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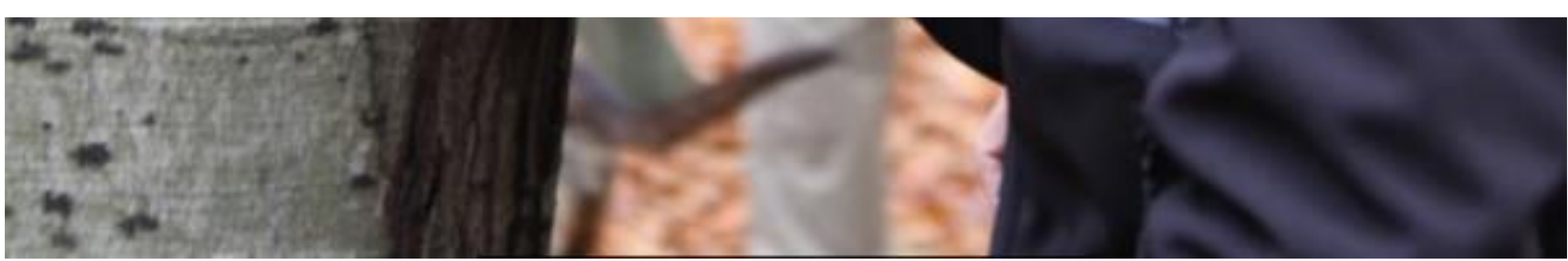
Active restoration practices for biodiversity conservation in managed forests

A REVIEW OF THE LITERATURE WITH A EUROPEAN FOCUS



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Reference

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https://integratenetwork.org/

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1. Introduction

Forests cover over 40% of Europe's land area, harbour the vast majority of Europe's terrestrial biodiversity, and provide many other ecosystem services (European Commission, 2021). The evidence that biodiversity is key for ecosystem health, functioning, and stability is well understood and growing (EEA, 2016; Muys et al., 2022). Biodiversity is also critical for forest resilience and adaptation to climate change (Thompson, 2009). However, forests and biodiversity are threatened by a wide range of factors including habitat loss and degradation, invasive species, and climate change (EEA, 2016).

European forests have a long history of human impact and as a result there are very few forests remaining that have been unmodified by humans (Sabatini et al., 2018). The majority of forests in Europe have a history of often intensive forest management towards wood production and today over 75% of forests are available for wood production (FOREST EUROPE, 2020). Sustainable forest management that aims to manage forests for multiple functions is therefore vital for increasing forest biodiversity and the provision of other ecosystem services, as well as increasing forest resilience and adaptation to climate change (European Commission, 2021). In addition, in order to safeguard forests and forest biodiversity in Europe, it will be necessary to invest in forest protection and restoration (European Commission, 2020).

Within the framework of sustainable forest management, integrative forest management aims to balance the provision of multiple forest ecosystem services from a managed forest at different spatial scales (Kraus and Krumm, 2013; Krumm et al., 2020). In continuous cover forestry, forest management practices are mainly focused on retention of deadwood and high conservation value habitat trees (Gustafsson et al., 2020), as they are associated with high levels of biodiversity, including saproxylic species (Brainerd et al., 1995; Ranius and Nilsson, 1997; Grove, 2002; Kosiński, 2006).

Despite efforts, these structures are often lower in managed forests compared to unmanaged forests, contributing to lower biodiversity (Paillet et al., 2010). In managed forests, trees are often harvested much before microhabitats and other forms of tree senescence begin (Kraus and Krumm, 2013). Therefore, the active creation of deadwood and microhabitats may represent an additional approach to restore forests and related biodiversity in managed forest stands (Sebek et al., 2013; Doerfler et al., 2020). Moreover, the importance of forest restoration has found increased attention and is reflected in the EU Biodiversity Strategy (European Commission, 2020) and the new EU Forest Strategy for 2030 (European Commission, 2021).

