Field Guide to Northern Tree-related Microhabitats

Descriptions and size limits for their inventory in boreal and hemiboreal forests of Europe and North America

WSL

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Further information:
Short videos on YouTube about tree-related microhabitats.

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Introduction

A tree-related microhabitat (abbreviated as TreM) is a morphological feature present on a tree, which is used by sometimes highly specialised species during at least one part of their life cycle. These features may serve as shelters, breeding spots, or crucial hibernation or feeding places for thousands of species. Trees bearing at least one TreM are called habitat trees (Fig. 1). Various biotic and abiotic events can create TreMs: for example, a falling tree can injure the tree bark, snow can break off a tree top, fire can create fire scars, and a woodpecker can excavate a breeding cavity in the trunk. For some TreMs, such as vertebrate nests and witches' brooms, the tree is merely a physical support. Only morphological features that are known to have a direct link with one or more associated species are classified as TreMs (Larrieu et al. 2018).

Each TreM provides very specific conditions to the inhabiting species, depending on its characteristics, such as size, shape, position in the tree, degree of decomposition of the surrounding wood, condition of the bearing tree (living or dead), exposure to sunlight, microclimate, and moisture content.

The diversity of TreMs in a forest stand directly influences the diversity of species because different TreMs provide optimal conditions for various species to thrive. However, TreMs are ephemeral, and when one deteriorates or ceases to exist, the species that are reliant on it must locate and colonise a new TreM. Thus, the more often a specific TreM occurs in a stand, the easier it becomes for the associated species to establish in a new TreM when the previous one is no longer viable. To reinforce biodiversity in a stand and thus improve its resilience, we need to know which TreMs are present, and to preserve and favour them through adapted management practices.

This field guide describes 52 TreMs: 47 according to Larrieu et al. (2018) and 5 additional ones identified in this work. These microhabitats can be categorised into 17 groups, with these groups falling within 7 overarching forms. The guide also indicates recommended minimum inventory sizes for each TreM in boreal and hemiboreal forests and gives information about the TreM's life traits, development rhythm, and associated species.

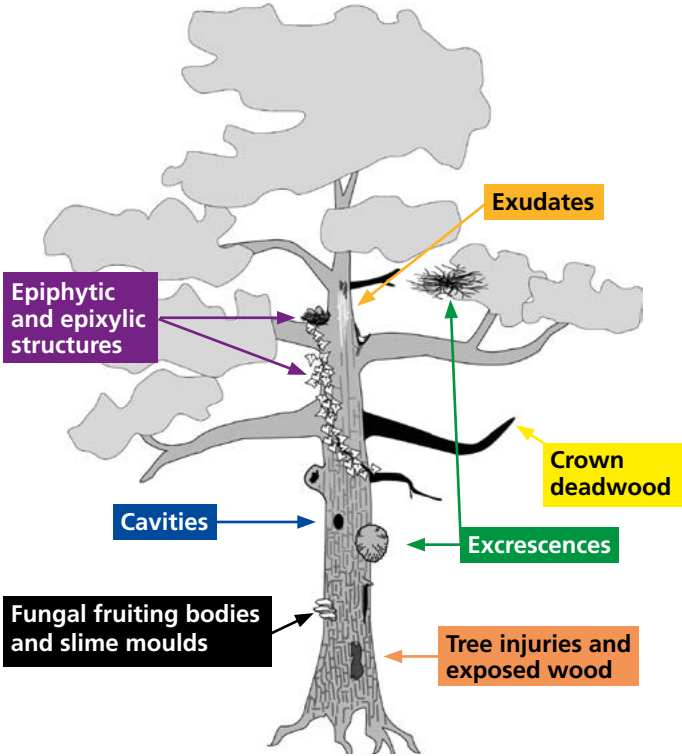


Fig. 1. A habitat tree bearing tree-related microhabitats essential to specialised species for shelter, breeding spots, hibernating or feeding, or even for their entire life cycle.

Area of utilisation

This booklet is based on the publication by Bütler et al. (2020) and is specifically tailored to boreal and hemiboreal forests. The boreal forest (or taiga) is the world's largest land biome, located in the high northern latitudes, between about 50°N and 70°N, where freezing temperatures occur for six to eight months of the year. It covers most of the inland areas of Canada, Alaska, part of the contiguous US, most of Scandinavia, much of Russia (including Siberia), and forested parts of Iceland, Kazakhstan, Mongolia, and Japan (Fig. 2). Boreal forests are typically composed of cold-tolerant tree species primarily within the genera *Abies, Larix, Picea,* and *Pinus,* but *Populus* and *Betula* occur as well. The most important natural drivers of boreal ecosystem dynamics are climate, fire, insect outbreaks, and diseases, including their interactions. Large-scale logging and forest fires are

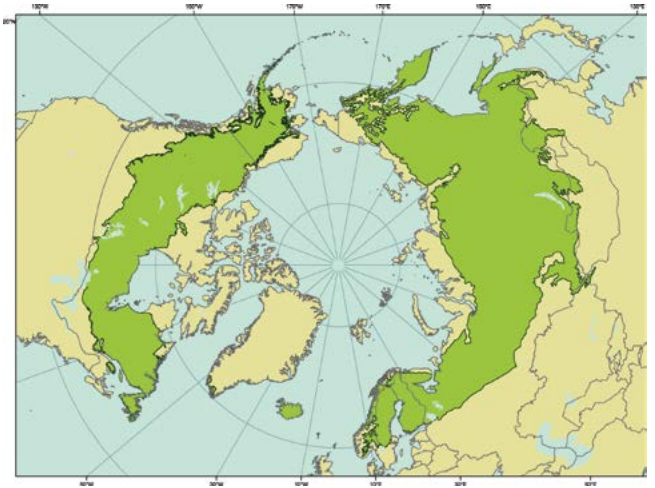


Fig. 2: Distribution of the circumboreal biome (reproduced from Environmental Reviews, Brandt *et al.* 21(4), copyright 2023; permission granted from Canadian Science Publishing, conveyed through Copyright Clearance Center, Inc.)

especially crucial disturbances and profoundly impact major ecosystem processes.

The hemiboreal zone (or sub-boreal zone) is a transitional zone between the boreal and temperate forest. It is characterised by the coexistence of boreal coniferous (main genera: *Abies, Picea,* and *Pinus*) and temperate broadleaved tree species (main genera: *Acer, Fraxinus, Ulmus, Tilia, Quercus*). The structure and composition of hemiboreal forests is maintained by a complex admixture of natural (e.g. fires, insects, and windfalls) and cultural disturbances (e.g. forestry and grazing). In Europe, this forest zone covers a narrow band in the southernmost parts of Fennoscandia, most of Estonia, Latvia, and Lithuania, north-eastern Poland, and northern Belarus, and it stretches eastwards across Russia towards the Ural Mountains (Fig. 3 left). In North America, the hemiboreal zone extends along the Canada–United States border in the eastern part of the continent, and in the west it shifts northwards to include the southern part of Saskatchewan and Alberta and most of British Columbia (Fig. 3 right).

