on the front page. It had to be cut down due to a widespread attack by *Meripilus giganteus.* The tree torso is far in its decay state and full of life such as a rare potential red listed rove beetle species found in the fruiting body of *Meripilus giganteus* by a Swedish beetle expert Mikael Sörensen back in 2012. This is a prime example of what the new beech torsos in

Fælledparken can become if left standing and how they eventually can help support biodiversity of rare saproxylic and semi-saproxylic species. The tree torsos in Utterslev Mose from the felling in 2009/2010 can also be considered old even though they don't seem to be that far in their decaying process compared to the one at Thorvaldsensvej. Due to the administrative basis being relatively new the amount of older tree torsos are few in the whole urban context compared to the amount of tree torsos that are present at the moment. Depending on how many of these can be allowed to stand for a longer period we can expect more older tree torsos in the future. This is possible if the gardeners can start taking ownership of the concept and receive positive feedback to further improve the concept and idea for them.

The motivation for leaving behind tree torsos is mainly governed by biodiversity purposes, but the managers also have different secondary purposes. These secondary purposes include teaching, practical considerations and economic reasons as seen with the case in Utterslev Mose where the trees got pollarded in 3-4 meters to enable subsequent felling without the use of a lift. It is expensive to use a lift and it is also easier to maintain the tree torsos that produce epicormic shoots which is almost all the trees in Utterslev Mose since they are mainly willow and poplar. After all the criticism the pollarding in Utterslev Mose 2009/2010 got, they made new initiatives to improve the habitats for bats as seen in Damshusengen where they made pollards of 7-8 meters as they were told that bats live in taller trees than 3-4 meters as also referenced earlier in this project. Other economic considerations are to reduce resource usage for inspection and pruning of tree torsos which is one reason why it is more difficult to accept tall tree torsos as these would need more frequent inspection and potential pruning after a period of time. Finally, leaving behind tree stumps and lying stems reduces the cost of removing the heaviest part of the stem and chipping the stump. In relation to leaving behind stumps it should be done with some volume and a height about 1 meter as there is no reason to leave behind a ground level stump. It is an easy and cheap way to do something good for biodiversity while also serving a recreational purpose as a bench or a playground for kids (Ravn *et al.,* 2017).

In relation to the reactions from the public regarding tree torsos, the managers mainly received positive comments from organisations, people working with nature and the public. Some even requested more tree torsos. Besides the positive reactions it is known that the pollarding in Utterslev Mose 2009/2010 was met with negative reactions from the public. This is not necessarily a negative opinion towards tree torsos, but rather the way the project was done and the lack of communication and citizen involvement (Thorsen, 2010, 2011). In retrospect, the management decision promoted biodiversity, since the trees were not removed completely, and most of the tree torsos are still alive with epicormic shoots. If possible, it is important to involve citizens affected by bigger projects in the planning process to avoid distrust and to gain their input and opinions on the concept. Workshops and guided tours can help people learn about the different implementations and the benefits they can have for biodiversity, which further can help avoid conflicts in the future.

Guidelines for management of hazard trees

The purpose behind this study was to improve guidelines for optimizing biodiversity when managing urban hazard trees. The guidelines are listed below and are based on the findings in this thesis.

- Small cavities can help deciding whether a tree should become a tall tree torso.

- Dendrotelms can be promoted by facing lying stems with cavities upwards.

- Cut trees a little higher up to allow for forks to be preserved if possible, but this is not always necessary as these structures also can be found on living tree.

- If possible leave some branches on the tree torso

- Leave behind tree structure types with rare species of fungi for preservation of these.

- Variation is key – have different tree structures and some of these can be allowed to decompose naturally.

- Consider the time horizon – the longer a tree structure can be allowed to remain the better in most cases. Should be left to decompose naturally if possible.

- Large tree stumps and lying stems can be as good as tree torsos in many aspects adding further to the importance of having a variety of different structures.

- Quality over quantity – be selective when choosing what tree should become a tree torso.

- Diversity in tree species further adding to the variation and quality – have different tree remnants of different tree species.

- Tree stumps and lying stems of different species should have high priority due to the amount of time they can be left, the benefits they provide for biodiversity and for economical reasons as it is cheaper.