This document aims to review and summarise the scientific evidence of the importance of deadwood and habitat trees for biodiversity as well as different methods to actively create different types of deadwood and tree cavities. The literature draws from many different sources, including from North America and Europe, but is intended to guide such practices in Europe. For each method, the document also provides advice on suitable forest types and trees for each method, as well as information on which species can benefit from the practice. This information may then be used as a reference guide for forest practitioners interested in such practices and support the elaboration of practical guidelines for their implementation (e.g., see Adelmann et al., 2021). While there are various other active restoration measures at the stand and landscape level for biodiversity conservation, this document focuses on tree-level measures only. The report also does not claim to have addressed all tree-level measures and may add such in the course of a future revision.

2. Creation of deadwood

2.1. Rationale

An estimated 20-25% of forest species are dependent on deadwood for all or part of their lifecycle (Grove, 2002; Stokland et al., 2012). Therefore, in forest ecosystems, biodiversity is largely dependent on the quantity and quality of deadwood (Siitonen, 2001; Brin et al., 2013). Among these species, which are also known as saproxylic species, beetles (*Coleoptera*) and fungi make up the two largest taxa, are largely responsible for wood decay, and contribute to nutrient cycling and ecosystem functioning (Lassauce et al., 2011). In addition to providing habitat for a wide variety of species, deadwood plays several significant roles in the forest ecosystem including carbon storage, nutrient cycling, and creation of forest soil (Siitonen, 2001; Lachat et al., 2013; Vítková et al., 2018).

Within the managed forests of Europe, several factors significantly reduce volumes of deadwood and related saproxylic species. First, longer and more intense management practices contribute to lower quantities of deadwood (Siitonen, 2001; Jonsson and Siitonen 2012). Compared to unmanaged forests, these quantities can be reduced up to 98% (Fridman and Walheim, 2000). Second, even when managed forests match unmanaged forests in terms of deadwood volume, certain types of deadwood such as large diameter pieces, deadwood created by forest fires, and pieces in much later stages of decay are often still lacking in these forests (Kruys et al., 1999; Jonsson and Siitonen, 2012). Third, long histories of management practices in many European forests have halted the continuous supply of deadwood and as a result, communities of saproxylic species remain different from primary and old-growth forests (Grove, 2002). Combined, these aspects result in a loss in the quantity and diversity of saproxylic species in managed forests, leading to many nationally rare and threatened species across Europe (Grove, 2002). Because many stands in managed forests are too young to produce deadwood, management practices which adopt active creation of deadwood may provide an option to creating habitats for saproxylic species in the near future (Jonsson and Siitonen, 2012).

Here we provide information and outline five methods for the creation of deadwood: (1) girdling, (2) creation of high stumps, (3) topping trees, (4) artificially uprooting trees, and (5) fungal inoculation. Before choosing which methods to implement, some consideration should also be taken regarding tree diameter, tree species, position, microclimate, and quantity of deadwood.

What diameters to aim for

When choosing the size of the tree to actively create deadwood from, all sizes are beneficial. However, special priority should be given to creation of deadwood with a large diameter as it has been shown to be related to increased species richness, incidence, or abundance as well as threatened species (Grove, 2002). Compared to small pieces, large pieces contain many different niches which are filled by different saproxylic species simultaneously, they take longer to decompose which allows them to maintain a stable microhabitat and remain in the environment for longer, and are more stable in their temperature and moisture (Grove, 2002; Lachat et al., 2013; Vítková et al., 2018). For these reasons, large diameter deadwood cannot be replaced by an increase in quantity of small deadwood (Vítková et al., 2018). However, small diameter deadwood should still be created and allowed to accumulate due to their importance for some saproxylic fungi, such as ascomycetes (Nordén et al., 2004).

Lying or standing deadwood?

The position of the deadwood, i.e., whether it is lying or standing, creates different decay rates, moisture levels, and sun-exposure (Bouget et al., 2012). Standing deadwood, particularly snags, tend to have lower decay rates, higher sun-exposure, and a more stable microclimate (Jonsson and Siitonen, 2012). Standing deadwood has been shown to host a higher diversity than lying deadwood, however lying deadwood tends to be more important for fungi and bryophytes (Bouget et al., 2012; Vítková et al., 2018). Therefore, when choosing the position of wood during deadwood creation, a combination of different positions should be prioritised to ensure that habitats are created for a wide variety of species (Bouget et al., 2013).