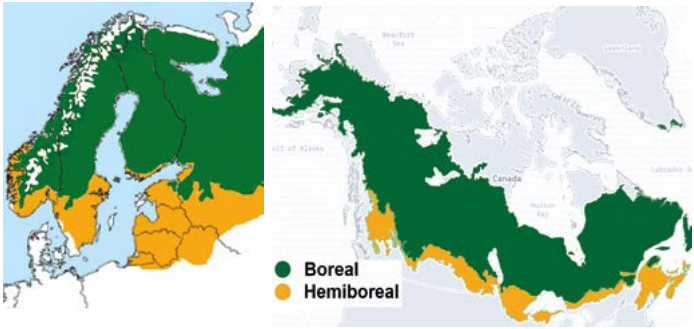


Fig. 3: Distribution of the boreal and hemiboreal zone in Europe (modified from Manton *et al.* 2022) and North America (data from www.nrcan.gc.ca)

Legends and definitions

DM stands for "difficult to monitor" and signifies that this TreM type is difficult to monitor in a routine inventory, due to its small size, its location, or its sporadic incidence.

Life traits: The different life traits describe the ecological characteristics of the TreM and indicate where it can be found.

Substrate type	Saproxylic	Contains deadwood in the process of decay; key resource for saproxylic taxa.
	Epixylic	Does not contain deadwood in the process of decay, and the tree serves mainly as a physical support; key resource for specialists.
	Wood mould	Contains wood mould, a mixture of decaying wood, fungal hyphae, insect frass, and other organic matter; key resource for wood mould specialists.
Tree condition	Living	Borne by living trees; resource for tree-associated species. (Living): sometimes borne by living trees.
	Snag	Borne by standing dead trees, called snags; resource for saproxylic species.
Tree category	Conifer	Borne by conifer trees; key resource for conifer-associated species. (Conifers): sometimes borne by conifers.
	Broad-leaved	Borne by broadleaved trees: key resource for species associated with broadleaved trees. (Broadleaved): sometimes borne by broadleaved trees.

Position on the tree	Base	Located at the base of the tree; resource available for non-arboreal species. (Base): sometimes located at the base of the tree.
	Trunk	Located on the trunk of the tree; resource not available for non-arboreal species.
	Crown	Located in the tree crown, i.e. the whole part of the tree currently bearing branches, dead or alive; resource not available for non-arboreal species.
Wetness	Dry	Dry conditions at the microhabitat scale; key resource for moisture-averse species. (Dry): sometimes dry conditions at the microhabitat scale.
	Wet	Wet conditions at the microhabitat scale; key resource for moisture-seeking species. (Wet): sometimes wet conditions at the microhabitat scale.
	Water-filled	Regularly filled with water; key resource for water-breeding species.
Shelter	Shelter	Can be used as shelter against rain, to regulate temperature and humidity, or to be safe from predators.
Soil contact	Soil contact	In contact with the humus of the soil; the ecotone between two humus-dominated habitats but hosting very different communities (soil-dwelling and wood-mould-dwelling ones).

Life span	Ephemeral	The microhabitat maintains its function for less than one year; short-term resource.
	Annual	The microhabitat maintains its function for about one year; medium-term resource.
	Perennial	The microhabitat maintains its function for more than one year; long-term resource.

Minimum size: The minimum size required for the TreM to be recorded in a survey. Certain size thresholds are related to the ecological requirements of the associated species. When these thresholds are unknown, the indicated values are defined by experts in order to reduce observer effects as much as possible ("experts' threshold").

Trigger frequency: Frequency of occurrence of the trigger of the microhabitat. If the microhabitat disappears, it takes only a short time to reappear if the trigger has a high frequency of occurrence (e.g. "woodpecker foraging excavation"). On the other hand, it takes a long time if the trigger has a very low occurrence frequency (e.g. "fire scar").

Development rhythm: The amount of time necessary for the microhabitat to become suitable for associated species after it is triggered.

	Very rapid / Days: resource very quickly suitable Rapid / Month: resource quickly suitable Fairly rapid / One year: resource fairly quickly suitable
	Fairly slow / Several years: resource unsuitable for a fairly long time Slow / Decades: resource unsuitable for a long time Very slow / Century: resource unsuitable for a very long time

Associated species: Species or species groups with a close relationship to the associated TreM, according to at least one reference in the scientific literature or based on the authors' own observations. The list below is not exhaustive, and the species mentioned should be taken as examples only.


Coleopterans


Dipterans


Hymenopterans


Ants


Butterflies


Aphids


True bugs


Spiders


Thysanoptera


Psocoptera


Siphonaptera


Myriapods


Springtails


Flagellates


Rotifers


Nematodes


Birds


Bats


Rodents


Carnivores


Amphibians


Reptiles


Gastropods


Mosses


Fungi


Lichens


Vascular plants


Ferns

Saproxylic species: a species that depends on decaying wood or other saproxylic species for at least one part of its life cycle (from the Greek words “sapros” = rotten, and “xylon” = wood).

Generally, five wood decay stages are distinguished:

Stage 1: Current-year deadwood; the wood is very hard and shows little or no signs of decay. All of the bark is still well attached.

Stage 2: The wood is hard and only slightly decayed; a knife blade can penetrate the wood with difficulty (<1 cm), even parallel to the grain. Virtually all the bark is intact, though it may no longer adhere very well.

Stage 3: The wood shows clear signs of decay and the surface has become soft or spongy; a knife can penetrate from one to several centimetres, parallel to the grain. The bark has partly or mostly fallen off. The piece of deadwood has not lost any of its initial volume.

Stage 4: The wood has decayed considerably; a knife can penetrate to the hilt, at least in some places. There is no more (or very little) remaining bark. The piece of deadwood has lost some of its initial volume.

Stage 5: The wood has lost its structure and is easily scattered manually. Remnants contain saproxylic and soil-dwelling organisms (e.g. earthworms). An in-depth inspection is necessary to identify the tree species.

Typology of tree-related microhabitats

Cavities: holes or sheltered spots in the tree, dry or wet, with or without wood mould; located on the trunk, in the crown, or at the root collar.

- **Woodpecker breeding cavity:** a cavity excavated by a woodpecker for nesting
- **Rot-hole:** a cavity containing wood mould (a mixture of decomposing wood, animal excretions, and animal remains)
- **Insect galleries:** holes and galleries excavated by saproxylic insects
- **Concavity:** a hole or hollow in the wood, either wet or dry, or a sheltered spot with no wood mould which was not excavated by insect activity

Injuries and exposed wood: sapwood or heartwood is exposed due to bark loss, splitting, or breakage.

- **Exposed sapwood:** bark loss has exposed the sapwood only
- **Exposed sapwood and heartwood:** breakage or splitting has exposed both the sapwood and heartwood

Crown deadwood: deadwood located in the crown of the tree.

