2.1 Habitat trees: key elements for forest biodiversity

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Habitat trees are very large, very old, and dead or living microhabitat-bearing trees. They are of prime importance for specialised forest flora and fauna

Habitat trees are defined as standing live or dead trees providing ecological niches (microhabitats) such as cavities, bark pockets, large dead branches, epiphytes, cracks, sap runs, or trunk rot. Depending on their characteristics, habitat trees go by different names. Veteran, ancient, or monumental trees are individuals of remarkable age or size, whereas wildlife or cavity trees host animals such as woodpeckers and other cavity-nesting species. Habitat trees and the microhabitats they host are of prime concern for forest biodiversity as they can harbour many endangered specialised species of flora and fauna (see Box 14). At least 25 % of forest species depend on or benefit from deadwood and habitat trees. Many of them belong to the most threatened organisms in European temperate forest ecosystems.
Veteran trees have always caught man's attention and have consequently acquired a symbolic role. For example, justice was long administered under old lime or oak trees in Central Europe. However, despite their cultural importance, such trees have undergone a marked decline for diverse reasons: the loss of their symbolic value through cultural change and the establishment of modern forestry and agriculture accompanied by the abandonment of traditional forest uses. Today, veteran trees are a legacy of the past and are of exceptional importance given the hundreds of years required for a tree to reach this status.

The abundance and diversity of microhabitats strongly increase with tree diameter and bark thickness, and therefore typically with tree age (Bütler and Lachat 2009; Vuidot et al. 2011, Larrieu and Cabanettes 2012). In southwest Sweden, for example, Ranius et al. (2009) found that less than 1 % of the pedunculate oaks (*Quercus robur*) younger than 100 years of age had cavities where the inner space was wider than the entrance (>3 cm in diameter). Between 200 and 300 years of age, however, 50 % of the oaks harboured such hollows, while all the 400+-year-old trees had wide cavities (Ranius et al. 2009). The ecological value of a tree therefore increases with its age. For these reasons, particular attention is being given to veteran trees, and they are currently being inventoried in several countries to promote their preservation. In Europe, veteran trees may be found in three different types of ecosystems: relicts of orchards or traditionally managed forest zones (coppices with standards, wooded pastures), old-growth forests, or parks.

Box 14. Microhabitats associated with habitat trees and their importance for biodiversity.

Dead trees, snags, and trees with large amounts of canopy deadwood have been relatively well studied. They are a substrate for a considerable part of forest biodiversity and constitute feeding, roosting, foraging, nesting and, generally speaking, dwelling grounds for a variety of species, including vertebrates and invertebrates, plants (bryophytes and lichens), and saproxylic fungi. However, our knowledge remains incomplete as scientific investigations on tree microhabitats and their importance for biodiversity have mostly focused on cavities (see Winter and Möller 2008, Vuidot et al. 2011). Without aiming to be exhaustive, below we summarize the current findings on tree microhabitats and the biodiversity that depend on them. Four main types have been defined:

- Cavities: four types of cavities may be distinguished, depending on their origin and morphology
  - Woodpecker cavities: excavated/drilled out by woodpeckers for nesting, they play an important role for numerous secondary cavity dwellers (birds, bats, rodents (Gliridae), and meso-mammals (mustelids)) and invertebrates (spiders, beetles, wasps). For birds in particular, cavities seem to support a complex network of species involving primary cavity builders such as woodpeckers and a cohort of secondary cavity nesters.
  - Non-woodpecker cavities: created mainly during wood decaying processes, these cavities differ from those previously mentioned in that they originate mostly from injuries during the life of the tree. These cavities are mainly used by bats for roosting, but may also be used by small and large mammals, lizards, amphibians, and birds. The more mould they contain (i.e. the more the wood has decayed), the more specialised the species community they support. For example, the endangered beetle Osmoderma eremita closely depends on cavities with mould for its survival.
  - Dendrothelms: very specific cases where a cavity is temporarily or permanently filled with water. Several insects (mainly diptera) or microcrustaceans depend on dendrothelms, especially when the bottom of the cavity is decayed.
  - Root-buttress cavities: at the base of the tree, these cavities are used as shelters by micro and meso-mammals, birds, and amphibians.
- Cracks and loose bark: more abundant on snags and decaying trees, but also found on living trees damaged by natural causes (e.g. struck by lightning) or harvesting operations, such microhabitats are particularly important for bats, which specifically nest under the bark. Cracks and peeling bark are also used by crack-dwelling birds, hemiptera (flatbugs), and spiders.
- Fruit-bodies of saproxylic fungi: these fruiting bodies of saproxylic fungi indicate a certain level of biodiversity per se, but they also benefit other forest dwelling species such as beetles, diptera, moths, and flatbugs.
- Other microhabitats: epiphytes (e.g. ivy, lianas, lichens, and bryophytes), witch-brooms, and sap runs benefit insects (mainly beetles and moths) as well as birds. However, these microhabitats are poorly studied and more research is needed to specify their links with biodiversity.