Location of deadwood in the forest

The location of deadwood, i.e., whether it is in a sun-exposed or shaded area should also be considered for deadwood creation. Sunny, exposed areas which naturally occur after disturbances such as forest fires and windstorms have been shown to support a greater diversity of saproxylic beetles, including those which are red-listed (Lindhe and Lindelöw, 2004; Djupström et al., 2012). Therefore, during deadwood management, special consideration should be given to create deadwood in forest gaps and open areas (Vítková et al., 2018). On the other hand, shaded areas, which are more moist than exposed areas, are important for fungi and bryophytes (Lachat et al., 2013). Therefore, management practices should seek to provide deadwood in a variety of different locations.

Photo: Lyla O'Brien

How much deadwood is enough?

The minimum amount of deadwood required to support the majority of saproxylic species depends on the forest type and has been estimated e.g., at 20-30 m^3/ha for boreal and coniferous forests, 30-40 m^3/ha for mixed montane forests, and 30-50 m^3/ha for lowland forests (Müller and Bütler, 2010).

Summary

1. Large diameter deadwood should be prioritised during deadwood creation, smaller deadwood pieces, while less important for saproxylic beetle diversity, should also be maintained.
2. Combinations of standing and lying deadwood should be created, with a higher prioritisation for standing deadwood.

3. Deadwood should be created in both sunny, exposed areas and shaded areas with a higher prioritisation for sunny, exposed areas.

4. The amount of deadwood required to sustain saproxylic species diversity varies according to forest type.

3. Active restoration practices to create deadwood

3.1. Girdling

Description and information

Girdling, also known as ring barking, is the severing of the bark, cambium, and occasionally sapwood in a complete ring around the circumference of the trunk or branch of a tree (Kilroy and Windell, 1999). If applied to the trunk, the tree is unable to transport carbohydrates produced during photosynthesis from the roots to the leaves via the phloem and slowly dies from starvation once all carbohydrate reserves have been exhausted, which may take several years (Kilroy and Windell, 1999). Girdling is traditionally used for thinning and killing unwanted trees such as invasive species, but the method is also used to create biodiversity beneficial snags which are naturally produced after storms, forest fires, insect infestations, tree diseases, and other disturbances (Vítková et al., 2018). In areas where these disturbances are absent, creating snags by girdling has shown to create increased nesting and foraging habitats for both cavity nesting birds and saproxylic species (Parks, 1999; Hallet et al., 2001; Vítková et al., 2018). Girdling is typically done at breast height but can also be applied to the crown of the tree, known as *crown girdling* (Lewis, 1998).

Photo: Andreas Schuck

Recommended forest and tree type:

Girdling can be applied in areas of a managed forest where wood production is a minor aim or can target trees which are low quality, small diameter, or located in areas which are difficult to access. This helps to ensure that the quality of harvested timber remains high (Vítková et al., 2018). Targeting invasive species is also considered a cost-effective way of creating snags via girdling (Vítková et al., 2018; Parks, 1999).

Species that benefit

Saproxylic species and cavity nesting birds such as woodpeckers (Parks, 1999; Lewis, 1998; Hallet et al., 2001).

Tips for effectiveness

Girdling is typically done with a chainsaw, axe, or handsaw (Kilroy and Windell, 1999, Adelmann et al., 2021). Smaller trees are most efficiently girdled with an axe or handsaw while larger trees can be girdled with a chainsaw (Kilroy and Windell, 1999). Other methods recommend using an axe or professional peeling knife to remove the bark (Adelmann et al., 2021) After the bark is removed, the phloem can then be scrubbed away with a wire brush to ensure that is dries quicker (Adelmann et al., 2021). The method is most easily done in spring and early summer because the bark is easier to remove and the cambium is easier to peel (Kilroy and Windell, 1999). If the goal is to kill the tree quickly, it is recommended to cut slightly deeper into the sapwood, a practice known as *notching* (Kilroy and Windell, 1999). Increasing the number of grooves can also speed up the death of the tree. If the aim is to create a taller snag, one can girdle around the base of the crown, known as *crown girdling*, and any leafing below the girdled ring must be removed to ensure the tree's death (Kilroy and Windell, 1999).