Main conclusions

The importance of having tree torsos and other woody debris such as tree stumps and lying stems are for variation in structures as these can create more niches and microhabitats. Some organisms such as e.g. frogs can benefit from a lying stem as it can hide underneath where it is more humid while other organisms can benefit from the sunlit surface. Differences in tree structures can help provide temperature and moisture gradients from top to bottom. However, a lying stem can't support birds and bats as they need a standing structure with a certain height which can be provided by a tree torso. A lying stem can instead provide a habitat for insects that can be used as a food source for birds and bats while also supporting different epiphytes. Furthermore, tree torsos are a way to implement a new structure of dead wood in the urban environment which also can be used in a recreational fashion. There could also be an economic aspect to it as it might be cheaper to leave the tree torso standing than having to pay for removal of the stump, but there is of course a lasting management of the epicormic shoots that might appear and monitoring of tall tree torsos. In relation to leaving behind tree stumps it is important to consider the volume and height as it is more beneficial to have a sufficient mass to work with which also can be used in a recreational fashion as e.g. a place to sit. It has been a habit to remove as much of the tree when felling, but there is no reason behind leaving a ground surface stump in relation to biodiversity. Put into perspective, more and more tree torsos are appearing in the parks and urban environments and is not only restricted to Denmark as there are examples from both Germany (Berlin) and Sweden (Skåne).

When deciding what should happen with a hazard tree it is important to have knowledge of what kind of tree species it is and what that tree species can provide in form of microhabitats as some microhabitats are more species specific than others. It is also important to know what structure type is more beneficial in some species. It was seen that tall beech torsos were better than <4m beech torsos while this was not the case with e.g. willow and poplar where the <4m tree torsos were better. Furthermore, it is relevant to consider what microhabitats there are present on the structure as some microhabitats are more important than others in terms of rarity and relevance for biodiversity. In general, there wasn't much difference between the four tree structure types studied in terms of the microhabitats they could provide with a few exceptions e.g. small cavities in tall tree torsos and different epiphytes on tree stumps and lying stems.

Until now, leaving behind tree stumps, lying stems or tree torsos have seemed to be a compromise between the need to manage hazard trees while still doing something positive for biodiversity. However, no systematic assessments of these tree remnants have been done in relation to the benefits they may have for biodiversity. Not every tree remnant provides a wide variety of microhabitats at first, and time is needed to develop more. This should influence the decision on the selection of trees to be left behind as tree torsos, especially tall specimens, often won't be allowed to stand for decades. The selection of trees for tree torsos should depend on variation in tree species, the different microhabitats they already have, and their potential to develop more microhabitats over time. Not every tree should be made into a tree torso as it is more important to have quality and variation over quantity. This study has shown, that in many cases a large stump and a lying stem can provide most of the microhabitats registered, except for nesting cavities for birds and bats. If quality is a factor of time as well as tree species and initial tree condition, e.g. rot or cavities, and if the management is more likely to leave tree stumps and lying stems to decay naturally, but feel that tree torsos are unsafe, perhaps tree torsos should only be used in specific cases. Thus, lying stems and tree stumps might be the best long-term solution in relation to improving biodiversity.

Acknowledgements

First, I would like to thank the different park managers from my research areas for answering my questionnaire and for giving others helpful comments towards the project. I would also like to thank those that helped identifying some of the more difficult tree species. Thanks to Anja Hartvig Spork, Henriette Lunn Vonsbæk, Nina Lønholt Martin, Gunner Thalberg and Lars Christensen from the Municipality of Copenhagen. Thanks to Lars Birck from the University of Copenhagen at Frederiksberg Campus. Thanks to John Nørgaard Nielsen and Kristin Seybold from The Agency for Culture and Palaces.

I would like to thank the Department of Geosciences and Natural Resource Management for allowing me to write my thesis at their section of Forest, Nature and Biomass.

I would also like to thank the Danish Society for Plant Diseases and Pests for inviting me to give a short talk about the topic of my master thesis on a tour of Bispebjerg Kirkegård.

I would also like to thank my family and friends for moral support and a special thanks to Anna Mariager Behrend that have been with me throughout my bachelor and masters while also helping me with editing some of the pictures.

Lastly, I would like to thank my supervisor Iben Margrete Thomsen, for all her guidance and optimism towards the project which helped me dealing with some of my own doubts. I would also thank her for the quick answers by email and feedback throughout the project. Furthermore, helping with identification of difficult tree species and teaching me about elements relating to the subject. I would also like to thank her for contacting the park managers and sending my questionnaire. Lastly, I would like to thank her for providing pictures of fungi that couldn’t be seen when collecting the data as these we either annual polypores or pulpy agarics.

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