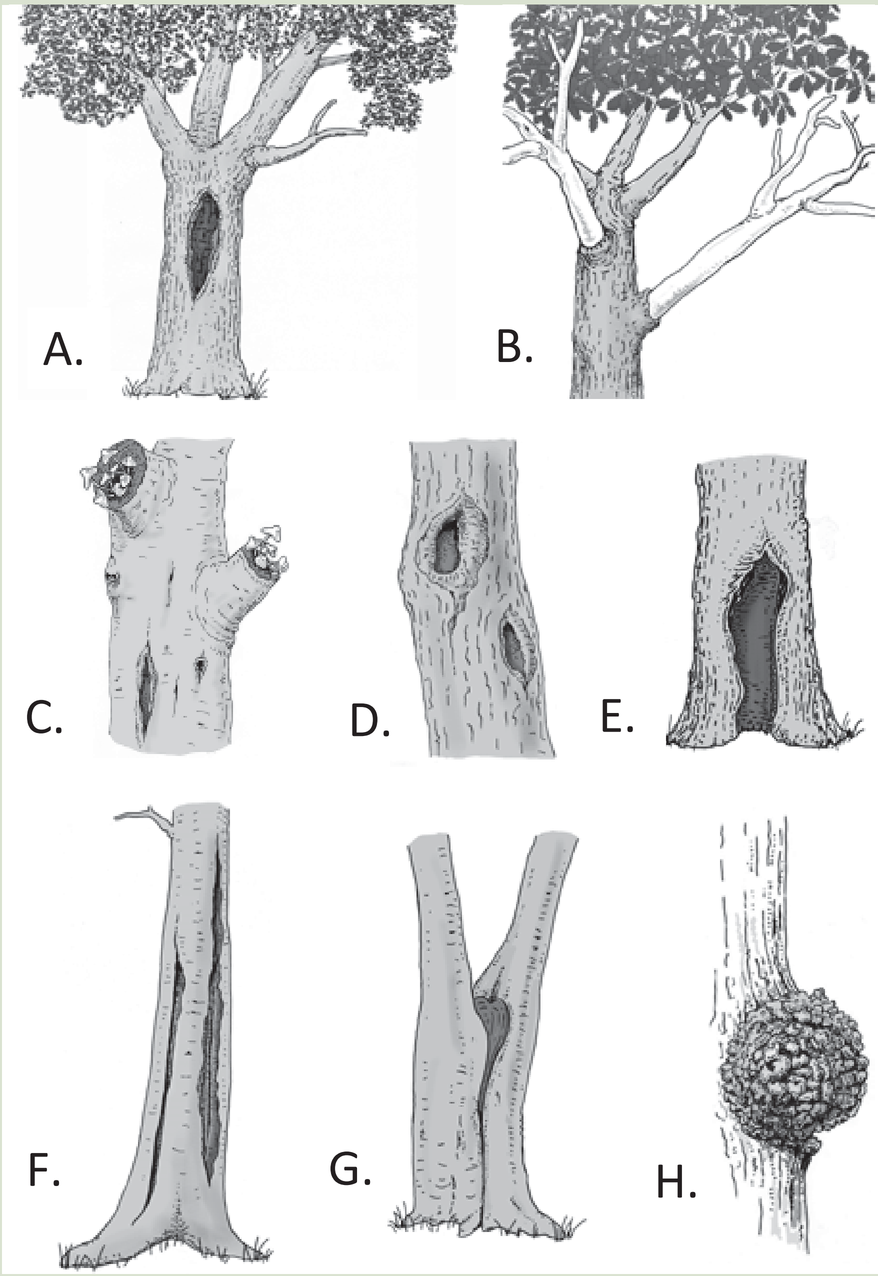

Figure 24. Different microhabitat types. A. Non-woodpecker cavity; B. Canopy deadwood; C. Fruit-bodies of saproxylic fungi; D. Cavities with mould; E. Root-buttress cavity; F. Cracks; G. Fork split; H. Burr. Source: © TU Berlin, Institut für Ökologie, Fachgebiet Ökosystemkunde/Pflanzenökologie. http://naturschutz-und-denkmalpflege.projekte.tu-berlin.de.