Excrescences: excrescences caused by a reaction of the tree to light or an attack by bacteria, fungi, viruses, or arthropods.
- **Twig tangle:** a dense packet of small twigs
- **Gall:** a deformity of a tree organ caused by a parasitic attack
- **Burr and canker:** ball-shaped excrescence of relatively dense woody material

Fungal fruiting bodies and slime moulds: the reproductive structures of saproxylic fungi or slime mould plasmodia, lasting from a few days to several weeks.
- **Perennial fungal fruiting bodies:** the reproductive structures of saproxylic fungi that develop over several years
- **Ephemeral fungal fruiting bodies and slime moulds:** the reproductive structures of saproxylic fungi that develop over one year or less, or slime mould plasmodia

Epiphytic and epixylic structures: formations or living organisms that use the tree mainly as a physical support.
- **Epiphytic and parasitic cryptogams and phanerogams:** vascular plants, mosses and lichens that use the tree as a physical support
- **Nest:** a vertebrate or invertebrate nest (excluding woodpecker breeding cavities) placed in the tree or in a cavity
- **Microsoil:** a small amount of newly created soil originating from the decomposition of organic matter from twigs, leaves, bark, or mosses
- **Alluvial deposit:** a clay or silt deposit on the tree trunk caused by flooding

Exudates: sap run or resinosis.

1 Small woodpecker breeding cavity (ø < 4 cm)

Woodpecker breeding cavity with a round entrance < 4 cm in diameter. *Dryobates minor, D. pubescens*, and *Sphyrapicus varius* cavities are generally found in the trunk of dead or senescent broadleaved trees.

Life traits: saproxylic, wood mould, living, snag, broadleaved, crown, dry, shelter, perennial

Minimum size: cavity entrance Ø < 4 cm

Trigger frequency

Development rhythm

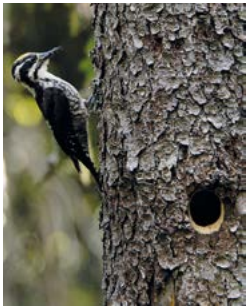
Associated species:

Did you know? In Fennoscandian boreal forests, lesser spotted woodpecker nesting trees typically have a mean diameter ≥ 25 cm. Woodpeckers generally prefer large trees and broadleaved species for excavating breeding cavities, but such trees are rare in managed forests of Fennoscandia and Eastern Canada. To sustain viable woodpecker populations, forest management needs to actively increase the number of old, dead, and broadleaved trees through set-asides and other measures.

2 Medium-sized woodpecker breeding cavity (ø = 4–7 cm)

Woodpecker breeding cavity with a round entrance 4–7 cm in diameter. *Dendrocopos major, D. leucotos, Picus viridis, P. canus, Picoides tridactylus, P. dorsalis, P. arcticus, and Leuconotopicus villosus* often use senescent and dead trees.

Life traits: saproxylic, wood mould, (living), snag, conifer, broadleaved, trunk, dry, shelter, perennial



Minimum size: cavity entrance Ø = 4–7 cm

Trigger frequency

Development rhythm

Associated species:

Did you know? The survival time of a European three-toed woodpecker cavity is about 5–17 years. The reuse of cavities by other cavity-nesting vertebrates, such as the starling, red squirrel, or boreal owl, is mostly restricted to the first 5 years after the excavation. Forest management should therefore ensure a continuum of suitable nest trees.

3 Large woodpecker breeding cavity (ø > 8 cm)

Woodpecker breeding cavity with an oval entrance > 8 cm in diameter. *Dryocopus martius, D. pileatus,* and *Colaptes auratus* generally excavate their cavities in the main tree trunk.

Life traits: saproxylic, wood mould, living, (snag), (conifer), broadleaved, trunk, dry, shelter, perennial

Minimum size: cavity entrance Ø > 8 cm

Trigger frequency

Development rhythm

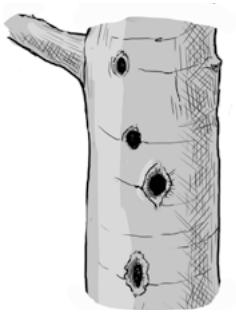
Associated species:

Did you know? Black woodpeckers use dead and green tree legacies in clearcuts if their diameter at breast height is at least 40 cm (for pine), 36 cm (for aspen) or 32 cm (for dead trees). In large trees, the cavity walls are thicker than in smaller trees, which ensures a more insulated internal microclimate, an advantage for the birds or mammals that breed or take shelter there.

4 Woodpecker “flute” (breeding cavity string)

At least three woodpecker breeding cavities aligned on the trunk, with less than 2 m distance between two neighbouring cavities.

Life traits: saproxylic, wood mould, living, (conifer), broadleaved, trunk, dry, shelter, perennial



Minimum size: ≥ 3 cavities in one line; cavity entrance Ø > 3 cm

Trigger frequency

Development rhythm

Associated species:

Did you know? Nitrogen input in the form of faeces, leftover food, deadwood, leaves, or carcasses is a food resource for many invertebrates that live inside the cavities and nest material. In addition, one can find vertebrate parasites, and predators and parasites of these invertebrates.

5 Trunk-base rot-hole (closed top, ground contact)

The cavity contains decomposed organic material or wood mould. It is protected from the external climate and rain; its bottom is in contact with the ground. Even so, the entrance may be located relatively high up on the trunk.

Life traits: saproxylic, wood mould, living, (conifer), broadleaved, base, dry, shelter, soil contact, perennial

Minimum size: cavity entrance Ø > 10 cm

Trigger frequency

Development rhythm

Associated species:

Did you know? A single rot-hole can harbour a population of beetles for several decades. Saproxylic beetles associated with rot-holes generally have a limited dispersal capacity. If the cavity-bearing tree disappears, for example due to felling, the beetle population will die out unless it finds another similar tree nearby.

6 Trunk rot-hole (closed top, no ground contact)

This cavity contains decomposed organic material or wood mould, with the quantity depending on rot-hole development stage. It is protected from the external climate and rain. The bottom of the cavity is not in contact with the ground.

Life traits: saproxylic, wood mould, living, (conifer), broadleaved, trunk, dry, shelter, perennial

Minimum size: cavity entrance Ø > 10 cm

Trigger frequency

low

Development rhythm

slow (very slow)

Associated species:

Did you know? If the water content of wood mould is sufficiently high, a cavity is cooler than the exterior during the day (because of evaporation) and warmer during the night. Besides wood mould, a particular set of species use other subsections of the cavity – the ceiling, walls and floor.

7 Semi-open trunk rot-hole

The cavity is not completely protected from the external microclimate and rain can enter. The bottom of the cavity is not necessarily in contact with the ground, and the entrance may be located relatively high up on the trunk.

Life traits: saproxylic, wood mould, living, (conifer), broadleaved, base, dry, (wet), shelter, soil contact, perennial

Minimum size: length ≥ 30 cm, width > 10 cm (experts' threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? Depending on the size and exposure of the opening, cavities can be dry, moist, or wet. This, in turn, affects the species composition of both fungi and insects colonising the rot-hole. The wood mould inside is nutrient-rich and has a high pH level, which favours specific rare species.