3.2. Creation of high stumps

Description and information

A high stump is a snag around the height of 2-4 meters created by cutting a tree with a chainsaw or harvester. Various studies have concluded that high stumps provide excellent breeding and habitat substrate for saproxylic beetles, provide sunny-exposed areas used by specialist species, and diversify deadwood types in the forest (Jonsell and Weslien, 2003; Lindhe and Lindelöw, 2004; Djupström et al., 2012). The technique has also been shown in a number of studies to increase population sizes of saproxylic beetles, including red-listed and threatened species (Lindhe and Lindelöw 2004; Djupström et al., 2012). Therefore, if one seeks to increase the diversity and population sizes of saproxylic species, creation of high stumps may provide a useful method.

Recommended forest and tree type

Spruce trees are commonly targeted for creation of high stumps. However, it is recommended to not only select a single target species, but instead choose a diversity of different tree species such as spruce, birch, aspen, and pine (Lindhe and Lindelöw, 2004). Aspen and birch in particular have been shown to recruit high numbers of saproxylic beetles in comparison with other species (Jonsell et al., 2004). If the aim is to support red-listed species, trees greater than 34 cm in diameter are suggested for cutting (Djupström et al., 2012).

Photo: Andreas Schuck

Species that benefit

Saproxylic species, particularly beetles including red-listed species such as *Peltis grossa* (Djupström et al., 2012).

Tips for effectiveness

It is recommended to create high stumps in sun-exposed logging sites to attract a higher diversity of saproxylic species (Lindhe and Lindelöw, 2004). Colonisation of new high stump patches may occur on its own, but the process may be sped up by creating high stumps on a rotational basis (Jonsell et al., 2004).

3.3. Topping trees

Description and information

Topping is the entire removal of the canopy of a tree. The technique is typically done either using a chainsaw or harvester to sever the trunk below the first whorl of branches or halfway up the tree, or with explosives by drilling and filling several holes in the trunk with explosive material (Lewis, 1998; Bull et al., 1981; Cavalli and Mason, 2003; Jonsell et al., 2004). The main difference between the methods is the appearance of the snag after topping. While a chainsaw or harvester creates a clear cut, explosives create a large area of shattered wood that closely resembles the damage caused my windstorm, lightning strikes, or heavy snowfall (Bull et al., 1981; Lewis, 1998). While in some cases snags created via explosives may more closely resemble natural habitats for cavity nesting species, snags produced from either method has been shown to provide useful, long-term habitats for foraging and nesting birds, particularly cavity nesters such as woodpeckers (Hallet et al., 2001; Bull and Partridge, 1986).

Recommended forest and tree type

Tree-topping can be used in any age-stand but only trees which are alive, healthy, and free from decay should be used, otherwise the explosive will not sheer the top of the tree.

Species that benefit

Cavity nesters such as woodpeckers, owls, and osprey (Bull and Partridge, 1986; Bull et al., 1997).

Tips for effectiveness

Trees topped with a chainsaw or harvester can also be modified to more closely resemble natural damage or appealing nest sites by cutting impressions in the top of the tree for owl species or by leaving a horizontal branch structure at the top of the tree for nesting birds such as osprey (Bull et al., 1997; Lewis, 1998).

3.4. Fungal inoculation

Description and information

Fungal inoculation is the practice of intentionally introducing wood decay fungi into a live, healthy tree to stimulate wood-decay processes that closely resemble natural heart rot decay. The technique is an inexpensive and efficient recovery tool for cavity dwelling wildlife and saproxylic species in forests with a lack of stand structure and subsequently low amounts of dead or dying trees (Bednarz et al., 2013). The most common application of the method includes inoculating a wooden dowel with a locally obtained fungus, drilling a hole at the site intended for inoculation, and inserting the inoculated dowel into the drilled hole (Lewis, 1998;

Bednarz et al., 2013). The decay column within the trunk of the tree and other hollows created from the rot provide a range of benefits for biodiversity, including the creation of hollows in the trunk and branches of the tree which function as long-term nesting, denning, roosting, and foraging habitat for birds including woodpeckers and other species (Lewis, 1998; Bednarz et al., 2013). Established inoculated trees may continue to spread fungal rot to other neighbouring trees over time, providing a continuous and cost-effective supply of habitat trees, reducing the need to periodically create snags via topping over the course of the harvest rotation (Bednarz et al., 2013). Fungal inoculation can also be done in combination with girdling or topping to speed up wood-decay processes and more closely mimic the resemblance naturally formed habitat trees (Lewis, 1998).