Habitat trees are common in unmanaged forests but require specific attention in managed forests

Changes in management practices in the 19th century marked the beginning of a dramatic decline in the number of old and hollow trees that had been maintained under specific management practices. This was especially true in the countryside, where pollarded trees, wooded pastures, and coppice with standards were common. Such habitat trees benefited many xerothermophilous species since, generally, they were well exposed to the sun. In most modern managed forests, logging systematically eliminates 'defective' trees with low economic value, which is often the case for trees hosting microhabitats or those with a high potential to develop them. In management aimed at producing large-diameter high-quality trees, microhabitat density is drastically reduced by positive tree selection during thinning and tending operations. As a consequence, microhabitat diversity and abundance are generally lower in managed than in unmanaged forests. This is also true for the number of trees hosting several different microhabitat types simultaneously (Winter and Möller 2008; Bütler and Lachat 2009; Larrieu et al. 2012).

Generally, the density of habitat trees with a diameter of over 70 cm remains less than 0.5 to 2 trees per hectare in managed forests (Bütler and Lachat 2009; Bütler et al. 2011), whereas 10 to 20 such trees occur in virgin forests in Central Europe and southern Scandinavia (Nilsson et al. 2002). On the other hand, certain types of microhabitats, such as dendrothelms (water filled tree holes) and bark losses, may be higher in managed forests as a consequence of harvesting activities (Vuidot et al. 2011; Larrieu et al. 2012).

Cavity-bearing trees are among the most important habitat trees for forest wildlife. Old cavities with decayed residue host several of the most threatened forest beetles

Cavities are probably the most well documented and studied type of tree microhabitat (Figure 25). Most cavities are produced either by avian excavators (woodpeckers) or by decay processes involving invertebrates and fungi, or by a combination of both (Cockle et al. 2012; see also Box 1). Snags are more likely to bear both woodpecker and non-woodpecker cavities than are living trees (Vuidot et al. 2011). However, snags generally account for less than 10 % of the standing trees in unmanaged forests and hardly exist at all in managed forests; this explains why most cavities (>80 %) are found in living trees (Larrieu et al. 2012).

The probability of cavity occurrence increases substantially with diameter in both live and dead trees, and greater wood thickness around cavities provides more buffered microclimatic conditions for sheltering bats or nesting birds. Consequently, cavity-nesting birds are less frequent in young trees than in older ones. There are also fewer cavity nesters in managed forests than in natural forests. However, cavity tree density has also been found to vary considerably among stands of the same age. Tree species also plays an important role. Even the amount of precipitation seems to positively influence the number of tree cavities. These

Figure 25. This sessile oak proves that woodpeckers may use the same cavity tree for several years. Old cavities can be re-used by secondary cavity users, both vertebrates and invertebrates (birds, bats, rodents, spiders, wasps, etc.). Photo by R. Bütler.

Figure 26. In French public forests, habitat trees to be maintained in managed areas are identified and marked to ensure they will be left untouched during thinning operations. Photo by Y. Paillet.

effects suggest that the distribution of tree cavities reflects the incidence of fungal heart rot in trees. Therefore, by reducing the number of fungus-bearing live trees, forest management is likely to have a broad-scale impact on cavity trees. In cavity-poor forests where wood decay processes are suppressed either climatically or by forest management, primary cavity nesters are consequently often rare.

Managing for natural features, including habitat trees, strengthens the ecological services that are becoming increasingly valued by society. Efficient management strategies include the retention of "old-growth islands" at the management unit level combined with the retention of habitat trees at the stand level when harvesting

Habitat trees have a low economic value yet have a high ecological value. Although this value is progressively recognized, they are still regularly removed in tending and harvesting operations. A shift in attitude in daily forestry practice towards their conservation may still often be needed. The retention of habitat trees suitably distributed across the landscape is a challenge for forest managers because such trees do not match silvicultural economic schemes. Snags and partially dead trees may also be a potential hazard for forest workers and visitors. Consequently, setting up a strategy of deliberate retention of habitat trees requires a

Box 15. Recommendations for management.

Conservation of (future) habitat trees should be an integral part of all forest operations, such as tending, thinning, and final harvest. For this purpose, specific indication on selection and density of such trees should be integrated in the operational guidelines.

At the stand level, at least five to 10 habitat trees per hectare should be retained to mitigate the effects of timber harvesting on organisms that depend on the structures provided by such trees. In selection systems, retention trees should be microhabitat-bearing trees (including snags) or non-vigorous low quality trees, which would be removed under conventional uneven-aged management. Generally, a combination of dispersed and aggregated retention is recommended ('variable retention') as wind damage is less pronounced in aggregated than in dispersed retention patterns. Furthermore, there is evidence that aggregated habitat trees provide better habitat for birds than do scattered individual trees. However, where scattered individual habitat trees already exist, they should be retained. In addition to retained habitat trees, trees likely to bear microhabitats in the future should be selected for recruitment; they should be properly identified and permanently protected from harvesting (Figure 26). Moreover, recruitment trees should be retained at each harvesting event at a rate that exceeds the number of senescent trees required. Both recruitment and retention trees can be marked in the field to guarantee their long-term conservation.