8 Chimney trunk-base rot-hole (ground contact)

The cavity is open at the top, often due to stem breakage. The cavity base reaches ground level, so the bottom of the cavity is in direct contact with the soil.

Life traits: saproxylic, wood mould, (living), snag, (conifer), broadleaved, base, wet, soil contact, perennial

Minimum size: cavity entrance Ø > 10 cm (experts' threshold)

Trigger frequency

low

Development rhythm

very slow (slow)

Associated species:

Did you know? When hollows develop in long-lived tree species, they can last for hundreds of years. As the tree grows larger and the hollow develops, it often collects a large amount of wood mould and becomes a critical habitat for many species.

9 Chimney trunk rot-hole (no ground contact)

The cavity is open at the top, often resulting from stem breakage. The cavity base does not reach ground level, so there is no direct contact with the soil.

Life traits: saproxylic, wood mould, (living), snag, (conifer), broadleaved, trunk, wet, perennial

Minimum size: cavity entrance Ø > 10 cm (experts' threshold)

Trigger frequency

low

Development rhythm

very slow (slow)

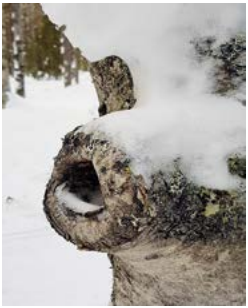
Associated species:

Did you know? Both microclimatic and physico-chemical conditions are different in suspended cavities and trunk-base cavities. As a result, the organisms associated with the two types of cavities are not the same. The nitrogen content of wood mould cavities is three to four times higher than in undecayed wood. More complex species communities maintain a greater amount of nutrients.

10 Hollow branch

A rot-hole located on a large – often broken – limb, often forming a more or less horizontal, tube-shaped shelter.

Life traits: saproxylic, wood mould, living, (conifer), broadleaved, trunk, dry, perennial



Minimum size: cavity entrance Ø > 10 cm (experts' threshold)

Trigger frequency

low

Development rhythm

very slow (slow)

Associated species:

Did you know? Coal tits and great tits prefer to nest in hollow branches rather than in woodpecker cavities.

11 Insect galleries and bore holes

Emergence holes left by wood-eating (xylophagous) insects indicate the presence of a cavity network in the wood. An insect gallery is a complex system of tunnels and chambers.

Life traits: saproxylic, (wood mould), (living), snag, conifer, broadleaved, trunk, dry, shelter, perennial

Minimum size: multiple bore holes > 300 cm^2 (A5/P5 sheet of paper; experts' threshold)

Trigger frequency

Development rhythm

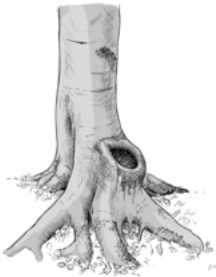
Associated species:

Did you know? Many solitary bees and wasps utilise holes in deadwood for offspring production. Many of them are dependent on the emergence holes of other wood-boring insects for their nesting sites. Wood-eating insects are sometimes considered to be forest pests. However, the vast majority of these species consume dead or decaying wood and do not cause tree dieback. Among the thousands of species of insects dwelling in the forest, very few (<1%, max. 50 species) can actually kill a healthy tree or cause large-scale damage of economic relevance.

12 Dendrotelm

Cup-shaped hollows where rainwater can accumulate and then gradually evaporate. Healthy bark may have sealed the inside of the hollow, or the edges and bottom may be in a state of decay.

Life traits: saproxylic, epixylic, (wood mould), living, broadleaved, trunk, crown, water-filled, ephemeral



Minimum size: opening Ø > 15 cm

Trigger frequency

fairly low

Development rhythm

slow

Associated species:

Did you know? Many species depend on water-filled tree holes for their larval stages (e.g. insects such as beetles and dipterans), for their entire life cycle (e.g. nematodes and other mesofauna), or as an important water source. The communities that assemble when these holes fill up with water depend largely on dead organic matter (mostly leaf litter) accumulating in the holes.

13 Large woodpecker foraging excavation

A hollow resulting from woodpecker foraging. The hollow is cone-shaped, in that the opening is larger than the cavity itself.

Life traits: saproxylic, (wood mould), snag, conifer, (broadleaved), trunk, dry, shelter, perennial

Minimum size: depth > 10 cm, opening Ø > 10 cm

Trigger frequency

Development rhythm

Associated species:

Did you know? When woodpecker foraging excavations are large enough, birds may use them to shelter their nests.

14 Bark-lined trunk concavity

A natural hollow in the tree trunk, with a hard bottom and bark on the inside walls.

Life traits: epixylic, living, conifer, trunk, dry, shelter, perennial

Minimum size: depth > 10 cm, opening Ø > 10 cm

Trigger frequency

Development rhythm

Associated species:

Did you know? Several species of undemanding cavity-nesting birds, for example the blackbird *(Turdus merula)*, use bark-lined trunk concavities as nesting sites.

15 Buttress-root concavity

A natural hollow with a hard bottom and bark on the inside walls formed between buttress roots or between a buttress and the ground. There is no presence of wood mould (classification is "trunk-base rot-hole" if wood mould is present).

Life traits: epixylic, living, conifer, broadleaved, base, dry, shelter, soil contact, perennial

Minimum size: Opening > 10 cm; depth > 10 cm; "ceiling" angle < 45° (experts' threshold)

Trigger frequency

low (very low)

Replacement rate

slow

Associated species:

Did you know? Trees growing on steep slopes, rocky terrain, nurse logs, or stumps often have buttress-root concavities. Located at the base of the trunk and formed by the roots of the tree, these concavities are used as shelters by small and large mammals, birds, and amphibians. They can be used both as shelters from rain and as damp refuges during dry periods.

16 Bark loss

Bark is missing and the sapwood is exposed (bark loss due to e.g. tree felling, skidding operations, falling trees, bark removal by mammals, rock fall, cultural bark-peeling).

Life traits: saproxylic, living, (snag), (conifer), broadleaved, (base), trunk, dry, (wet), perennial

Minimum size: surface > 300 cm^2, (A5/P5 sheet of paper; experts' threshold)

Trigger frequency

fairly low

Development rhythm

very rapid

Associated species:

Did you know? Areas of exposed sapwood are easily colonised by fungi and insects. The tree can eventually heal a small injury. In this case, the exposed sapwood will only play a short-term ecological role. Larger injuries generally do not heal over. If the tree survives and stays in place, the injury will eventually become a rot-hole. This process takes several decades. Coniferous and broadleaved trees host very different fungal communities.

17 Fire scar

Fire scars located at the trunk base (often triangular in shape) or higher up along the stem (as cracks into the wood). Charred wood is often visible, and in conifers resin flows may occur on the exposed wood or surrounding bark.