Photo: Lyla O'Brien

Recommended forest and tree type

It is generally recommended that if the aim is to recruit habitat trees for woodpecker species and cavity nesting birds, mid-aged or older stands (i.e., >40 years) should be selected for inoculation as birds typically choose older trees for nesting and other activities (Bednarz et al., 2013).

Species that benefit

Cavity nesters, woodpeckers, saproxylic species (Lewis, 1998; Brandeis et al., 2002; Huss et al., 2002; Bednarz et al., 2013).

Tips for effectiveness

When selecting the fungus for inoculation, it is important to choose a species for which there is evidence of its ability to cause decay (Bednarz et al., 2013). If the aim is to create habitat for primary cavity nesters, a fungus species which is associated with primary cavity nester sites should be selected. When possible, it is recommended that the fungal cultures used for inoculation should be obtained, isolated, and grown from existing trees infected with the same fungus in the local landscape (Bednarz et al., 2013). In order to prevent the tree from resealing the wound from the drilled hole, it is recommended to insert a cut piece of PVC pipe into the hole (Bednarz et al., 2013).

3.5. Artificial tree uprooting

Description and information

During natural disturbances such as windstorms, trees can be uprooted from the soil and can either fall to the ground, creating lying deadwood, or remain leaning against a neighbouring tree, creating standing deadwood. In both forms, uprooted trees provide a range of benefits to the surrounding forest ecosystem as they diversify deadwood types, provide microhabitats for saproxylic species, cause beneficial re-mixing of the soil, and promote natural regeneration (Cavalli and Mason, 2003; Šamonil et al., 2010; Vítková et al., 2018) . The tip-up mound that forms around the roots of an uprooted tree has also been suggested to recruit particular plant species, create nesting sites for particular bird species, and serve as important moist habitats for amphibian species during droughts (Beatty, 1984; Peterson et al., 1990; Goodburn and Lorimer, 1998). In areas where naturally uprooted trees are scarce, artificial methods for uprooting can be implemented to mimic these beneficial structures in either lying or standing form.

Recommended forest and tree type

Artificially uprooting trees can be done in any forest and to any tree type. Tree species which uproot more commonly as a result of storm damaged include spruce trees.

Species that benefit

The main species that benefit are saproxylic species (Cavalli and Mason, 2003; Vítková et al., 2018).

Photo: Adobe Stock

Tips for effectiveness

Recommended minimum DBH for uprooting is 30 cm (Cavalli and Mason, 2003). To create lying, uprooted trees it is recommended to use a tractor mounted winch or a harvester to either pull or knock down the tree, respectively (Cavalli and Mason, 2003). If the aim is to create standing uprooted trees, it is recommended to first girdle the target tree and then use a tractor mounted winch to uproot the tree against a neighbouring tree so that it can lean against it (Cavalli and Mason, 2003). If the aim is to mimic clearings of uprooted trees that sometimes occur naturally after a windstorm, many trees within an area can be uprooted to face in the same direction.