At the management unit level, complete forest stands should also be set aside where trees can complete their natural cycle, including senescence and decomposition. Strict forest reserves and old-growth islands are two instruments that promote habitat trees at this level. Generally limited in size to a few hectares, old-growth islands are often recommended to create stepping stones between larger protected forest areas.

In order to develop a functional network of old-growth elements, a combination of such larger and smaller set-asides should be completed with a good quality matrix of managed stands with habitat trees (see chapter 2.3 on connectivity).

shift in management attitudes and a reorientation of practices to encourage the development of old-growth structures. Retention at harvesting is justified based on two assumptions: first, retaining habitat trees at the stand level helps to maintain a higher level of biodiversity and better ecosystem functioning, and second, retained structures accelerate the recovery of biodiversity and ecosystem functioning in damaged systems (Bauhus et al. 2009). Depending on their location, habitat trees can be promoted at both the stand level and the management unit level (see Box 15).

> *Setting up a network of trees and stands that will never be logged is essential to guarantee the minimum habitat requirements of logging-sensitive species, though this appears incompatible with economic interests*

For example, the critical forest age threshold for a satisfactory diversity of lichens, mollusks, and birds in beech (*Fagus sylvatica* L.)-dominated forests ranges from 100 to 170 years in sub-montane forests and from 160 to 220 years in montane forests (Moning and Müller 2009). On the other hand, production forestry aims to shorten the rotation length in beech stands to less than 120 years to avoid the formation of red heartwood. Therefore, management strategies should be applied that guarantee a functional network of habitat trees and set-asides, without jeopardizing basic forestry goals. Considering that in natural forests in Central Europe, late developmental stages cover between 20 and 60 % of the surface area, and bear the majority of endangered forest biodiversity, it is essential to dedicate a sufficient share of the surface area in managed forests to approximate the level of biodiversity inherent in old-growth forests. Larrieu et al. (2012) recommend that a minimum of 10–20 % of the surface area of a management unit should be confined, in a more or less aggregated manner, to the conservation or recruitment of microhabitat-bearing trees. As stated before, these should not be the most valuable trees, most productive, or most accessible sites. Forest managers can take advantage of particular local features such as rocky outcrops, wetlands, or steep slopes to establish set-asides with minimal economic impact. However, set aside stands should not be confined only to marginal sites, but should be representative of all forest types available at the landscape level.

Habitat tradition – defined as the continuity in supply of old-growth, deadwood, and various forest structures – also seems to play an important role for preserving forest biodiversity

Several authors have highlighted the importance of the continuity of deadwood supply and presence of old trees in the conservation of red-listed species, and Buse (2012) showed that relict saproxylic species are correlated with the continuity in forest cover. The retention of habitat trees both at the stand and management unit levels should therefore be planned to ensure long-lasting habitat continuity. However, a time gap may occur between the very old trees remaining today from abandoned traditional management and the next generation of habitat trees. To bridge this gap, it is possible to artificially accelerate the development of structures typically associated with old trees. This strategy involves wounding or killing younger trees, inoculating young trees with decay-forming fungi, or thinning to accelerate the rate at which trees develop structures such as hollows. Such active management may be limited to very specific cases, where few microhabitat-bearing trees are available and strong conservation issues have been identified, such as the presence of relic populations of endangered species.

Microhabitats could also be adopted for use as biodiversity indicators in European forests. A clear list of habitat tree features should be drawn up to help monitor microhabitats and correlate them to biodiversity levels

Today, the importance of habitat trees for forest biodiversity is widely accepted and their ecological services are becoming increasingly valued by society. Consequently, foresters should consider them positively. Standing, these trees provide habitat for many species; fallen, they become a source of coarse woody debris and finally, through decay and nutrient cycling, become incorporated into the forest soil and contribute to maintaining important ecosystem functions. During the last few decades, the number of big trees, and consequently the number of habitat trees, has increased in some parts of Europe. For example, the number of trees with a diameter above 80 cm has almost doubled in Switzerland over the last 30 years, although this is not only explained by deliberate conservation efforts, but also by low market prices for wood. However, in many parts of Europe, the future of habitat trees (and their microhabitats) will also strongly interfere with policies on forest biomass production. Explicit conservation strategies will be needed to ensure that the increased demand for fuel wood and biomass will not lead to a strong decrease in habitat trees in managed forests since virtually all trees, even snags, can be harvested for this goal. Therefore, enacting harmonized measures to protect habitat trees and their microhabitats should be of prime concern.

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