Life traits: saproxylic, (wood mould), living, conifer, broadleaved, base, dry, (wet), soil contact, perennial

Minimum size: surface > 600 cm^2 with pieces of charred wood (A4/P4 sheet of paper; experts' threshold)

Trigger frequency

very low

Development rhythm

rapid (fairly rapid)

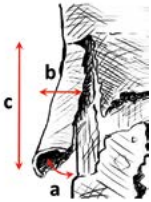
Associated species:

Did you know? Forest fires are natural in boreal forests, shaping their dynamics. Historically, fire scars and partially burned deadwood were common, fostering specialized pyrophilous (fire-loving) species, mostly fungi and insects. These organisms require charred wood for development and have adaptations to locate it; for instance, pyrophilous insects can detect fire from tens of kilometers away. Fire suppression harms many species, especially those like pyrophilous lichens that require time to establish.

18 Bark shelter

Loose hanging bark (peeled off from sapwood or from remaining bark) creates a shelter along the trunk (with an opening at the bottom).

Life traits: saproxylic, snag, conifer, (broadleaved), trunk, dry, shelter, perennial



a > 1 cm
b > 10 cm
c > 10 cm

Minimum size: space between bark and sapwood > 1 cm, width > 10 cm, length > 10 cm (experts' threshold)

Trigger frequency

Development rhythm

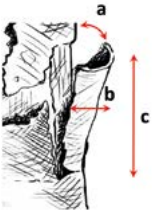
Associated species:

Did you know? A shelter of loose bark is of interest to many animals, since it offers protection from the rain. Species that use these shelters include bats, birds (e.g. treecreepers, Eurasian wren *Troglodytes troglodytes*), flat bugs and other arthropods, tree spiders, and acarians. Bats prefer bark shelters or cracks that are 1 to 5 cm wide, > 10 cm deep, and located more than 1 m above the ground. Some fungi occur mainly in these shelters, for example *Orbilia comma* on *Ulmus* spp.

19 Bark pocket

Slabs of bark detached from the trunk (peeled off from sapwood or from the remaining bark) that create pockets where wood mould and humus can accumulate (with an opening at the top).

Life traits: saproxylic, wood mould, snag, conifer, (broadleaved), trunk, wet, perennial



a > 1 cm
b > 10 cm
c > 10 cm

Minimum size: space between bark and sapwood > 1 cm, width > 10 cm, length > 10 cm (experts' threshold)

Trigger frequency

Development rhythm

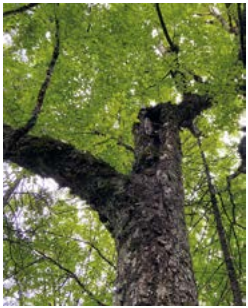
Associated species:

Did you know? Many arthropods, including arachnids, live in the organic matter that accumulates in the pockets formed by the detached bark. Bats, on the other hand, prefer to use bark shelters with an opening at the bottom so that they are protected from the rain.

20 Stem breakage

The trunk has broken off and the heartwood has been exposed. The tree is still alive. The deadwood below the breakage is in contact with living wood where the sap still flows.

Life traits: saproxylic, living, conifer, broadleaved, crown, wet, perennial



Minimum size: stem Ø at breakage > 10 cm (experts' threshold)

Trigger frequency

low

Development rhythm

fairly slow

Associated species:

Did you know? When a new top grows from a broken stem, decomposition and growth occur at the same time in very close proximity within the tree. The juxtaposition of these two processes creates a vital tree microhabitat for a few highly specialised invertebrates.

21 Limb breakage

A large limb or a fork has broken off and the heartwood has been exposed. The damaged area is surrounded by living wood where the sap still flows.

Life traits: saproxylic, living, broadleaved, crown, (dry), wet, perennial

Minimum size: exposed surface > 300 cm^2 (A5/P5 sheet of paper; experts' threshold)

Trigger frequency

low (fairly low)

Development rhythm

fairly slow

Associated species:

Did you know? Because the heartwood is dead, it has a very different chemical composition from that of the adjacent sapwood and the living wood, and this influences the roster of associated species.

22 Crack

Cracks through the bark and into the underlying wood. See "lightning scar" for the case where the crack is caused by lightning.

Life traits: saproxylic, (living), snag, broadleaved, trunk, (crown), dry, shelter, perennial

Minimum size: length > 30 cm, width > 1 cm, depth > 10 cm

Trigger frequency

low (very low)

Development rhythm

very rapid

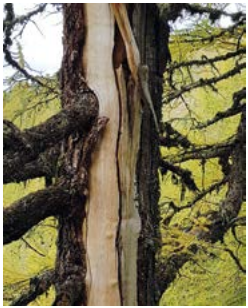
Associated species:

Did you know? Cracks shelter many types of animals: bats, treecreepers, flat bugs, tree spiders, mites, and other arthropods. Bats prefer cracks that are 1 to 5 cm wide, > 10 cm deep, and located more than 1 m above the ground. Arthropods can use shallower cracks. Cracks are more common in dead trees than in living trees.

23 Lightning scar

A crack caused when a tree is struck by lightning; a lightning scar generally spirals along the trunk and the wood is splintered (multi-fissured crack).

Life traits: saproxylic, living, conifer, (broadleaved), trunk, crown, dry, shelter, perennial



Minimum size: length > 30 cm, width > 1 cm, depth > 10 cm

Trigger frequency

low (very low)

Development rhythm

very rapid

Associated species:

Did you know? Lightning scars provide a source of partially burned deadwood. The multiple fissures created by the splintered wood in a lightning scar often have such different characteristics that a wide variety of animals can co-exist in the same split trunk: spiders, bats, birds, and gastropods.

24 Fork split at the intersection

Crack at the intersection of a tree fork. If one of the main branches of the fork has fallen off, the classification is “limb breakage”.

Life traits: saproxylic, living, broadleaved, crown, wet, (shelter), perennial

Minimum size: length > 30 cm (experts’ threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? Cracks formed by the separation of the two limbs at a fork offer shelter but little protection from precipitation. Furthermore, falling organic material (e.g. leaves, twigs) often accumulates in the opening created; this material decomposes and can create a “crown microsoil”, where secondary tree roots can grow.

25 Trunk gnawed by beavers

A tree trunk with the deep feeding marks of a beaver, which are typically hourglass-shaped. In many cases broad teeth marks are visible on the hardwood.

Life traits: saproxylic, living, (conifer), broadleaved, base, wet, perennial

Minimum size: surface > 300 cm^2 (A5/P5 sheet of paper; experts' threshold)

Trigger frequency

fairly low

Development rhythm

rapid

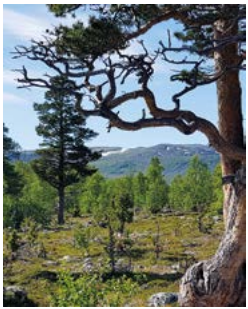
Associated species:

Did you know? Beaver activity can enhance the species richness of calicioid lichens and fungi. Their disturbances tend to create new relatively competitor-free living spaces for calicioids and other small organisms that grow on hard standing wood. In forests without beaver activity, lignicolous bryophytes and macrolichens rapidly colonise stumps and fallen logs and can effectively outcompete calicioids.