4. Active restoration to create cavities

4.1. Rationale


Photo: Andreas Schuck

Old, large trees with cavities, hollows, and holes are often referred to simply as “habitat trees” because of the irreplaceable habitats they provide for a wide variety of species such as invertebrates, fungi, birds, and mammals (Brainerd et al., 1995; Ranius and Nilsson, 1997; Kosiński, 2006). Many of these species are also often highly specialised or threatened (Bütler et al., 2006). For saproxylic beetles and fungi, the soft decayed material known as wood mould builds up in the hollows and ensures that there is an uninterrupted supply of deadwood (Sebek et al., 2013). For vertebrates, the cavities and hollows provide structures for denning, roosting, and nesting (Remm and Lõhmus, 2011). Much like deadwood, habitat trees are less prevalent in managed forests compared to unmanaged (Remm and Lõhmus, 2011; Courbaud et al., 2021), as trees with rot or other defects that can lower timber quality are often selectively removed (Goodburn and Lorimer, 1998; Cosyns, et al., 2020). As a result, species which rely on these habitat trees have been affected, reducing forest biodiversity and compromising ecosystem health (Lindenmayer et al., 2012). Without immediate efforts to increase the number of habitat trees, many threatened and endangered cavity dependent species are at high risk or may even become extinct (Manning et al., 2013).

Retention of habitat trees is becoming a more common approach to biodiversity conservation in managed forests (Gustafsson et al., 2012). However, trees accumulate microhabitats as they grow (Courbaud et al., 2021) and cavity development varies in time depending on the species, e.g., pendulate oak, microhabitats such as hollows are most likely to occur in trees over 200 years old (Ranius et al., 2008). Therefore, active management to create artificial habitats that mimic those provided by habitat trees, or triggering processes to create cavities may thus be an effective solution to increase the number of habitat trees more quickly than natural processes (Sebek et al., 2013).

4.2. Pollarding

Description and information

Pollarding is a common historical silviculture practice similar to coppicing, the main difference being that pruning occurs above ground, instead of at the base of the tree. To create a pollard tree, the trunk is typically cut at a height of two meters and as a result regrows long, thin straight stems, traditionally used as firewood (Thomas, 2014). The practice was historically done in agricultural landscapes, as stems were above the reach of grazing animals. Pollarding has been shown to lead to the development of many tree hollows in the stems, and formation is suggested to be faster and more frequent than in trees which are not managed as pollards (Sebek et al., 2013). The large number of cavities provide a wide range of microhabitats, and as result pollard trees typically support a high diversity of saproxylic species, including endangered and specialist species. The cavities also often contain a larger quantity of wood mould than in cavities of unmanaged trees, a substrate important to many saproxylic species (Todarello and Chalmers, 2007; Sebek et al., 2013). Because pollarding does not kill the tree, it is an excellent active management practice to implement in areas where natural tree cavities are scarce. A single pollard tree can potentially provide microhabitats for hundreds of years (Sebek et al., 2013).

Recommended forest and tree type

Pollarding can be done in any forest type but in order to increase the probability that the tree produces hollows, it is recommended to choose trees that have a faster growth rate and are prone to infection, such as willows (Sebek et al., 2013). Beech forests are typically not recommended for pollarding, because as beech trees become older and branches become larger, their regrowth ability deteriorates (Cantero et al., 2014).

Species that benefit

Main species that benefit are saproxylic species including the endangered hermit beetle (*Osmoderma eremita*) and Rosalia longicorn (*Rosalia aplina*) (Sebek et al., 2012; Sebek et al., 2013), various bird species (Cantero et al., 2014).

Tips for effectiveness

Pruning should be done with an axe, rather than a chainsaw, because an axe is more likely to encourage regrowth (Cantero et al., 2014). When pruning, an attempt should be made to maintain straight cuts to avoid water accumulation (Cantero et al., 2014). Pollarding can be applied to both large and small trees, but if the aim is to create cavities as fast as possible, young trees are recommended (Cantero et al., 2014). Creating pollard trees in sunny, open areas increases the chances that cavities will provide the necessary habitats conditions for endangered and specialist species (Cantero et al., 2014).

4.3. Mechanically carved hollows

Description and information

Mechanically carved hollows are cavities that are cut directly into the trunk of a tree using a chainsaw. The method usually follows a series of steps including cutting a faceplate at a height of around 4 m, making a series of plunge cuts with a chainsaw to create a grid of individual wood pieces that are subsequently hammered out to create a hollow cavity, drilling an entrance hole into the faceplate, and finally reattaching the faceplate over the carved cavity with screws (Gano and Mosher, 1983; Rueegger, 2017). Unlike external nest boxes, the technique creates an internal cavity which is protected from weather extremes from a several centimetre-thick faceplate (Rueegger, 2017).