26 Dead branches

Dead branches in the crown, including branches lower on the stem.

Life traits: saproxylic, living, conifer, broadleaved, crown, dry, (wet), perennial



Minimum size: branch Ø > 10 cm, or > 10% of the crown is dead (experts' threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? Unlike deadwood lying on the forest floor, dead crown branches are subjected to frequent desiccation and widely varying temperatures. Besides invertebrates, many fungal species are specialists of dead tree branches. Branch fungi have to protect themselves against drought. Some species produce minute, short-lived fruiting bodies only under humid conditions, while others give rise to sterile, tough, and leathery fruiting bodies that start to produce spores only during longer periods of humid weather.

27 Dead top

The top of the tree has died and the deadwood is generally exposed to the sun.

Life traits: saproxylic, living, conifer, broadleaved, crown, dry, perennial

Minimum size: Ø > 10 cm at the base (experts' threshold)

Trigger frequency

fairly low (low)

Development rhythm

rapid

Associated species:

Did you know? Unlike dead branches inside the crown, dead tops are directly exposed to the sunlight. Their decomposition is carried out by more thermophilous species, which are able to withstand widely varying microclimatic conditions.

28 Remnants of a broken limb

A large limb has broken off. The remaining stub has shattered but the injury does not affect the trunk of the tree (if so, the classification is “limb breakage”).

Life traits: saproxylic, living, conifer, broadleaved, crown, dry, (wet), perennial

Minimum size: branch Ø > 10 cm at the break, stub length > 50 cm (experts’ threshold)

Trigger frequency

fairly low (low)

Development rhythm

rapid

Associated species:

Did you know? The stub of a large broken limb hosts species that are different from those in an intact dead branch, even when the wood is the same diameter and at the same decay stage. The reason for this is that this complex tree microhabitat type features both cracks and a jagged break, with a large deadwood volume and surface area.

29 Witches' broom

A dense mass of intertwined twigs on a branch.

Life traits: epixylic, living, conifer, broadleaved, crown, dry, perennial

Minimum size: Ø > 20 cm (experts' threshold)

Trigger frequency

fairly low (low)

Development rhythm

slow (fairly slow)

Associated species:

Did you know? Several organisms can trigger witches' brooms, e.g. the fungus *Taphrina betulina* on birch, the fungus *Melampsorella caryophyllacearum* on *Abies* spp., the bacteria *Phytoplasma* on pine, *Rickettsia*-like bacteria on larch, and the parasitic plant *Arceuthobium tsugense* on hemlock.

30 Epicormic shoots

A dense mass of shoots on the trunk sprouting from dormant buds under the bark.

Life traits: epixylic, living, conifer, broadleaved, trunk, (dry), wet, perennial

Minimum size: > 5 shoots (experts' threshold)

Trigger frequency

fairly low (low)

Development rhythm

fairly slow

Associated species:

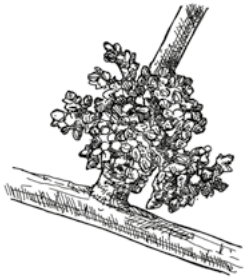
Did you know? The intertwined epicormic shoots sometimes support the nests of small songbirds like the song thrush and the blackbird.

31 Galls

DM

Deformity of a tree organ (twig, leave, flower, bud) caused by a parasitic attack by bacteria, fungi, mites or insects. Galls are most frequently found on leaves (about 65%), but can also affect stems (20%), buds (10%), roots, flowers, or fruits (5%).

Life traits: epixylic, living, conifer, broadleaved, crown, dry, ephemeral



Minimum size: > 20 galls (experts' threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? Galls stand out as extraordinary outcomes of biological evolution. These structures are created by plants exclusively to benefit another organism – the gall-inducer. In addition to the gall-inducer, the galls can be inhabited by fungi, natural enemies, and inquilines (commensal herbivores or omnivores). Many gall midges (Cecidomyiidae, Diptera) oviposit fungal spores together with the eggs which colonise the gall and serve as food for the developing larvae.

32 Burr (burl)

A proliferation of cells with rough bark but no rotten wood.

Life traits: epixylic, living, conifer, broadleaved, (base), trunk, dry, (wet), perennial

Minimum size: Ø > 20 cm (experts' threshold)

Trigger frequency

Development rhythm

Associated species: 

Did you know? When a tree is under stress (e. g. from injuries, fungi, bacteria, or viruses), it produces chemicals that tell the cells in its bark to grow in a different way. This results in the formation of burrs. Unlike the wood found in cankers, burr wood has no rot and the bark appears intact.

33 Canker

Canker with rotten wood and exposed sapwood, for example caused by the fungus *Lachnellula willkommii* on larch.

Life traits: saproxylic, living, conifer, broadleaved, trunk, dry, (shelter), perennial

Minimum size: Ø > 10 cm or covering a large part of the trunk

Trigger frequency

low (fairly low)

Development rhythm

fairly slow

Associated species:

Did you know? The fungus *Inonotus obliquus*, also called "chaga", causes a canker-like growth on birch trees; it was once widely used as a folk remedy in Russia and the Baltic countries. Indeed, it protects cells from oxidative stress. Recent research has shown that polysaccharides extracted from this fungus seem to stimulate the immune system and can be effective in fighting cancer. The red-listed beetle species *Mycetophagus decempunctatus* is associated with chaga.

34 Perennial polypore

Fruiting bodies of perennial bracket fungi with a woody texture and several layers of tubes (if more than one year old).

Life traits: epixylic, saproxylic, (living), snag, (conifer), broadleaved, trunk, dry, perennial

Minimum size: Ø > 5 cm (experts' threshold)

Trigger frequency

fairly high

Development rhythm

fairly slow (fairly rapid)

Associated species:

Did you know? Perennial fungal fruiting bodies are complex habitats, providing food to various mycophagous insects: the context tissue, the mycelium and chemically altered plant cells of the host tree, and spores. In Europe, the hoof fungus *(Fomes fomentarius)* hosts around 600 arthropod species, including *Bolitophagus reticulatus* and *Neomida haemorrhoidalis*, which exclusively feed on it. Beetles help disperse wood-decay fungi spores. Fruiting bodies of heartwood-decaying fungi predict cavity-nesting bird density.

35 Annual polypore

Fruiting bodies of annual polypores remaining fresh for several weeks (which can still be observed until the following spring). European annual polypores have only one layer of tubes and are generally rather elastic and supple (with no woody parts).

Life traits: epixylic, saproxylic, (living), snag, (conifer), broadleaved, trunk, dry, annual

Minimum size: Ø > 5 cm or group of > 10 polypores (experts' threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? Fungal fruiting bodies are a much richer energy source than wood. For example, the nitrogen content is 2 to 10 times higher in fruiting bodies than in sound wood. Associated invertebrates consume the spores, the tube layer, or the mycelium of the fruiting body. In a Swedish riparian forest a total of 117 insect taxa were found, either feeding on or breeding in the fungus *Inonotus radiatus*. The birch polypore *Fomitopsis betulina* can even host more than 250 different animal species.

36 Pulpy agaric

Large, thick, and pulpy or fleshy, gilled fruiting bodies (order Agaricales), generally remaining for several weeks.

Life traits: epixylic, (living), snag, broadleaved, (base), trunk, wet, ephemeral

Minimum size: : Ø > 5 cm or group of > 10 fruiting bodies (experts' threshold)

Trigger frequency

fairly high

Development rhythm

very rapid

Associated species:

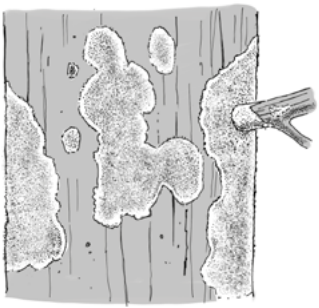
Did you know? The ephemeral fruiting bodies of pulpy agarics decompose too fast for most insect larvae to complete their development. That is why these fruiting bodies only host species with very short larval and pupal development periods, primarily Diptera but also a few beetle species. They also provide beetles with an ecological fast-food service: their nutritional resources are often available for their visitors after the invertebrates have hatched from pupae but before their breeding hosts appear.

37 Corticoid fungi (crust fungi)

DM

A group of Basidiomycota fungi typically having sheet-like, smooth fruiting bodies that are mostly formed on the undersides of dead branches or dead tree trunks.

Life traits: epixylic, saproxylic, snag, (living), conifer, broadleaved, crown (trunk), wet, annual



Minimum size: > 50 cm² (experts' threshold)

Trigger frequency

fairly low

Development rhythm

rapid

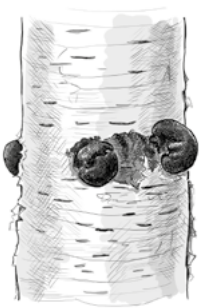
Associated species:

Did you know? Several fungus gnat species (Mycetophilidae, Diptera) lay their eggs on corticoid fungi and their larvae feed on the fruiting bodies. Thrips species are among the smallest of the winged insects (1.5 to 3 mm). The thrips *Hoplothrips fungi* lives beneath encrustations of corticoid *Peniophora* fungus on dead oak branches.

38 Large pyrenomycetoid fungi (stromatic sordariomycetes)

Usually black stromata, flat or hemispherical in shape, that resemble lumps of coal and contain many small perithecia.

Life traits: epixylic, (living), snag, broadleaved, (base), trunk, dry, perennial



Minimum size: stromata Ø > 3 cm or group covering > 100 cm^2 (experts' threshold)

Trigger frequency

fairly high

Development rhythm

rapid

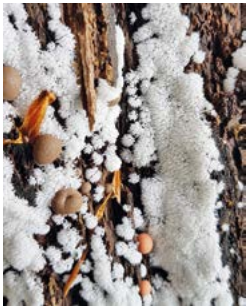
Associated species:

Did you know? Pyrenomycetoid fungi are generally quite small (mostly < 1 mm in diameter) and cover patches of the trunk with hard dark bumps. However, the species *Daldinia loculata* can reach several centimetres in diameter and can host over 100 animal species in its stromata, in particular the very rare and specialised Diptera species *Amiota alboguttata*. The flat bug *Aradus bimaculatus* lives in the stromata of the pyrenomycete *Entoleuca mammata* (aspen canker).

39 Myxogastria (myxomycetes or plasmodial slime moulds) DM

Organisms that exist as slimy, gelatinous masses when fresh and are commonly found on decaying plant matter.

Life traits: epixylic, (living), snag, (conifer), broadleaved, (base), trunk, (crown), wet, ephemeral



Minimum size: Ø > 5 cm (experts' threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? This slimy jelly-like mass is not an animal, plant, or fungus, yet it can move up to several centimetres per hour when foraging for its food, which consists of bacteria, algae, or fungi. Myxogastria are also found on dead branches in the canopy. Researchers have measured the time it takes for a myxomycete spore to reach the ground: 5 hours from a height of 30 m. This shows that Myxogastria have a relatively high dispersal ability. Most of the species that consume slime moulds are strictly dependent on the relationship.

40 Bryophytes (mosses and liverworts)

Trunk covered in moss or liverworts (Hepaticophyta).

Life traits: epixylic, living, (conifer), broadleaved, base, wet, perennial

Minimum size: > 10% of the trunk is covered (experts' threshold)

Trigger frequency

fairly low (fairly high)

Development rhythm

slow

Associated species:

Did you know? The epiphytic species (mosses and lichens) carry out their own photosynthesis. They therefore only use the tree as a physical support and do not use the wood as a source of energy; they are not parasitic or damaging. Moss carpeting a tree may harbour other species. For example, the *Peltigera collina* lichen only grows on moss-covered trees.

41 Foliose and fruticose lichens

Foliose lichens (lobe-shaped) or fruticose lichens (bushy).

Life traits: epixylic, living, (snag), conifer, broadleaved, crown, dry, (wet), perennial

Minimum size: > 25 % of the trunk or branches is covered, thickness > 1 cm (experts' threshold)

Trigger frequency

fairly low (fairly high)

Development rhythm

slow

Associated species:

Did you know? Because of their small size and slow growth, lichens must find habitats poorly suited to plants to avoid being out-competed. Tree trunks, like stones and rocks, provide such habitats. Other organisms may use epiphytic lichens as a food source or as shelter or nest material. Certain fungi grow only on epiphytic lichens. A lichen is a composite organism that arises from algae or cyanobacteria living among filaments of a fungi in a mutualistic relationship.

42 Ivy and lianas (woody vines)

Lianas and other climbing phanerogams, such as ivy and clematis.

Life traits: epixylic, living, snag, (conifer), broadleaved, (base), trunk, dry, (wet), perennial

Minimum size: > 10% of the trunk is covered (experts' threshold)

Trigger frequency

fairly low (fairly high)

Development rhythm

slow

Associated species:

Did you know? Ivy flowers in the autumn and its fruit is available at the end of winter, during a time when plants offer little food. In addition, its leaves and twisted branches create small shady, moist niches where specialised epiphytic fungi grow.

43 Ferns

Ferns growing directly on the trunk or at the intersection of a branch (as an epiphyte).

Life traits: epixylic, living, (snag), broadleaved, crown, wet, annual

Minimum size: > 5 fronds (experts' threshold)

Trigger frequency

fairly low (low)

Development rhythm

fairly slow

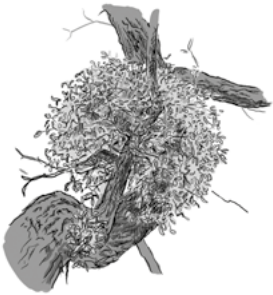
Associated species:

Did you know? Insects rarely feed upon ferns. Nonetheless, several species of sawflies (Hymenopterans) spend their entire life cycle on fern fronds. Since they are not parasites, epiphytic ferns grow on other plants without hindering their growth or development. Some invertebrates can spend their entire life among the fronds of epiphytic ferns without ever descending to the forest floor.