Photo: Andreas Schuck

As a result, mechanically carved hollows have been shown to provide much more stable thermal conditions than traditional nest boxes and most closely resemble natural cavities (Griffiths et al., 2018). They are also durable, long-lasting, and cost-effective in the mid to long term (Rueegger, 2017). If quantities of trees containing natural tree hollows in a managed forest are low or absent, mechanically carved hollows can provide supplementary habitats for hollow dependent species.

Recommended forest and tree type

For mechanically carved hollows for birds, bats, and other vertebrate species, it is recommended that trees at least 30 cm DBH be selected and residual wall thickness surrounding the decay cavity should be > 0.3 of the stem's diameter in order to reduce the risk of tree failure (Gano and Mosher, 1993; Rueegger, 2017). Trees chosen for hollows should be alive to better ensure that the wood-wound healing processes seal the faceplate to the tree, creating more stable thermal conditions Rueegger, 2017). Tree cavities should be made in well-stocked stands (Gano and Mosher, 1983).

Species that benefit

The main species that benefit are cavity roosting bats, owls such as little owl (*Athene noctua*) and tawny owl (*Strix aluco*), wryneck (*Jynx torquilla*), spotted flycatcher (*Muscicapa striata*), tits including marsh tit (*Parus palustris*), blue tit *(Parus caeruleus*) and great tit *(Parus major*), nuthatch (*Sitta europaea*), and starling (*Sturnus vulgaris*) (Cavalli and Mason, 2003). To support the provision of habitats for honeybees in the wild (*Apis* mellifera), specially designed cavities can be built (see: //freethebees.ch/).

Tips for effectiveness

It is recommended that mechanically carved hollows be done in combination with basal slits (see section 4.4) so that the decay progressing downwards from the cavity and the decay progressing upwards from the basal slits eventually converge to create an entirely hollow tree that better benefits biodiversity (Cavalli and Mason, 2003). The cut faceplate should be several centimetres (at least 4 cm) thick to avoid shrinking and cracking that compromises thermal stability (Rueegger, 2017). The cavity dimensions, size, and location of the entrance hole can be customised to the target species (Cavalli and Mason, 2003). For detailed information regarding mechanically carved hollows for wild bee species see the image below and https://freethebees.ch/.

Photo: Andreas Schuck

4.4. Basal slits

Description and information

Basal slits are a series of vertical cuts made to the base the trunk, which stimulates decay that overtime leads to the creation of wet rot at the tree base (Cavalli and Mason, 2003). The method involves making a series of three successional vertical cuts with a chainsaw, followed by horizontal cuts that allow for a plug of the trunk to be removed to promote water accumulation and wet rot (Cavalli and Mason, 2003). These basal cavities do not usually kill the tree (Zapponi et al., 2014) and therefore provide important long-term habitats for cavity roosting bats (Kunz et al., 2003). The basal slits also promote the creation of sap which seeps from the wound, which provides a necessary substrate for specialist saproxylic species (Cavalli and Mason, 2003). As water accumulates in the slits, this also creates habitats for water dependent species (Zapponi et al., 2014).

Recommended forest and tree type

Large trees may provide more stable microclimates for cavity roosting species such as bats (Kunz et al., 2003). Using the method of basal slits on exotic and invasive tree species is a cost-effective method for supporting the development of wet rot, hollows, and ultimately deadwood that then provide a diversity of tree related microhabitats (Zapponi et al., 2014).

Species that benefit

Saproxylic species including the endangered violet click beetle (*Limoniscus violaceus*) (Sebek et al., 2013), water dependent species such as hover flies and drone flies, specialist saproxylic species that rely on sap seepage, and cavity roosting bats (Cavalli and Mason, 2003).

Tips for effectiveness

If the tree is large enough, basal slits should be made in combination with mechanically carved tree hollows (see section 4.3) so that the decay progressing downwards from the hollow meets up with the decay progressing upwards from the basal slit, ultimately creating a hollow trunk that would normally be seen in old trees (Cavalli and Mason, 2003). Choosing trees that have moderate to high levels of sun-exposure may increase the chances of roosting by cavity roosting bats (Kunz et al., 2003).

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