44 Mistletoe

These hemiparasitic epiphytes generally grow in the tree crown and include *Viscum* spp., *Arceuthobium* spp., and *Loranthus* spp.

Life traits: epixylic, living, (conifer), broadleaved, crown, dry (wet), perennial



Minimum size: Ø > 20 cm for *Viscum* spp. and *Loranthus* spp.; > 10 clumps for *Arceuthobium* spp. (experts' threshold)

Trigger frequency

fairly low (fairly high)

Development rhythm

fairly slow (slow)

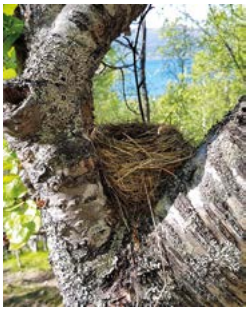
Associated species:

Did you know? In Europe, there are eight known insect species specific to the common mistletoe *Viscum album.* Mistletoes also provide abundant pollen and nectar; in addition to many nectarivorous species, a broad range of insectivorous species have been recorded feeding from mistletoe flowers. The fruit of mistletoes is appreciated by certain birds in the winter, when other food is scarce. Mistletoes are used extensively as sites for nesting and roosting by birds (e.g. *Asio otus*) and mammals.

45 Vertebrate nest

Bird or rodent nest.

Life traits: epixylic, living, (conifer), broadleaved, crown, dry, (wet), annual



Minimum size: Ø > 10 cm

Trigger frequency

Development rhythm

Associated species:

Did you know? Large bird nests provide nesting sites among their twigs for small birds, as well as habitat for invertebrates like beetles in the Histeridae family (clown beetles).

46 Invertebrate nest

DM

Nest containing invertebrate larvae, for example those of pine processionary caterpillars, saproxylic ants, and wild bees.

Life traits: saproxylic, epixylic, living, (conifer), broadleaved, (base), trunk, dry, (shelter), annual, (perennial)

Minimum size: presence (direct observation or associated insects)

Trigger frequency

fairly high

Development rhythm

rapid

Associated species:

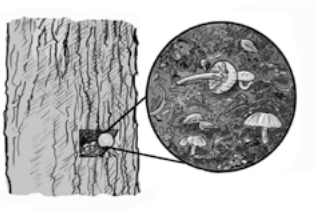
Did you know? Invertebrate nests can provide a home for other insects. These can be predators, parasites consuming the food or the larvae in the nest, or commensal species scavenging food waste. Sometimes, insects live as clandestines near another species' nest, where they can feed on the remains of organic matter (e.g. food debris, faeces).

47 Bark microsoil

DM

Microsoil in fissures on the trunk bark formed from moss, lichen, or epiphytic algae residues and old, thick, and decaying bark.

Life traits: epixylic, living, broadleaved, trunk, (dry), wet, perennial



Minimum size: presence (direct observation or presence of fungi)

Trigger frequency

fairly low

Development rhythm

fairly slow

Associated species: 

Did you know? Bark microsoils provide a habitat for a few highly specialised saprophytic fungi, which are sometimes dependent on a single host species.

48 Inter-bark microsoil

DM

Microsoil developed within the bark itself, borne by old trees of species that develop very thick bark as they grow old.

Life traits: epixylic, living, conifer, base, dry, perennial

Minimum size: presence of humus on at least 300 cm² A5/P5 sheet of paper

Trigger frequency

Development rhythm

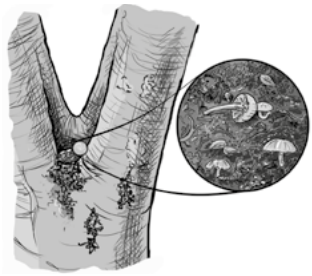
Associated species:

Did you know? This rare microhabitat is currently only known to occur on larch. An accumulation of organic matter (leaves, twigs) on the uphill side at the base of the trunk allows neighbouring trees (sometimes of a different species than the microsoil-bearing tree) to reach the microsoil and spread their roots.

49 Crown microsoil

Crown microsoil forms from decaying leaves and woody debris fallen from the canopy or neighbouring trees, often hosting secondary roots from the tree. It is typically located between two joined trees, in flat areas of the crown, or in forks.

Life traits: epixylic, living, (conifer), broadleaved, crown, wet, perennial



Minimum size: presence

Trigger frequency

Development rhythm

Associated species:

Did you know? Old trees sometimes harbour microsoil pockets in their canopy. Aerial roots sometimes sprout from the microhabitat-bearing tree and colonise the microsoil. Crown microsoils are much richer in organic carbon than the soil on the ground and can be more easily penetrated by fine roots. The organic matter is thus recycled and reused directly by the tree or by other organisms.

50 Clay or silt deposit

Base of the trunk or lower part of the stem covered by clay or silt deposits following flooding.

Life traits: epixylic, living, (conifer), broadleaved, base, wet, perennial

Minimum size: surface > 600 cm^2 (A4/P4 sheet of paper; experts' threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? Flood-mosses grow where flooding is intermittent but often deep. They are often confined to lower parts of the stem, boles, and roots of trees growing in the flood zone of lowland rivers and streams. Tree trunks with deposits of clay and silt are among their preferred substrates.

51 Sap run

Sap running along the trunk.

Life traits: epixylic, living, broadleaved, trunk, wet, annual

Minimum size: length > 10 cm (experts' threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? Sap runs contain sugars, nutrients, and various vitamins and are an attractive food source for numerous adult insects. Insect larvae living in sap runs do not consume the sap itself but rather the yeasts and bacteria that develop there.

52 Heavy resinosis

Flow of resin, either fresh or old casts.

Life traits: epixylic, living, conifer, trunk, dry, wet, perennial

Minimum size: length > 10 cm (experts' threshold)

Trigger frequency

Development rhythm

Associated species:

Did you know? Resin is excreted by certain conifers to form a protective barrier rich in antimicrobial elements, which prevent pests and pathogens from penetrating the bark and entering the wood. The resulting antiseptic substratum is therefore quite inhospitable to living organisms. Even so, some so-called "resinicolous fungi", for example *Sorocybe resinae, Sarea resinae*, or *Sarea difformis*, microscopic ascomycetes, live exclusively in resin flows.

Bibliography

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Supplementary Material

Appendix 1: TreM-associated taxa
Appendix 2: Bibliography
Appendix 3: TreM pictures
Download link: wsl.ch/fg-trems-boreal-supplementary

Photo credits

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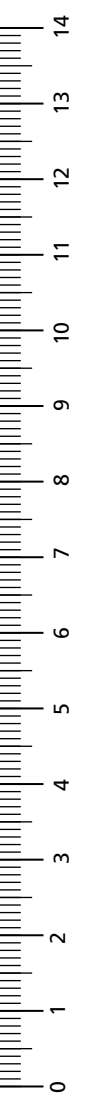

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